

Wood Cladding in Non-residential Construction: Overcoming the Barriers to Leverage the Opportunities

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Wood cladding is used in the residential market. However, the use of wood cladding in nonresidential and large multi-residential projects can sometimes be difficult. This paper highlights the barriers to the use of this material and draws recommendations to overcome them. A triangulation approach was used to enhance the validity of the findings with a deep literature review, interviews with different stakeholders, and analysis of several websites. The cross-compared analyses indicated that four main obstacles have hampered the use of wood cladding in non-residential projects. In order of importance, these obstacles are the recurring maintenance needed, restricting regulations (building code fire-safety and architecture implementation), appearance issues, and technical considerations regarding detailing and installation. To overcome the barriers of wood use in the non-residential market, three development axes are proposed based on communication with stakeholders, product adaptation for non-residential markets, and new product development with regards to product maintenance performance. These recommendations can guide manufacturers in adapting their product development strategies.

Keywords: Wood cladding; Non-residential building; Barriers; Recommendations

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INTRODUCTION

In North America, wood is traditionally used in the single-family housing sector for light-frame structures, as well as aesthetic products (O'Connor *et al.* 2002; Drouin *et al.* 2013; Gaston 2014). However, the material is much less commonly used in non-residential and multi-residential construction (RISI 2008). Because of its size and growth, the non-residential construction market has a greater potential for substituting other materials with wood. Moreover, the environmental benefits of wood makes using it advantageous compared with other materials in non-residential construction projects (Thormark 2006; Sathre and O'Connor 2010; Oliver *et al.* 2014). Non-residential construction includes buildings for commercial, industrial, and institutional purposes. The non-residential construction sector has important economic potential because its value typically equates to the residential market (O'Connor *et al.* 2004). Furthermore, large multi-residential building projects tend to increase the urbanization of city centers (Wang *et al.* 2012).

When considering the non-residential construction sector as a strategic segment and the environmental performance of wood, it is important to consider the implications of wood as a building material in as many functions as possible throughout a building (Gaston 2014). Of the various architectural systems, the envelope and, more specifically, cladding could capture a greater market share (Robichaud 2010; Pousette and Gezelius 2016). Wood cladding product in the US is forecast to reach 12.5% on a total demand of 930 million square meters in 2019. Knowing that wood cladding is strongly linked to the residential market, an opening on the non-residential market will have a considerable impact since the non-residential market is forecast to account in the US for 25% of the total demand in 2019 (Freedonia 2015).

The objectives of this study are: 1) to confirm the technical and normative barriers to the use of traditional wood cladding in non-residential construction, including large multi-residential construction, and 2) to propose recommendations to overcome the barriers to the use of wood as a cladding material. These recommendations can guide manufacturers in their product development strategies. To achieve this, a deep literature review of wood cladding barriers along with exploratory interviews with construction stakeholders were compared with an analysis of wood cladding manufacturer websites. This study also presents a review of the previous research on the wood cladding market share and opportunities, discusses the results obtained by the stepwise methodology, and develops recommendations to overcome the barriers identified to the adoption of wood as a cladding material in non-residential construction

Wood cladding in non-residential buildings

The literature review by Gosselin *et al.* (2017) reported many works on the needs of stakeholders, opportunities, barriers, and recommendations to increase the use of wood as a structural material in non-residential construction. However, there are very few studies available on the use of wood as a cladding material (Damery and Fisette 2001; L'Observateur 2010; Robichaud 2010; Lamason *et al.* 2012; Drouin *et al.* 2013). Building on previous research, this project focused on non-residential construction and considered all of the participants involved in the cladding material supply network (Du *et al.* 2003). Thus, architects, contractors, subcontractors, and clients all provided insight.

Wood is one of the oldest building materials, particularly in countries where this resource is abundant. As a cladding material, it is traditionally used when the structure is also made of wood. This is the reason why wood cladding is mainly used in residential construction. Spetler and Anderson (1985) demonstrated that the amount of wood products used is inversely proportional to the surface area of a building.

