CANADIAN NUCLEAR LABORATORIES

Case Study and Environmental Impact Analysis

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PREPARED FOR:

Canadian Wood Council
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wood WORKS!
A Canadian Wood Council Program

PREPARED BY:

MANTLE DEVELOPMENTS

CANADIAN NUCLEAR LABORATORIES

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Natural Resources Canada Ressources naturelles Canada
Canada

Ontario

Federal Economic Development Agency for Northern Ontario Agence fédérale de développement économique pour le Nord de l'Ontario

ABBREVIATIONS

AECL	Atomic Energy of Canada Limited
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIM	Building information Modeling
CaGBC	Canada Green Building Council
CO_2	Carbon dioxide
CO_2eq.	Carbon dioxide equivalent
CLT	Cross-laminated timber
CNL	Canadian Nuclear Laboratories
CNC	Computer numerical control
EPD	Environmental product declaration
FSDS	Federal Sustainability Development Strategy
GFA	Gross floor area
GHG	Greenhouse gas
GHGi	Greenhouse gas intensity
GWP	Global warming potential
Glulam	Glue-laminated timber
HVAC	Heating, ventilation, and air conditioning
IPD	Integrated project delivery
JIT	Just-in-time (inventory management)
LCA	Life cycle assessment
LCI	Life cycle inventory
LFRS	Lateral force resistance system
LEED	Leadership in Energy and Environmental Design
MRR	Micro Modular Reactor
NRC	National Research Council Canada
NRCan	Natural Resources Canada
NFPA	National Fire Protection Association
NBC	National Building Code
NFC	National Fire Code
OBC	Ontario Building Code

EXECUTIVE SUMMARY

The Government of Canada has committed that all new federal buildings will be net-zero ready, to support its pathway to achieve a target of net-zero emissions by 2050 as part of the Greening Government Strategy.

This commitment requires the adoption of new and innovative construction materials and practices. Federal divisions, agencies, organizations, and contractors must update their design and planning processes for all new construction projects. A central challenge is that solely following minimum guidance from codes, standards, and prescriptive guides will not guarantee that the buildings are net-zero ready. Instead, there is a need for collaboration and innovation, with lessons from successful projects being shared and emulated.

A recent example of a successfully executed low-carbon federal construction project is three buildings recently commissioned by Canadian Nuclear Laboratories (CNL) at their Chalk River Laboratories site (Chalk River).

In constructing the three new buildings, the Science Collaboration Centre, the Minwamon Building, and the Support Facility, the federal government successfully demonstrated the use of mass timber, an innovative structural material. Mass timber has less material-related carbon relative to other structural alternatives like steel or concrete. The energy performance of the three buildings is also well below federal baselines.

By conducting a whole building life cycle assessment (wbLCA), it was determined that each of CNL's buildings exceeded the federal targets of reducing their greenhouse gas intensity (GHGi) by 80% from their 2005 baseline.

The project success goes beyond environmental performance. From an execution and administration perspective, CNL's three new buildings were deemed a unanimous success by the project owner and team members. The project was completed nearly on budget, even as its schedule was reduced, and there was minimal scope creep or change orders during construction. The exposed natural wood also enhances the project's aesthetic and provides certain health benefits for CNL staff. At the time of construction, this was the largest mass timber project to be undertaken in the federal government's portfolio.

At the core of the project's success was a shared vision and collaborative effort. This enabled the team to challenge pre-existing assumptions and test ideas using first principles of design and engineering. The collaborative environment was credited to the use of integrated project delivery (IPD) as a contractual format and project delivery method.

Some of the central lessons that can be applied to future federal projects include:

- **Establish a shared vision:** Establish a shared vision and values to foster collaboration across the entire project team. This will help the team align, discover efficiencies, and identify potential challenges for project design, delivery, and construction. IPD is a proven procurement contract format that can enable a collaborative environment in federal projects. This vision and values will be used throughout the project for decision making which means decisions will not always be based on financial implications alone. Less financially-tangible benefits, like biophilic design and furthering innovation adoption domestically can be incorporated into the decision making process.

- **Challenge pre-existing assumptions:** The project team challenged their initial assumptions and addressed ongoing challenges in innovative ways. For example, they had initially assumed that by using mass timber, the project budget would increase by 20%. When the team measured the budget holistically, they discovered that mass timber was actually cost neutral.

