

Arbora

An exposed wood structure in a major residential project



© Photo: Studio Point de Vue - Alexandre Parent and Félix Audette

cecobois

Centre d'expertise
sur la construction
commerciale en bois



© Photo - Studio Point de Vue - Alexandre Parent et Félix Audette

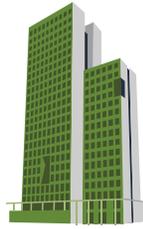


Montreal's Griffintown district is home to a world record-breaking building: Arbora is the world's largest residential complex made of solid engineered wood. It boasts three 8-storey buildings, each 25 m high, for a total of 55,515 m² and 434 housing units. Records can be broken, but the unmatched aesthetic quality of Arbora's exposed wood beams and columns will endure. Sotramont has assembled a team of skilled professionals to complete this project, the first of its kind in Canada.

Compare:



Arbora (Montreal)
8 storeys
55,515 m²



Hoho Vienna
(Vienna)
24 storeys
5,000 m²



Brock Commons
(Vancouver)
18 storeys
15,115 m²

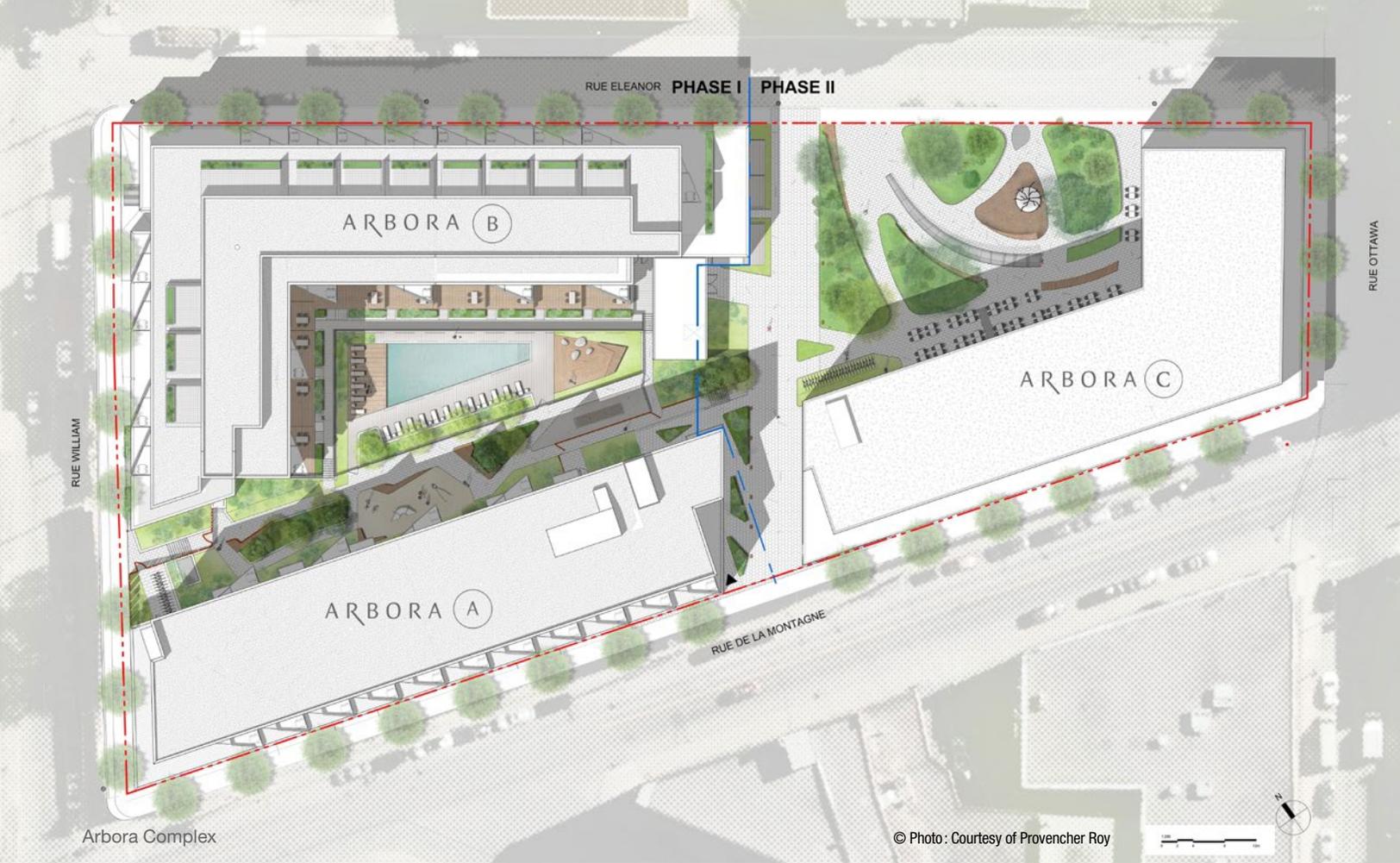


Origine
(Quebec)
13 storeys
9,968 m²

© Courtesy of Think Wood



© Photo: Studio Point de Vue - Alexandre Parent and Félix Audette

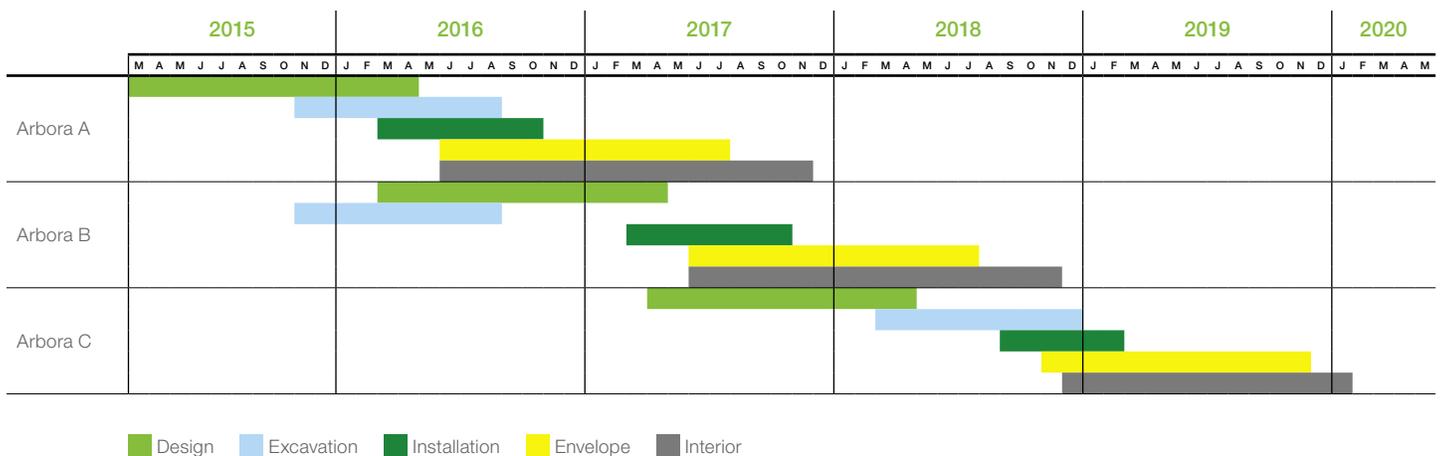


The complex covers the block bordered by De la Montagne, Ottawa, William and Eleanor. The buildings are composed of 8 aboveground storeys and 2 levels of underground parking. Buildings A and C feature a ground floor concrete platform for commercial use. The wooden storeys (8 in Building B and 7 in Buildings A and C) are residential units. The rental apartments in Buildings A and C are located on De la Montagne and Ottawa, whereas the condominiums in Building B open onto William and Eleanor. Arbora also features a 40% green area at the centre

of the complex. Phase I is already LEED Platinum Certified and Phase II aims for the same.

Sotramont’s decision to use wood for this project was natural following its success with the TOD in Ville St-Laurent. Construction ran from 2016 to 2019, with all three buildings undergoing two successive phases. Erected as part of Phase II and outlined herein, Building C reflects the valuable experience gained during the construction of the first two buildings.