Architects are often identified as the main decision-makers in the choice of cladding material (Robichaud 2010; Lamason *et al.* 2012; Garmston *et al.* 2012; Drouin *et al.* 2013). Two surveys conducted in 2010 and 2014 in the Province of Quebec, Canada revealed that exterior wood cladding is used in 20% of new building construction projects (L'Observateur 2010; Drouin and Robichaud 2015). The surveys included 895 non-residential buildings and 1125 non-residential buildings with less than 4 stories. In a North American study, Kozak and Cohen (1999) revealed that the proportion of wood used as an exterior cladding material was 20% when compared with masonry, concrete, and steel products. Finally, Lamason *et al.* (2012) surveyed 44 firms across Canada. The results indicated that 82% of architects and engineers specified wood as the cladding material if technical information was readily available and the product met performance expectations.

Therefore, there is a strong interest in using wood as a cladding material. Architects desire the aesthetics of wood so much that several other materials mimic its appearance (O'Connor *et al.* 2002).

EXPERIMENTAL

To fully determine the main barriers to using wood cladding in non-residential construction and propose recommendations to increase its use, this study was based on a stepwise design methodology. This three-step methodology uses qualitative data to gain a holistic overview of the research question (Miles and Huberman 1994). The objective of the first step was to gain insight about the barriers. Thus, a deep literature review was conducted and enriched with thirteen exploratory interviews with clients, architects, contractors, and subcontractors. The second step consisted of an analysis of manufacturer websites. Finally, the third step was a comparison of the results from the three data sources. The triangulation approach was adopted to cross-validate the qualitative findings from these data sources. By minimizing the potential bias, triangulation reinforces the reliability and validity of the findings, and allows for the construction of a meaningful proposition of the observed phenomenon (Mathison 1988). The three data sources and content analysis method used to analyze the qualitative results are discussed below.

Materials- Data Sources

Literature review

The first data source was a review of the current literature. The analysis of 15 documents, including scientific articles and technical reports, made it possible to identify the barriers of the use of wood as a cladding material. Of these fifteen documents, five were considered to be major and closely related to the subject under study. The keywords used to retrieve information were wood, appearance, cladding, non-residential, barrier, multi-story, and perception. The documents were chosen because the main subject was about the barriers to the use of wood cladding in construction. The analyzed documents were written between 2002 and 2016. The conclusions presented in those documents emerged primarily from the survey of architects. The literature review focused on studies whose subject had a North American context.

Interviews

The second data source used to understand the needs of the stakeholders was exploratory interviews, as suggested by Blanchet and Gotman (2007). The purpose of the exploratory interviews was to verify and support the findings suggested by the literature review. The following two questions were asked to clients, architects, contractors, and subcontractors: 1) What are your impressions of wood cladding? and 2) What improvements to the product would be required to increase its use in non-residential building? Table 1 presents the characteristics of the thirteen Canadian stakeholders who participated in the interviews. The only constraint imposed on the recruitment was to have at least two participants for each stakeholder group. Participation was based on willingness. The participants were contacted by email obtained from an internet industry listing data bank (iCRIQ 2017). The duration of the interviews was 15 min to 20 min. To be as impartial as possible, the participants were not aware that the study focused on the use of

wood cladding, and therefore, the interviews addressed the general topic of all building cladding materials.

Website analysis

The third data source was the content analysis of manufacturer websites. The website analysis allowed for the validation of the information gathered from the other sources. More specifically, the analysis was based on the criteria presented in Table 2. Based on these presented criteria, the website analysis provided data on the actual practices of manufacturing. This data was then cross validated with the barriers identified from the two other data sources, which made it possible to validate or invalidate the previous results. Manufacturing companies were selected from a list of manufacturers from the Center of Expertise on Commercial Wooden Construction website (CECOBOIS 2017). The manufacturers that were chosen operate in North America, specifically the Province of Quebec, Canada. When no further information was perceived through the analysis of new websites, it was determined that data saturation was reached (Mucchielli 1996; Pires 1997). A total of eight manufacturer websites were analyzed.