- **Technology adoption needs collaborative practices:** In this case study, the decision to use mass timber was unanimous across the project team. Collaborative efforts enabled the team to effectively support different facets of the project from design to delivery. The IPD format was central to enabling this collaborative environment and many team members thought it should be used in most projects moving forward.
- **New material and technology education is a pillar for high performing buildings:** The team relied heavily on the expertise of their mass timber supplier, Quebec-based *Nordic Structures.* A deeper understanding of the innovative material and technology was a catalyst for better design and risk reduction.
- **Mass timber has numerous benefits:** Mass timber provides other project benefits in addition to carbon reductions. When project budgets are holistic and have broader considerations such as schedule improvements, project risk reduction, and reduced interior finishing materials, owners can realize higher performance buildings for the same cost as traditional construction.
- **Building codes and standards barriers can be addressed through alternative design:** Building codes and standards may not always have provisions for new technologies, materials, or techniques. If codes and standards are a barrier, design teams can work with code consultants to prove that the design meets or exceeds the performance objectives of the Code's prescribed acceptable solutions and propose a solution through the alternative solutions pathway to Code compliance. In this case-study, the design team worked with their code consultant to show that their design satisfied code objectives.
- **Use whole building life cycle assessments (wbLCA) to support net zero infrastructure strategies:** Achieving net-zero will require a combination of measures that address operational carbon, embodied carbon, on-site renewable energy, and potentially carbon credits. A wbLCA can measure a building's operational and embodied emissions, inform material selection for future projects, and quantify the remaining emissions to inform the offsets through on-site renewable energy and carbon credits.

Project Impact Compared to Greening Government Strategy: The greenhouse gas intensity (GHGi) target was set to 50.3 kg CO_2eq./m²/year for each building based on the 2050 target of 80% reduction from CNL 2005 baseline emission levels which is 251.5 kg CO_2eq./m²/year.

Building	CNL 2005 Baseline (kg CO_2eq./m²/year)	Current GHGI intensity (kg CO_2eq./m²/year)	Reduction % from emission baseline
Science Collaboration Centre	251.5	34.3	86.4%
Minwamon Building	251.5	10.5	95.8%
Support Facility	251.5	16.4	93.5%

Timber Construction Volumes

Building	Glulam (m³)	CLT (m³)
Science Collaboration Centre	790	600
Minwamon Building	390	455
Support Facility	470	470

INTRODUCTION

Canadian Nuclear Laboratories (CNL) and its project team recently constructed three new mass timber buildings at its largest campus, the Chalk River Laboratories (herein referred to as "Chalk River") in Chalk River, Ontario.

At the time of construction, the project was the Canadian federal government's largest and most ambitious mass timber project.

These buildings are a triumph which showcases sustainable materials and net-zero-ready construction. They are clear examples of the federal government finding successful and replicable approaches to foster innovation which can be replicated across the country with multiple co-benefits. The project team entered previously unprecedented territory to economically support Canada's low-carbon objectives and support the future of the construction sector.

CNL leadership considered mass timber construction for its numerous benefits including lower embodied carbon, improved thermal performance, aesthetics, biophilic advantages, and to honour the Ottawa Valley's historic connections to the timber industry. However, CNL was determined to explore mass timber in detail as the project team had some reservations about mass timber's potential barriers, such as its upfront costs, longevity, and safety, particularly against fire risks. A novel challenge for the team was that at the time of construction, there were no provisions differentiating mass timber from other forms of combustible construction materials to its governing structural code, the 2015 National Building Code (NBC), which is now being addressed in the 2020 update.[1]

The CNL project team leveraged integrated project delivery (IPD) as the backbone of the design and construction process, which validated that mass timber was the best structural solution for the project. IPD enabled the team to create a unified project vision, objective, and purpose, and to support each other

1 *Interview with Morrison Hershfield*

through the process. Furthermore, it helped them holistically identify challenges and risks to proactively address them. The project resulted in an innovative low-carbon building that had a shortened construction cycle that was enabled by the use of prefabricated building components. The project also was completed nearly on budget with some delays attributed to constraints from the COVID-19 pandemic. A key finding for this project is that mass timber can be cost-neutral when compared to traditional materials if the budget is considered in its entirety rather than just comparing the structural component costs. This would include the cost impact on schedule, interior finishes, labour, quality assurance, risk management and additional less tangible impacts like environmental benefits and biophilic design.

This report is a case study of the CNL's three new buildings:

1

The Science Collaboration Centre
(formerly known as the "Business Hub")

2

The Support Facility

3

The Minwamon Building
(formerly known as the "Logistics Warehouse")

The project was deemed a unanimous success by its owners and project team. Lessons from this case study can offer guidance to other government agencies and organizations to accelerate the adoption of innovative materials, technologies, and processes to address climate change.

This report will begin by establishing the context and background of the site, followed by a discussion of the site. Next, it will discuss federal green building objectives and how this site was able to achieve these objectives. The project innovation section will present the findings obtained through qualitative interviews with six key stakeholder groups. Finally, the conclusions provide lessons that can be used by others as a roadmap to selecting mass timber as a primary construction material for large-scale projects, especially publicly owned buildings and infrastructure projects.