Construction Schedule for the 3 Phases of Arbora





Arpora - Building C

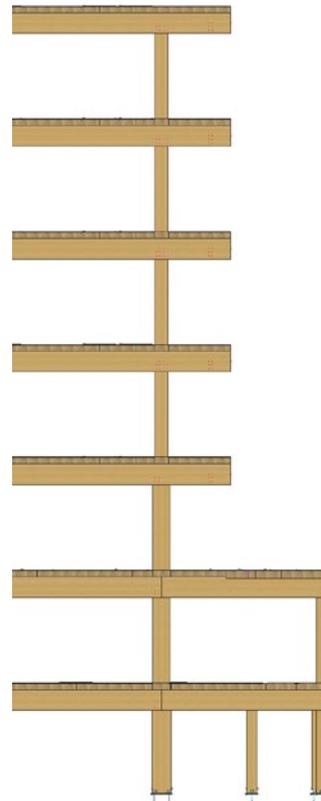
© Photo : Courtesy of Provencher Roy

The success of the Arpora project is largely due to its exposed wood structure, but its prime location also plays a role; The Griffintown district, steps from downtown Montreal, is tremendously popular.

A 100% wood structure featuring cross-laminated timber and glued-laminated timber

Building C is L-shaped, with one arm over 60 m long and the other over 30 m long. Both arms are 20 m wide. Above the concrete platform that makes up the ground floor is a 7-storey structure (storeys 2 to 8) made of 100% wood, including elevator shafts and stairwells. Storeys 2 and 3 overhang the sidewalk, while storeys 4 to 8 are set back, creating a terrace for residents on the 4th floor. This interplay of forms gives Building C its multidimensional character.

Resistance to gravity loads is ensured by a system of glue-laminated timber (glulam) beams and columns. Three rows of columns are located along the front and rear facades as well as at the centre of the building. The columns on the 2nd floor have a cross-section of 390 x 500 mm, a measurement that decreases on the upper floors due to a reduction in gravity load. Storeys 2 and 3 have a cross-section of 390 x 450 mm and the remaining storeys have a cross-section of 390 x 350 mm. In addition, the front facade has a row of smaller columns (279 x 279 mm) that support the 3rd floor loggias and the 4th floor rooftop terrace.



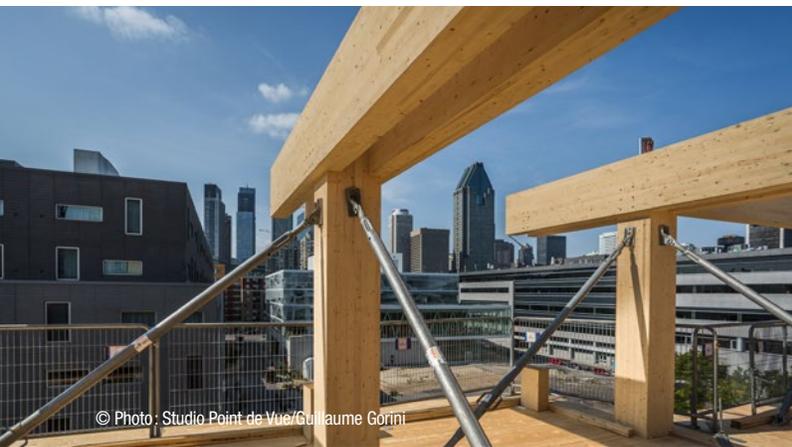
© Courtesy of Nordic Structures

Layout of the 7 wooden storeys



© Photo: Cecobois

Self-tapping screws are used to secure the beams in case of fire



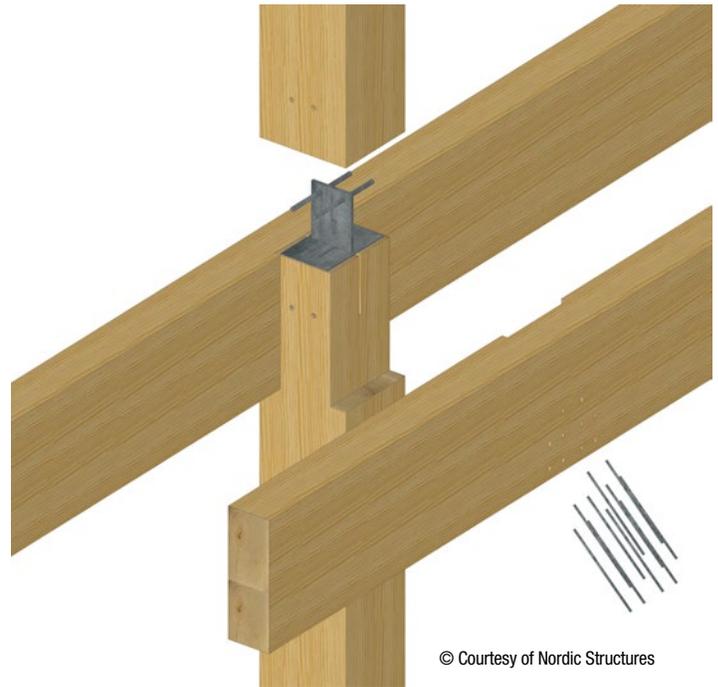
© Photo: Studio Point de Vue/Guillaume Gorini