Table 1. Interview Sample Group: Stakeholder, Position in the Enterprise, Experience, and Gender

#	Stakeholder	Position	Experience (years)	Gender
1	Architect	Associated Architect	20	Male
2	Architect	Associated Architect	20	Male
3	Architect	Associated Architect	17	Male
4	Architect	Associated Architect	20	Male
5	General contractor	Project Manager	8	Male
6	General contractor	President	30	Male
7	General contractor	Project Manager	20	Male
8	Subcontractor	Project Manager	8	Male
9	Subcontractor	Project Manager	10	Male
10	Subcontractor	Owner	10	Male
11	Client	Strategic Planning Advisor	12	Female
12	Client	Construction Supervisor	8	Female
13	Client	Architect	7	Male

Table 2. Content Examined on the Manufacturer Websites

Level of Communication and Promotion	Collaboration with professionals, architectural precedents, videos, branding, global structure of the website
Product	Personalization potential, product variety, architectural components, special features
Cladding Performance	Wood species proprieties, long-term durability, warranties, maintenance, material quality, fire performance, environmental performance, codes and standards
Construction Details	Construction details adapted to non-residential market, installation guide, codes and standards

Methods

Content analysis

A content analysis method was used to gather and analyze the qualitative data from the literature review, interviews, and websites. The methodology used for the content analysis followed the analysis tactics proposed by Groat and Wang (2002). This iterative approach consisted of identifying the main themes, regrouping the data that had a similar meaning, synthesizing the information, and interpreting the results according to the themes and stakeholders. The software package N'Vivo (QSR International Pty. Ltd., Doncaster, Australia) was used to facilitate the data coding. When subsequent participant interviews revealed no new information, data saturation was indicated, which meant the end of the analysis (Mucchielli 1996; Pires 1997).

RESULTS AND DISCUSSION

In this section, the results obtained from the three data sources are presented. The barriers identified in the literature and interviews are compared with the information presented on the manufacturer websites. The results included all of the stakeholders involved in the use of exterior cladding, from material selection to maintenance. Thus, clients, architects, contractors, and subcontractors provided a holistic and representative view of the industry as a whole. The results showed that there were four major barriers to the use of wood as an exterior cladding material. The four barriers were, in order of importance, the material maintenance performance, regulations, appearance, and technical considerations.

Maintenance Performance

The maintenance performance of wood cladding is undoubtedly the main barrier for its adoption and use in non-residential construction. All of the participants confirmed the literature findings that maintenance is the major concern for wood cladding (O'Connor *et al.* 2002; Tabarsi 2004; Hegger *et al.* 2006; Robichaud 2010; Davies 2011; Lamason *et al.* 2012; Drouin *et al.* 2013; Hislop *et al.* 2013; Freedonia 2015). In the interviews, many of the architects mentioned that wood specification depended greatly on the client. Wood is a material that polarizes clients, they are either prone to use it or reluctant. Thus, it is important to make sure the clients understand the maintenance issues at the beginning of the building project. The interviews revealed that when architects specify wood, they are forced to impose product maintenance on the client. This places them in an uncomfortable position. Stakeholders noted that both private and public clients opt more and more for low-maintenance and long-lasting cladding. It was mentioned more than once that real estate management, operators, and unions have an unfavorable bias against the use of wood cladding. Wood in exterior applications such as cladding is susceptible to degradation. All such degradation stems from its exposure to the environment and is called "weathering". The most degrading factor is the light, which combined with oxygen and water, leads to photodegradation phenomena. To protect the wood, the main strategy is the use of finishing systems. Numerous technologies are currently available, and they make it possible to increase the lifetime in service of wood cladding. Thus, the maintenance issue is intrinsic to the finishing system. The website analysis showed that the warranties for clear and opaque finishes are 4 to 8 and 15 to 25 years, respectively. These warranties covered

finishes that peel, blister, and crack due to normal weathering for the warranty period. Manufacturers also provided the cost of a sufficient amount of coating and labor for the first 3 to 10 years, which depended on the type of coating and manufacturer. For the remainder of the warranty period, they only cover the cost of the coating. Generally, manufacturers suggest maintenance shortly before the end of the warranty period. This warranty information was hard to find or even absent for most of the websites analyzed.