Double beams run through the building

These columns support the double beams that run from the front of the building to the back, in a single piece, supported by three columns. Most have a total reach of 17.2 m, but some measure up to 19.8 m. They have a cross-section of 184 x 546 mm, except for at the ends of the building, where the columns have a cross-section of 184 x 502 mm.

The beams are bolted to slots at the top of each column. If a load-bearing section of a column catches fire, the beam will still be supported by the self-tapping screws. A connector plate at the top of each column is used to affix columns from upper floors and ensures the continuity of the columns over the full height of the building.

Beams and columns are therefore relatively uniform in size throughout the building, which simplifies the planning and installation of the structure.



© Courtesy of Nordic Structures

Beam-column connection

The beams support 5-ply (175 mm) cross-laminated timber (CLT) panels that run the length of the building and have a theoretical support length of 5.85 m between each beam. The CLT panels are joined by strips of plywood and steel plates on the periphery and the length of the shear walls to ensure the transfer of diaphragm loads.

As a special feature, the designers included davits on the roof to facilitate maintenance work on the side walls facing the inner courtyard where bucket trucks are not permitted. Because of the loads they have to support, the davits are installed along the beams close to the columns.

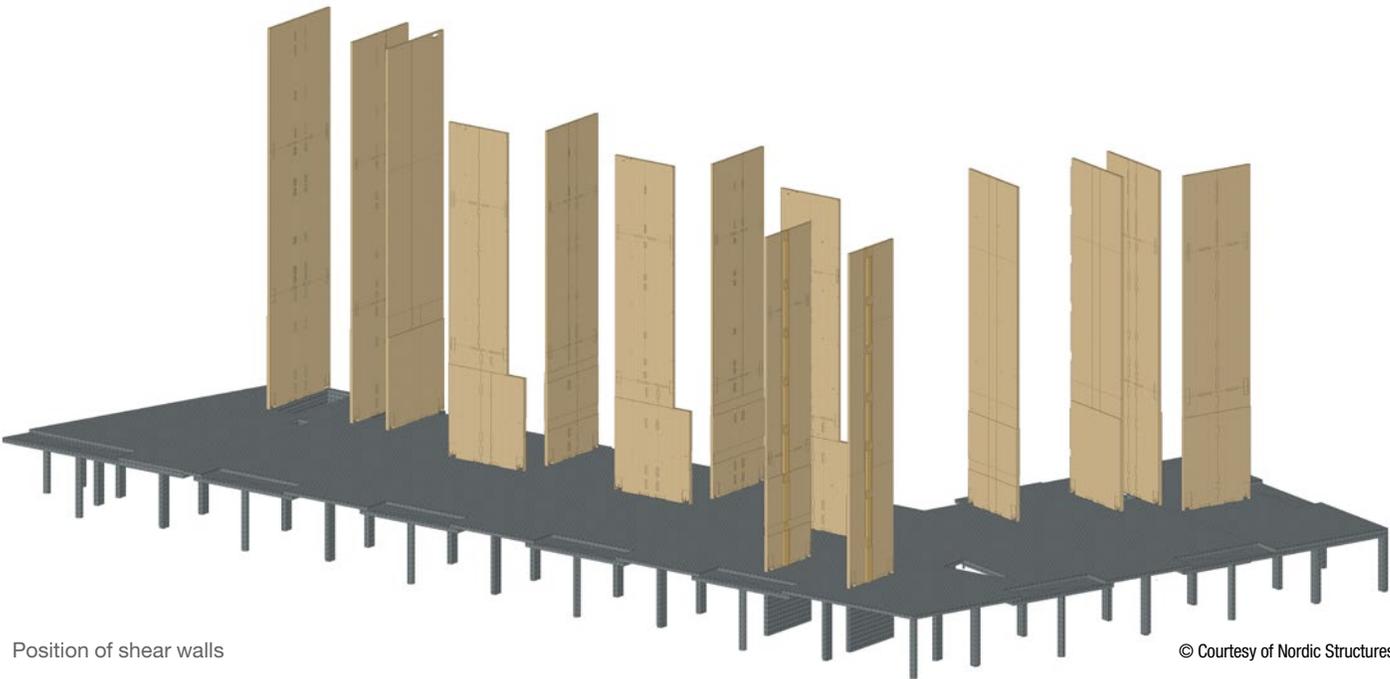
The lateral load resistance system consists of 14 shear walls located as follows:

- 3 on the longitudinal axis in the middle of the long arm of the L;
- 1 on the longitudinal axis in the middle of the small arm of the L;
- 8 on the transverse axis on the courtyard side, including 5 in the stairwells and elevator shafts;
- 2 on the transverse axis on the street side.



CLT floors joined by plywood strips

© Photo: Adrien Williams



Position of shear walls

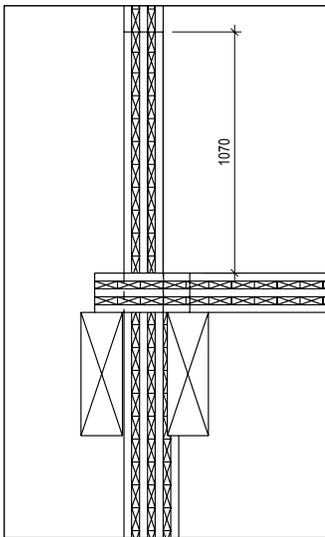
© Courtesy of Nordic Structures

The shear walls consist of 7-ply (244 mm) CLT on storeys 2 and 3, and 5-ply (175 mm) panels on the 4th storey and above. More precisely, the transition between the two thicknesses of CLT is located 1.07 m above the CLT floor on the 4th storey. In order to secure the construction site, a section of the CLT panels protrudes from the floor to serve as a guardrail for the workers. The engineers had to devise a system to prevent a recess 1 m off the ground on the 4th floor wall due to the transition between CLT panels of different thicknesses. The principle capitalizes on the two existing 7-ply panels (the 7s and the 7l).

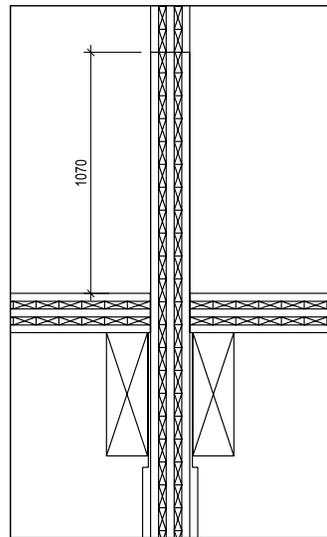
In the 7s configuration, the plies are alternating, making it possible to form a continuous wall on one side by placing a 5-ply panel on a 7s panel, leaving 2 plies overhanging on the inside. As a result, there is a recess on the side of the 2 plies, whereas the other side is continuous. However, the recess can be eliminated by machining the 7-ply panel, removing the 2 excess plies all the way to the CLT floor. This same solution is used for the shear walls and exit shafts.

In the 7l configuration, each outer ply is in the same direction as the previous ply. To ensure the continuity of the plies of two superimposed panels, a 5-ply panel is placed at the centre of the 7l, leaving one outer ply overhanging on each side. The resulting recess on the walls of each side is then removed by machining the outer plies all the way to the floor. The designers chose this solution for the shear walls in the housing units.

On the 2nd floor, the 7-ply panels are held in place by anchor plates embedded in the concrete. The panels are connected laterally and vertically by bolted steel plates. On each floor, shear fittings are used to connect the shear wall panels to the floor.



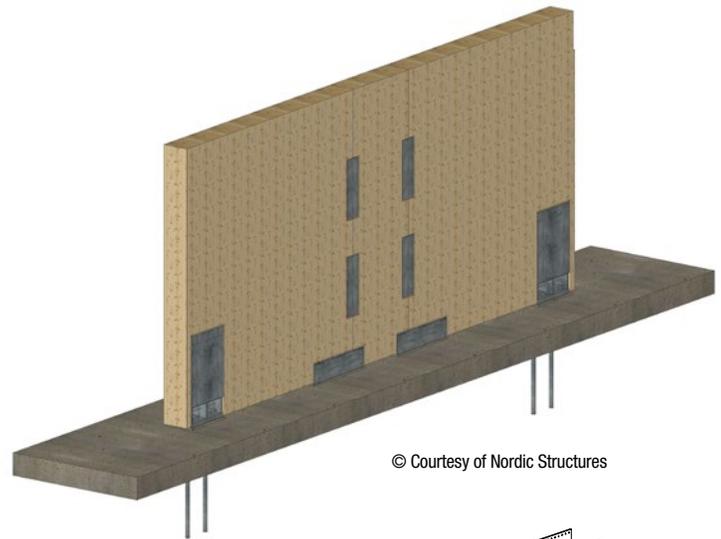
© Courtesy of Nordic Structures



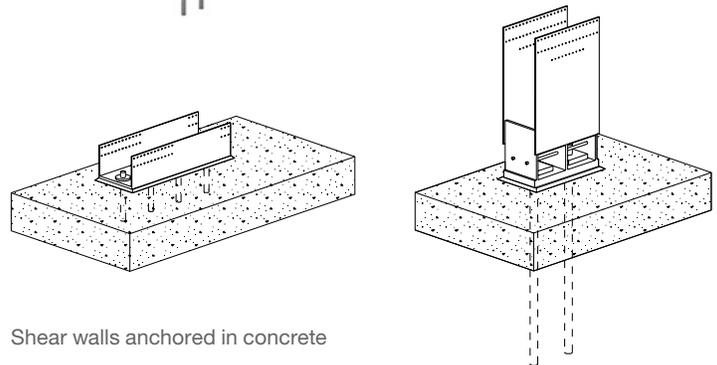
© Courtesy of Nordic Structures

Configuration of exterior shear walls or shear walls adjacent to a stairwell or elevator shaft (configuration Nordic X-Lam 244-7s)

Configuration of interior shear walls (configuration Nordic X-Lam 244-7l)



© Courtesy of Nordic Structures



Shear walls anchored in concrete



© Photo: Adrien Williams

Installation of wrought metal reinforcements to support the masonry (facade)

Masonry and balconies

Masonry

Municipal regulations require that masonry make up 80% of the exterior siding. Brick masonry adds weight to the building and it is a fragile material that is sensitive to structural movement. To address these concerns, given the load-bearing elements on the facade, the engineers designed two fastening systems based on the position of the CLT.

At the ends of the building (parallel to Eleanor and Williams), the facade is transected by beams that rest on the perimeter columns supporting the CLT panels. It is therefore possible to secure the masonry to the CLT using metallic parts.

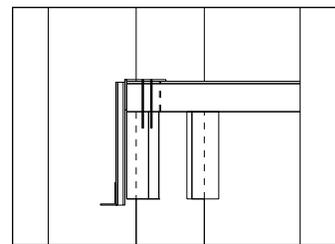
The fastening system consists of:

- steel angle plates bolted to the CLT;
- vertical steel tubes fastened to the plates;
- a horizontal corner iron fastened to the bottom of the tubes.

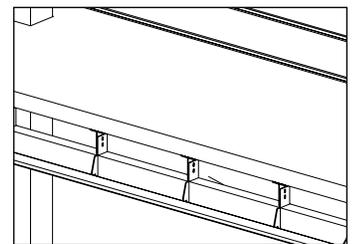
On the front and rear facades, there are no beams supporting the CLT panels, which are on their weak axis: the CLT is not strong enough to transfer the loads to the rest of the structure. The designers had to use wrought metal reinforcements supported by the main beams. These reinforcements consist of:

- steel angle plates bolted to the side of the columns;
- vertical steel tubes fastened to the plates between each column. They are also secured by retaining plates under the CLT to limit their rotation;
- a horizontal corner iron welded to the tube.