The literature and interviews differed concerning the long-term durability of wood products. Several studies have mentioned long-term durability issues (Spelter and Anderson 1985; Robichaud 2010; Drouin *et al.* 2013). Conversely, the interviewed clients, architects, contractors, and subcontractors considered wood to be a durable material when properly maintained. The manufacturer websites agreed by offering 45- to 50-year warranties that cover wood rot if construction details and regular maintenance has been adequately done. The reference book on material properties by Hegger *et al.* (2007) stated that wood has a durability of 40 to 70 years. For comparison, solid clay brick, fiber-cement sheet, and corrugated aluminum sheeting have a durability of greater than or equal to 80, 40 to 60, and 70 to 100 years, respectively. The long-term durability of wood cladding was related to the quality of the back wall, construction details, installation, and maintenance. Long-term durability issues were more related to the fact that wood cladding does not maintain its original appearance over time. When the building is properly designed and built, wood cladding has a very long durability. A good example of that is Hronsek Church in Slovakia. This building built in 1726 is covered with red spruce and oak. The cladding is treated with bee wax coating, and the cladding has never been restored (Dudas *et al.* 2006).

Although all materials require maintenance, Robichaud (2010) summarized the problem of wood by noting that in non-residential construction wood is competing with materials having low maintenance requirements. Despite a low initial cost, two clients noted the fact that the maintenance cost of wood exceeds that of the other non-maintenance-requiring materials.

In summary, the main barrier to the adoption of wood cladding in non-residential construction is the maintenance performance of the product. Maintenance quality has an impact on the appearance and long-term durability. Recurring maintenance leads to an acceptance problem among clients, and architects do not want to impose maintenance on clients.

Regulations

The adoption of wood was also hampered in non-residential construction due to certain regulations. The literature identified fire-safety codes and the architectural implementation and integration plan (AIIP) as the two main regulations that limit the adoption of wood in non-residential buildings (O'Connor *et al.* 2002; Tabarsi 2004; NRC 2010; Robichaud 2010; Davies 2011; Lamason *et al.* 2012; Drouin *et al.* 2013; Hislop *et al.* 2013). The AIIP is a qualitative assessment of a permit application that allows the municipality to ensure the quality of the implantation and architectural integration, while taking into account the particulars of each project and territory. If there is no AIIP, then architects must follow zoning regulations. The interview responses agreed with these findings. Two architects indicated that wood is quickly discarded in some projects because of the fire-safety regulations in the National Building Code of Canada (NBC) (NRC 2015).

The NBC is based on a material combustibility approach rather than a system performance approach (O'Connor *et al.* 2002). Thus, in an incombustible construction, an architect might be obligated to use an incombustible cladding depending on the use of the building, number of floors, area, presence of sprinklers, neighboring buildings, and distance from the public road (NRC 2015). Cladding is not structural, and so it is not subject to the fire resistance rules, but rather to fire reaction. This characteristic represents the propensity of a product to participate in the development of flame propagation. The NBC clause 3.1.5.5 states that a building for which a noncombustible construction is required may include an exterior non-loadbearing wall assembly that includes combustible components if:

- the building is not more than three stories in building height, or is equipped with sprinklers throughout;
- the interior surfaces of the wall assembly are protected by a thermal barrier conforming to Sentence 3.1.5.12.(3);
- the wall assembly satisfies the criteria of Sentences 3.1.5.5.(2) and (3) when subjected to testing in conformance with CAN/ULC-S134 (ULC 1998)

Moreover, before such testing (CAN/ULC-S134), wood cladding must be submitted to testing according to ASTM D2898 (2010). The existence of an appropriate treatment that meets both standards is limited (Karacabeyli and Lum 2014).

In addition to the code constraints, two architects also identified the importance of adhering to the AIIP. The urban planning advisory committee may refuse a project if the choice of materials does not harmonize with the neighboring buildings. Robichaud (2010) confirmed that some municipalities are very strict about the use of exterior wood cladding for large wall surfaces, especially when all of the surrounding exterior cladding is brick or other types of materials.

Currently, the second most important barrier is the building code requirements for fire-safety regulations. As long as the code is not modified and there are no efficient fire-resistant treatments, it will continue to not be possible to use wood cladding in large buildings.

Appearance

The appearance (aesthetic) issues for wood were mainly related to two distinct concepts, wood weathering and product variety. As previously mentioned, all of the stakeholders who participated in the interviews highlighted the problem of losing the original finish appearance in the long-term. The architects mentioned that they like to use wood for what it is, meaning they want to work with clear finish products to preserve the natural grain of the wood. Unfortunately, this type of finish reacts with atmospheric conditions and deteriorates faster than an opaque finishing system. The willingness to use the wood image and its natural grains is discernible. Contractors and subcontractors agreed that they are installing more and more wood imitation products. However, some of the clients and architects that were interviewed expressed reservations about these types of products. Finally, two clients spoke of a gap between the desired use and expectations of performance for the clear finish. The literature and stakeholders agreed that in North America, wood weathering is not regarded with sufficient concern (Robichaud 2010; Drouin *et al.* 2013).

The second major problem with appearance concerns the variety of products. Drouin *et al.* (2013) mentioned that there is too much diversity in the product range, and not enough in terms of style. The wood mainly allows Victorian, rustic, and country designs, and it is rarely different from the traditional wood plank-look (Robichaud 2010; Lamason *et al.* 2012; Drouin *et al.* 2013; Pousette and Gezelius 2016). Many of the interviewed architects mentioned that what they are looking for is a unique materiality. According to them, it is difficult to achieve this with wood products. The website analysis confirmed that there was low product differentiation among wood cladding manufacturers. Generally, manufacturers offer a choice for the wood species, color, surface finish, profile, and width of the profile. The cladding is usually delivered in variable lengths, and thus it is hard to seek fixed lengths. Finally, the range of architectural accessories, such as corner moldings, is relatively small and not very innovative. It was concluded that wood cladding appearance issues were mainly related to the long-term durability of the finish and products offered by manufacturers.

Technical Considerations

The technical issues were mainly related to the construction details and installation. The architects mentioned that ensuring the long-term durability of wood requires proper technical detailing and installation. However, there are no real installation guides or standards adapted for non-residential construction. The only information is in Part 9 of the NBC (9.25.5 to 9.25.7) for houses and small buildings. In the Province of Quebec, Canada, architects are required to sign and seal any plans for the construction of a non-residential building. Thus, it is their responsibility to indicate the detailing and installation. Usually, they follow the manufacturer's recommendations (Drouin and Barbuta 2017).

The interviewed architects mentioned that they indeed request specific wood construction details. Unfortunately, they find very few. This indicated a need for more available details, as architects want to be taught about how to maximize the performance of wood. The results of Robichaud (2010) and Lamason *et al.* (2012) agreed on the importance of details, such as roof overhangs, in wooden construction. Well drained and ventilated wood cladding increases its life expectancy (Hoad 2002). The website analysis also revealed that manufacturers have provided very little about construction details. Davies (2011) identified nine important construction details for wood as a cladding material (Table 3).

Table 3. Description of the Nine Groups of Construction Detail

Type of Junction	Description of Group
Horizontal	1) Eaves and parapets
	2) Floors (separating or intermediate)
	3) Ground level, flat roof, and other
Vertical	4) External corner
	5) Internal corner (intermediate or separating)
	6) In-line junctions (intermediate or separating)
Miscellaneous	7) Windows and doors
	8) Junctions between cladding boards
	9) Junctions with other cladding materials

Information from Davies (2011)

Of these nine construction details, the website analysis showed that manufacturers generally provide details 3, 4, 5, and 8. Moreover, the presented details are not suited for non-residential construction techniques, such as roof details with a parapet, the use of metal studs, split-insulated walls, and junctions with a masonry wall.

With regards to the installation issues, the literature review indicated a lack of installation standards. The interviewed contractors and subcontractors mentioned that wood installation was simple and easy. However, two of the three contractors pointed out the excessive variability in wood installation. They cited “touching up” the ends of cut boards as an example of this variability during installation. According to the interviewed contractors, the percentage of error related to the installation was too high because of the amount of small details and manipulations. As reported by the contractors, subcontractors known as installers have their share of responsibility in installation issues, especially in the installation of fastening systems, management construction details, and moisture management through rain screen systems. Two of the contractors had several negative experiences with wood cladding installations. Most of the errors had been committed on site and were relative to the use of silicone. These results were similar to the findings of Tran *et al.* (2014) on the abusive use of silicone to seal building enclosure systems in North America. The website analysis showed that information on installation is variable for different manufacturers. Very few manufacturers have extensive guides with detailed information, while others stick to the strict minimum amount of information.