The corner iron runs all the way around the building and serves as a base for laying bricks up to the next floor.



Support system for the masonry at the ends



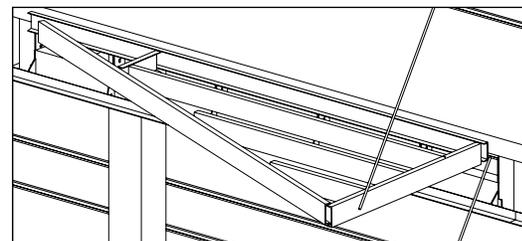
Support system for the masonry on the facade

© Courtesy of Nordic Structures

Balconies

Arbora's distinctive volumetry is further enhanced by its trademark triangular balconies. These balconies are made of steel sections with a fibrocement coating and are secured to the CLT floor with metal connectors and held in place by a metal cable fastened to both the CLT plate and the glued-laminated wood beam. In addition to its pleasing esthetic, this design reduces thermal bridges and prevents the extension of the building's steel structure.

Other rectangular balconies have a more classic cantilever design and are supported by steel bars that run through the wall between the CLT floor and the steel bar of the masonry fastening system.



Balcony fastening system

© Courtesy of Nordic Structures

Fire resistance assured with exposed wood

According to the Québec Construction Code, Arbora's 8-storey structure requires that its load-bearing elements have a two-hour fire resistance rating. In addition, fire separations must be capable of resisting a fire for 1 or 2 hours depending on where they are in the building to prevent the spread of flames and smoke.

Nevertheless, studies carried out as part of the Origine project, a 12-storey CLT building erected at the same time as Arbora, have made it possible to go even further. These engineered wood materials performance tests made it possible to provide the Régie du bâtiment du Québec (RBQ) with measures equivalent to the requirements of the Québec Construction Code. The tests led the RBQ to publish *Bâtiments de construction massive en bois d'au plus 12 étages*, a guide for the construction of wood buildings in compliance with the Québec Construction Code. Although the document was not yet available when Arbora was designed, the engineers were made aware of the test results and the guidelines were followed.

An alternative solution to keep wood beams and columns exposed

Encapsulated wood loses its beauty and warmth, such as with Origné, where none of the wood is visible.

Arbora makes an effort to showcase the material by putting glulam beams and columns on display in each apartment. The wood is encapsulated on one side of the wall, for example, in the bedroom, and exposed on the other side, in the living room.

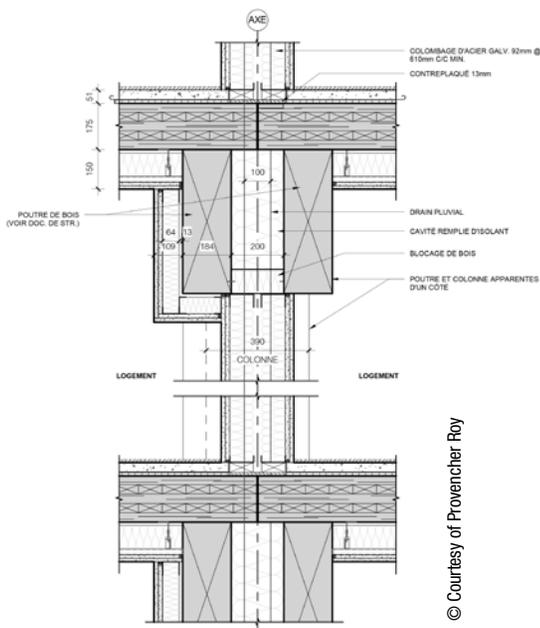
To leave the wood partially exposed, the designers compared Arbora's fire load with that of a similar building constructed of non-combustible materials. The fire load represents the amount of heat released by a fire and is based on the combustible materials present in the building. The engineers calculated Arbora's fire load, taking into account the beam and column sections that would be exposed to a fire and made sure that it was less than the fire load of a similar building constructed of non-combustible materials. On the basis of this calculation, a request for equivalent measures was submitted to the RBQ and was accepted.

The engineers also compared three of Arbora's safety measures to the Construction Code's requirements for non-combustible buildings.

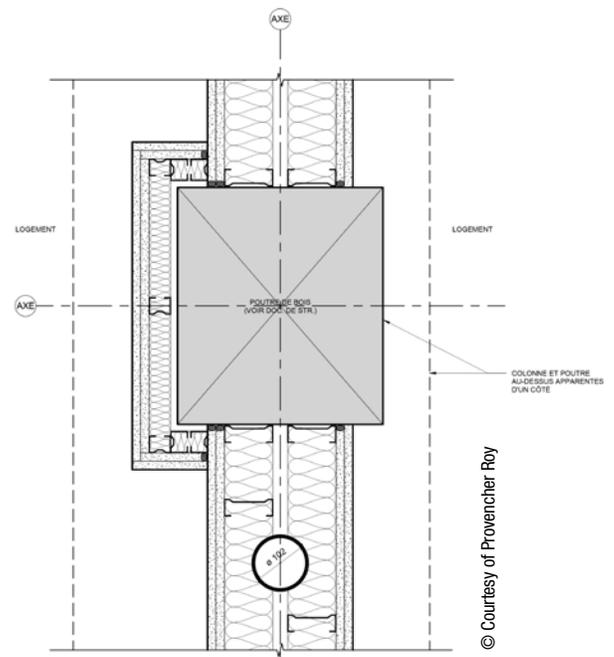
In accordance with the guidelines set out in the *Bâtiments de construction massive en bois d'au plus 12 étages*, stairwells are equipped with a pressurization system to prevent the spread of flames and smoke. This system is safer than simply venting the stairwells as required by the Construction Code for non-combustible buildings.

Still in accordance with the guide, the building's ground area is less than 1,500 m², whereas the Construction Code does not specify a limit.

Finally, whereas the Construction Code requires that the distance to the nearest exist be less than 45 m, it is no more than 30 m in Arbora.



Cross-section of a partition wall with exposed beam



Plan of a partition wall with exposed column

Arbora is the first building over 6 storeys to feature exposed wood and has helped pave the way for new recommendations set out by the National Building Code 2020 (NBC2020). The proposal for the new NBC 2020 will allow up to 35% exposed wood surface area per suite, subject to several conditions.

Guaranteed acoustic comfort

Gypsum board, integral to fire safety, is also used for soundproofing apartments. Because sections of beams and columns were left exposed, it was important to ensure that soundproofing standards were met. The Arbora team benefited from the acoustic expertise acquired while working on several other projects, including the TOD in Ville St-Laurent.

The transmission of impact noise through wall and floor assemblies was tested by the National Research Council of Canada (NRC). It was also necessary to determine the apparent impact insulation class (AIIC) for the housing units. Measurements were taken in accordance with ASTM 1007 and ASTM E989 standards by installing an impact generator in one room and measuring the noise in the room on the floor below. AIIC values of 55 were measured in accordance with the recommendations of the National Building Code.



© Photo: Adrien Williams

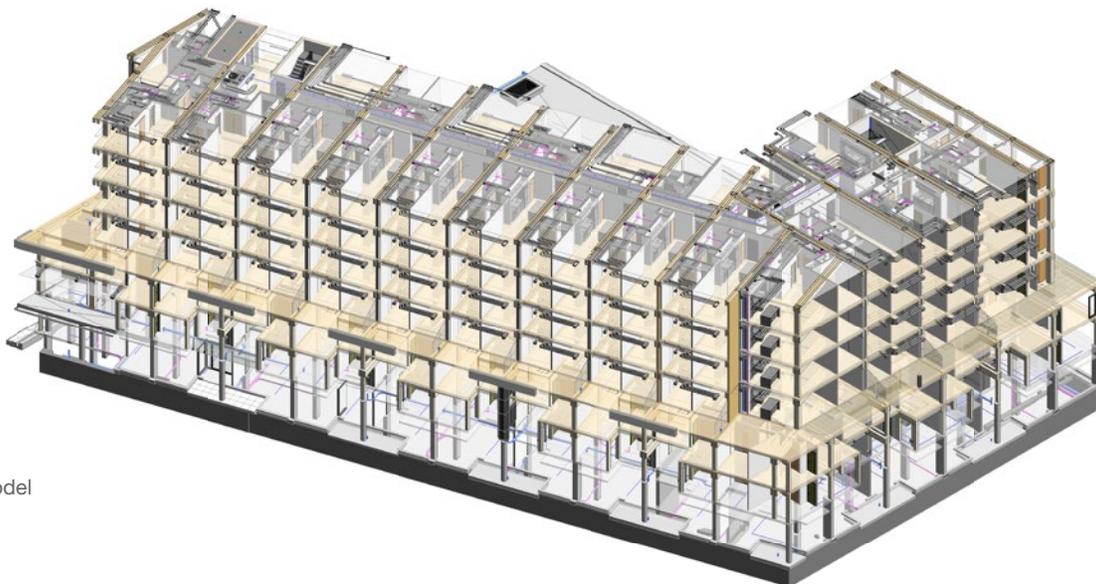
Soundproofing

Faster construction thanks to integrated design and modelling

Building C benefited from the experience gained from Buildings A and B, and from the integrated design process that helped to facilitate and accelerate construction.

During the first phases, the wood pieces arrived on site prefabricated, but some still had to be drilled in order to install machinery. The structural engineers had to make sure that the holes did not interfere with the strength of the structure, which could have slowed down construction.

The integrated design process put in place for Building C, and the BIM software used by the entire team (including subcontractors), made it possible to coordinate many usually unforeseen details prior to construction. The engineering plans for the concrete, wood and mechanical structures were integrated into a single 3D model and sent to the engineered wood supplier, who was able to manufacture the wood parts with the holes already drilled.



Arbora C BIM model

© Courtesy of Provencher Roy



Beams with pre-drilled holes for machinery



Some CLT panels are left on the ground while others remain on the trailer

Overall, the structure of Building C was erected in 16 weeks with anywhere from 7 to 9 workers on site. It is important to note, however, that the work was carried out in winter in suboptimal conditions and was often slowed and even interrupted by snow and cold weather. More specifically, each floor took 8 days to build: 4 days for the CLT panels and 4 days for the beams and columns.

Given the limited space in downtown Montreal, the site was designed to facilitate the handling of materials. The upper level of the

underground parking lot was constructed to accommodate the trucks that delivered the wood. Deliveries were made at a rate of 2 truck trailers of wood every 3 days. The glulam was unloaded on crossbeams high enough to keep them away from water on the concrete slabs. The CLT was organized on the trailers to avoid having to unload the plates. A truck carrying a load of CLT simply had to leave its trailer at the site and drive away with an empty trailer.

Life cycle analysis

In order to gain a better understanding of materials with a low carbon footprint, the Quebec ministère des Forêts, de la Faune et des Parcs (MFFP) and the Fonds vert commissioned a life cycle analysis (LCA) on the Arbora C building, under the direction of FPInnovations. To do this, the researchers assessed the environmental impacts and the carbon footprint of two scenarios, specifically: Arbora as it was built and its functional concrete equivalent (reference building), designed by an external team of professionals. The analysis was carried out on the basis of a 60-year life cycle and includes the stages of production, construction, operation and end of life.

The study covers the structure, but also the envelope, the fire resistance and soundproofing system of all above-ground floors. For example, designers had to use more gypsum in Arbora than they would have used in the concrete equivalent to meet fire resistance requirements and meet acoustic standards. The same goes for the acoustics: a concrete screed and other materials were added to the CLT panel to meet the standards. In addition, the piping cannot be installed directly on the CLT panel, which therefore presents an advantage for the concrete scenario. Indeed, the ceilings of the floors were by 6 inches, offering savings in materials for the envelope.

To assess the environmental impact of the two scenarios, the researchers used the TRACI method with the following indicators:

Global warming: refers to the contribution of emissions from human activities on radiative forcing in the atmosphere, a phenomenon commonly referred to as the greenhouse effect. These emissions contribute to the increase or decrease in the temperature of the Earth's surface, with the resulting impacts on ecosystems and human health. This indicator is measured in kg equivalent of CO₂.