The technical barriers to the adoption of wood cladding consist of the lack of construction details and issues related to installation. The results exposed the installation dualism. Contractors and subcontractors expressed that wood cladding is easy to install, but at the same time, the amount of details and manipulations required for a successful installation cause a lot of variability.

Recommendations

The literature review, interviews, and website analysis revealed four barriers to the use of wood in non-residential construction. In order of importance, the recurring maintenance, regulations, appearance issues, and technical considerations hamper wood adoption in the non-residential market. The results in Guy-Plourde *et al.* (2017) identified that the needs of architects for non-residential buildings are, in order of importance, maintenance performance, appearance, and warranties. Therefore, there was a considerable gap between the needs of architects and properties of wood cladding. To reduce this gap, this section discusses the previous issues and proposes recommendations to promote the use of wood. It is important to note that the identified categories of barriers are not independent. The problems included in each category can have an influence on the others (systemic influence). For example, the quality of the construction details contributes to the durability and facilitates installation. Therefore, the proposed solutions address several issues simultaneously. The recommendations have been grouped into three categories: communication, adaptation, and development. Most of the recommendations came from the testimonies of the architects and contractors. The clients and subcontractors mainly discussed the issues, and they elaborated much less on potential solutions or recommendations.

Communication

The goal of communication is not to convince architects to use wood, but simply to facilitate their work (Robichaud 2010). The recommendations about communication were grouped into two themes, to teach and to inform. Communication should not be conducted with just the architects, but throughout the complete value chain.

To teach

Architects want to be taught about wood because they are not specialists. Thus, wood product manufacturers should identify the best practices (advantageous typologies and applications) for increasing the performance of wood. For example, manufacturers should provide guides on the good and bad practices. In terms of appearance, architects want to quickly understand the complete range of possibilities offered by a product. The website analysis showed that manufacturers gave very few examples of non-residential architectural precedents. Architects want to be inspired, and the current practices do not facilitate their work. An architect summarized this situation by mentioning that “wood can be used in a thousand other ways than the traditional horizontal bevel” (architect #4). Manufacturers must also teach subcontractors by providing the necessary documentation to minimize errors during installation. A contractor gave the example of manufacturing companies that visit the construction site to assist and validate the installation. According to this contractor, this practice tends to reduce the frequency of installation mistakes at large construction sites.

To inform

Wood cladding is still seen as a commodity product, not an architectural product (Drouin *et al.* 2013). In a non-residential context, architects are looking for information to support their choice, especially when working on the behalf of a public client. Architects research data on product stability, long-term durability, species characteristics, maintenance, origin of the wood, fire performance, environmental performance, and delivery schedule. This information must be readily available, verified, and reliable.

Adaptation

If wood manufacturers wish to expand into non-residential construction, they should offer products properly adapted to this market. Adapting the product to the non-residential construction market can be done according to two main themes, appearance and technical solutions.

Appearance

The aesthetic possibilities of wood are problematic. Designers are looking for a larger variety of products to meet their needs. Drouin *et al.* (2013) noted that architects currently perform the design function. Manufacturers must facilitate the work of architects by offering more personalization. Products of varying dimensions and the possibility of carving wood were elements that were identified in both the literature and interviews. Moreover, there is potential for innovation in architectural accessories, such as corners and molding. According to some architects, the possibility of using 3D modeling during the design phase allows a product to stand out from the others. The product families, such as the REVIT architectural software, allow an architect to “shop during the design”. Some

designs from Australia, Europe, and the UK are very innovative. Thus, North American manufacturers might gain inspiration from the practices of other countries.