Destruction of the ozone layer: refers to emissions that have an impact on the thinning of the stratospheric ozone layer. The depletion of the ozone layer allows more ultraviolet rays to reach the Earth's surface, with this phenomenon having an impact on ecosystems, human health and biochemical cycles. This indicator is measured in kg equivalent of CFC - 11.

Smog: refers to emissions contributing to photochemical smog which is known to be harmful to human health and ecosystems. This indicator is measured in kg equivalent of O₃.

Acidification: refers to emissions with the potential to form H⁺ ions which, carried by rain, fog, snow and dew, have the capacity to acidify the Earth and waterways. This indicator is measured in kg equivalent of SO₂.

Eutrophication: refers to emissions that increase the presence of phosphorus (P) and nitrogen (N) nutrients in the environment, contributing to the eutrophication of aquatic environments. This indicator is measured in kg equivalent of N.

The comparison of the two scenarios is presented in Figure 1. The relative differences between the two scenarios were judged to be insignificant for all impact categories, except for global warming. The GHG emissions for the wooden building are 6.9 kt CO₂ equivalent, compared to 8.6 kt CO₂ equivalent for the concrete building. This difference in GHG emissions between the two buildings corresponds to avoided emissions of nearly 1.7 kt of CO₂ equivalent.

The researchers then isolated only the structural materials to measure their impact against the rest of the building's life cycle. The comparison of the structures of the two scenarios can be found in Figure 2. For the global warming indicator, a reduction of 65% is observed for the 4.4 kt of CO₂ equivalent avoided.

Figure 1. Comparison of the environmental profile of a wood versus concrete building

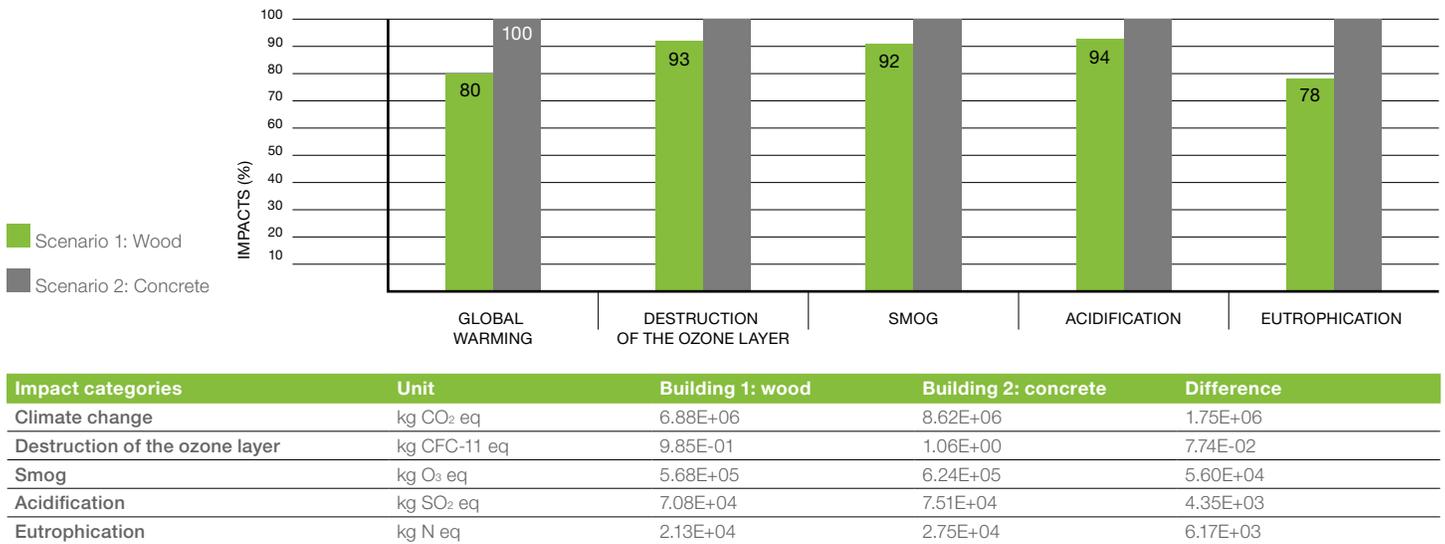
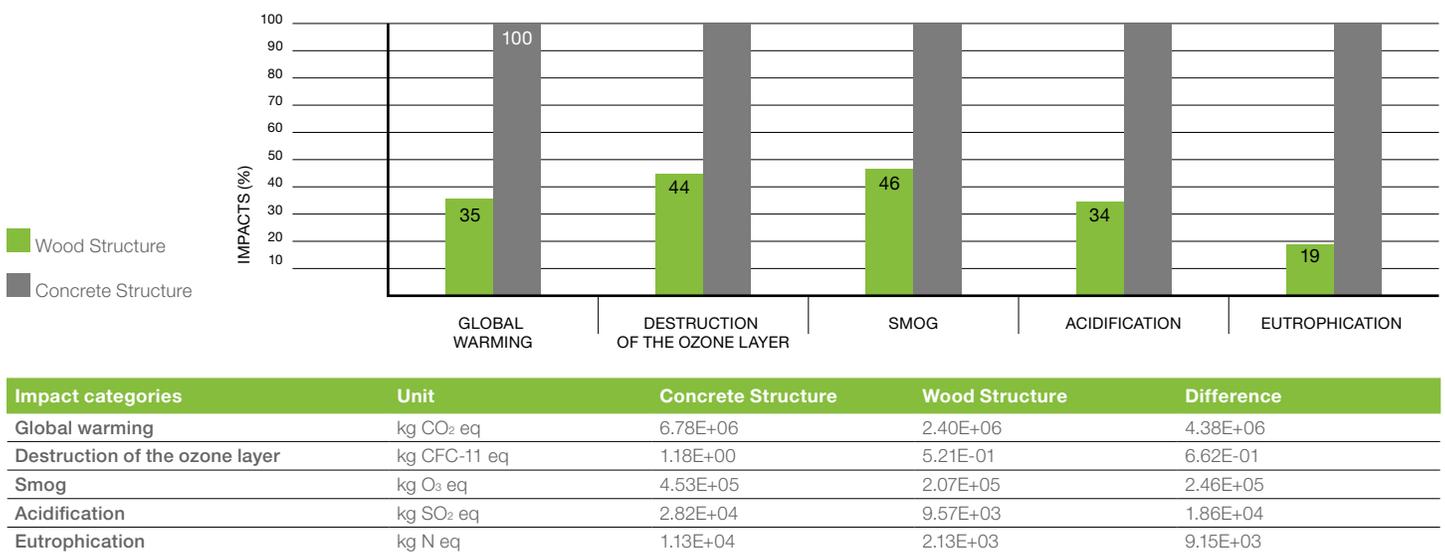