Technical solutions

Architects and installers are seeking solutions that allow for the quick covering of larger facade surfaces. Panel products are an element that were proposed in the interviews, as well as previous literature (Robichaud 2010; Drouin *et al.* 2013). However, installers may be reluctant to use this type of product if they are completely custom-made. Installers appreciate the possibility of modifying a product on site to correct errors and minimize losses (Guy-Plourde *et al.* 2017). The contractors also look for uniform installation guides and simplified installation. They search for reliable and faultless products with few variables during installation. Manufacturers must also provide construction details tailored to non-residential construction, such as eaves, exterior and split insulation, and metal studs. Ultimately, to be able to offer a value-added service, the manufacturers must understand and consider the main issues for each project. According to one architect, this project-specific understanding could be expressed in terms of warranties that can be adapted to the type of application, type of building, and facade.

Development

The improved knowledge of wood processes and product treatments will help to address wood maintenance and combustibility concerns.

Improvement of finishes

All of the stakeholders identified maintenance issues as the main barrier to the use of wood cladding. Because wood is a biological material, it will always be subject to weathering. In addition to suitable construction details and installation, the finishing system needs to be improved. A clear resistant finishing system that allows the natural grains of the wood to be seen is highly desired. Research into clear finishing systems and the natural wood-weathering process are research avenues that should be encouraged. A 25-year maintenance cycle, which is half the life of a building, was identified as a reasonable maintenance cycle (Garmston *et al.* 2012; Lamason *et al.* 2012; Guy-Plourde *et al.* 2017).

Flame retardant

Manufacturers must also work closely with flame retardant suppliers to ensure that fire retardant-treated wood satisfies the weathering regulation ASTM D2898 (2010) and fire resistance of CAN/ULC-S134 (ULC 1998). The high cost of this type of treatment makes it unpopular at this time. It is the role of the manufacturers to offer the possibility of flame retardant-treated wood. This type of product should be constructed in accordance with the codes and standards, and be properly certified by an accredited third party.

These results showed that the development efforts of wood manufacturers are mainly focused on the production of products for the residential market. The website analysis showed that the current development strategies are focused on the single-house market, and the targeted customers are single-family homeowners. Thus, a paradigm shift must be made if they want to expand towards the non-residential market. In the non-residential market, communication must be addressed to the architects, who are the main material specifier. This dynamic means that manufacturers must rethink their communication strategy, adapt their product to the non-residential market, and improve the performance of the product in relation to maintenance and fire resistance.

The environmental characteristics of wood make its use more advantageous compared with other materials. The literature review highlighted the desire of architects to use wood. Thus, the proposed recommendations are realistic. They will allow manufacturers to market a product that meets the expectations of the stakeholders. All of these elements could make wood a viable, feasible, and desirable cladding material for non-residential construction.

These results must be treated with caution, and some limitations need to be emphasized. The interviewed stakeholders and analyzed manufacturer websites were all from the Province of Quebec, Canada. An extension of the results to other regions must be handled carefully. Participation based on willingness also introduced self-selection biases. Moreover, the results were mainly based on testimonies. Thus, further studies that scientifically compare wood cladding with other materials should be conducted. Methods, such as a whole life cost analysis and life cycle assessment and simulation, can be used to validate these findings. Finally, the proposed recommendations are broad guidelines. It is suggested that these broad guidelines should be developed and refined to fit within an industrial context.

CONCLUSIONS

1. The non-residential market has a large amount of potential for the adoption of wood cladding. However, there is a gap between the needs of the non-residential construction stakeholders and attributes of the wood cladding products.
2. The barriers identified in this paper were consistent with the results found in previous literature. In order of importance, the use of wood in non-residential construction is hampered by the recurring maintenance, NBC fire-safety regulations and AIIP, low product variety, and technical considerations.
3. Communication with the different stakeholders is the first concern that should be addressed to facilitate the use of wood. Manufacturers need to teach designers about various typologies and applications on the proper way to use of wood cladding. They also need to inform architects by presenting verifiable and comparable data.
4. Manufacturers need to adjust their practice to adapt to non-residential construction. In terms of appearance, there is a demand for more product customization possibilities. Installation also needs to be adapted to large buildings by reducing the variability during installation and offering systems that quickly cover larger surfaces.
5. Finally, manufacturers need to improve performance with regards to the durability of the finishing system and fire performance. A minimum 25-year maintenance-free life expectancy for a clear finish is desired. Manufacturers are also requested to offer efficient and weather-resistant fire retardant-treated products. These products need to be provided by the manufacturer, standardized, and approved by a third party.

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