Figure 2. Comparison of the environmental profile of a wood versus concrete building



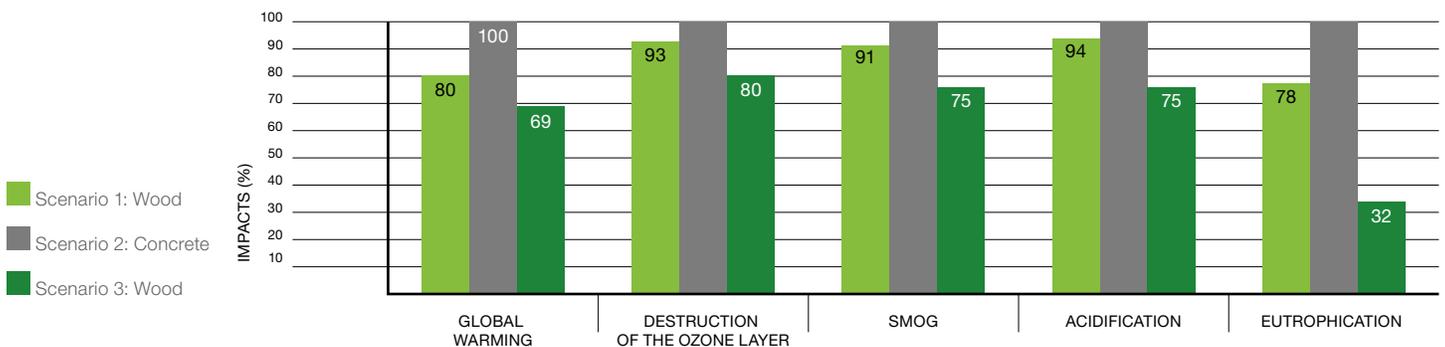
It is very clear that the wooden structure contributes enormously to the reduction of environmental impacts in the Arbora project. But where do the other emissions come from? The production of materials which go into the composition of the building turns out to be the largest emitter (64.4% for the wooden building and 71.8% for the concrete building). Interestingly, the predominant use of hydroelectricity in Quebec in the building operation phase reduces GHG emissions, which would not be the case in other Canadian provinces or elsewhere in the world. This phase contributes 27% in the wood scenario and 22% in the concrete scenario. Construction and end of life complete the picture.

In the wood scenario, the production of steel (16.9%) which was used for the interior walls and the production of aluminum (14.9%) for the window frames and exterior cladding are the largest emitters in terms of manufacturing materials. Emissions associated with wood production are estimated at 3.4%. In the concrete scenario, the production of the material is the largest emitter (24.4%), followed by the production of steel (17.5%) and aluminum (11.9%).

Although the current Building Code does not allow it in high-rise wooden buildings, the researchers wanted to assess the impact of replacing steel studs with wooden studs in partitions and façade walls. The relative variations for climate change and eutrophication indicators are significant. In this hypothetical scenario, the variation would correspond to avoided GHG emissions of 0.93 kt of CO₂ equivalent.

In light of this study, we can therefore say with certainty that the use of wood in the Arbora project has contributed to reducing its environmental footprint compared to its concrete equivalent. The use of wood in partitions as a substitute for steel would further reduce the impact on the environment.

Figure 3. Impacts of replacing steel studs with wood studs in partitions and façade walls in wood buildings



Impact categories	Unit	Scenario 1: Wood	Scenario 2: Concrete	Sensibility 1: Wood
Global warming	kg CO ₂ eq	6.88E+06	8.62E+06	5.95E+06
Destruction of the ozone layer	kg CFC-11 eq	9.85E-01	1.06E+00	8.55E-01
Smog	kg O ₃ eq	5.68E+05	6.24E+05	4.67E+05
Acidification	kg SO ₂ eq	7.08E+04	7.51E+04	5.66E+04
Eutrophication	kg N eq	2.13E+04	2.75E+04	8.68E+03



© Photo : Studio Point de Vue - Alexandre Parent and Félix Audette

The Building

- **Building function:** mixed use, residential and commercial
- **Construction dates:** 2016 to 2019
- **Surface/height:** 55 515 m² / 25 m
- **Main wood products:**
 - 5 and 7 ply CLT panels (175 and 244 mm)
 - Glulam beams and columns
- **Project cost:** \$130 million

Design Team

- **Builder :** Sotramont and LSR Gesdev
- **Architecture:** Lemay et associés (building A) and Provencher-Roy (building B and C)
- **Engineering:**
 - Wooden structure: Nordic Structures
 - Electromechanics: Bouthillette Parizeau
- **Supplier of wood products:** Nordic Structures
- **Interior design:** Humà Design + architecture
- **Building envelope consultation:** PTVD
- **LEED Consultation:** Écohabitation
- **Acoustic consulting:** MJM acoustique
- **Erector:** Les Constructions FGP
- **Landscaping:** Lemay

Drafting: Valérie Levée, Katia Lavoie, Simon T. Bellavance

Revision committee: Katia Lavoie, Simon T. Bellavance, Gérald Beaulieu, Julien Brousseau (MFFP)

With the collaboration of Keven Durand (Nordic Structures), Julie Frappier (Nordic Structures), Jean-René Larose (L2C Experts-Conseils), Patrick Lavoie (FPInnovations), Nicolas Lévêque (MJM acoustique), Marc-André Roy (Sotramont), Catherine St-Marseille (Provencher Roy)

This case study is based on information gathered by Cecobois and its representatives.
The study represents the interpretation of the facts and information we received about the Arbora Project.

cecobois thanks Natural Resources Canada and the ministère des Forêts, de la Faune et des Parcs du Québec for their contribution to this study.

PARTENAIRES



Legal Deposit Bibliothèque nationale du Québec
Legal Deposit National Library of Canada

March 2021

cecobois

Centre d'expertise
sur la construction
commerciale en bois

www.cecobois.com