2

PROJECT BACKGROUND AND CONTEXT

CNL sought to commission three new buildings at their Chalk River Laboratories campus (Chalk River) that aligned with the government's low carbon targets while honouring the site's rich history and local considerations.

This is being done through a $1.2 billion investment by AECL through the Government of Canada to revitalize the Chalk River campus.

2.1 Site History and Future

Chalk River is the largest single complex in Canada's science and technology community. Atomic Energy of Canada Limited (AECL) was incorporated in 1952 and owns the site and nuclear liabilities. CNL is responsible for the maintenance and operation of the site.[2]

Chalk River Laboratories was CNL's and AECL's original campus. Today, CNL operates and manages facilities across Canada. Chalk River contains more than 50 unique facilities and laboratories, including several licensed nuclear facilities that support advancements in nuclear technology, most notably Canada Deuterium Uranium (CANDU®) reactor technology.

CNL is part of the forefront of nuclear innovation in energy, health, environment, and safety and security. CNL developed a sustainability strategy document called Vision 2030,[3] that outlines its long-term sustainability related vision and charts its activities for the upcoming decade. The report highlights several commitments to advance the next generation of energy research for Canadian and international benefits, such as furthering Micro Modular Reactor (MRR) technology.

2 *Canada's National Nuclear Laboratory*, Canadian Nuclear Laboratories (2022)

3 *Vision 2030 - A Strategy for a Sustainable CNL*, Canadian Nuclear Laboratories

At a site and operational level, CNL and AECL have committed to enabling sustainable campuses of the future. AECL has committed to reaching carbon neutrality at Chalk River by 2040.[4] As a federal site, Chalk River had also aligned with the net-zero-ready emissions targets set by the Federal Sustainability Development Strategy (FSDS).

CNL's leadership had long been interested in exploring mass timber construction. In addition to the low-carbon benefits, there was a desire to honour the local history of the region. The regions and municipalities surrounding the Chalk River campus have deep roots in the timber and logging industry. CNL leadership has aspirations to support the local community by enabling growth of a new industry, mass timber construction.

Table 1 illustrates the historical progress of Chalk River, from its inception in 1944 as a laboratory site for the new defense industry, to the announcement in 2017 of a $1.2 billion investment to revitalize the campus.

Figure 1. **Science Collaboration Centre (formerly called "Business Hub")**

Table 1. Chalk River Laboratories History

1944	Chalk River, Ontario, is officially chosen as the site of the new Defence Industries Laboratory.
1947	The laboratories are transferred to the National Research Council (NRC).
1952	The laboratories are transferred to the newly-incorporated federal crown corporation Atomic Energy of Canada Limited (AECL).
2014	AECL launched a wholly-owned Canadian Nuclear Laboratories (CNL) subsidiary to manage and operate the AECL laboratories, sites, and projects.
2017	AECL, on behalf of the Government of Canada, announced the investment of $1.2 billion into revitalizing the Chalk River Laboratories. This includes the construction of new infrastructure, support buildings, and the Advanced Nuclear Materials Research Centre.

2.2 Building Overview

CNL's revitalization introduced three new buildings to Chalk River:

- **The Science Collaboration Centre** (formerly known as the "Business Hub")
- **The Minwamon Building** (formerly known as the "Logistics Warehouse")
- **The Support Facility**

2.2.1 The Science Collaboration Centre

This new six-storey building[5] has a gross floor area of 8,999 m^2. It contains offices with supporting spaces such as meeting rooms, a site wide data centre, library, 200-seat auditorium, infrastructure for future health centre, and areas for supporting amenities.[6]

There are offices on all floors except Level 3, which provides easy central access to large meeting rooms and the auditorium. The building is constructed from a mix of combustible and noncombustible construction materials and features cross-laminated timber (CLT) floors, walls and roofs from Levels 2 to 6. The CLT Panels are supported by glue-laminated timber (glulam) columns, beams, purlins and a glulam bracing system for lateral load resistance. The design offers openings above the dropped beam and between the purlins, tucking

4 *Atomic Energy of Canada Limited 2021 Annual Report*, Atomic Energy of Canada Limited (2021)

5 *Supplier Document: Business Hub Code Compliance Report B703-20000-REPT-001*, Morrison Hershfield (2019)

6 *Supplier Document: Whole Building Life Cycle Assessment for Conventional New Builds B703-20000-REPT -004*, Athena Sustainable Material Institute (2022)

away building services such as heating, ventilation, and air conditioning, (HVAC) ducts, plumbing, electrical conduits, and sprinkler pipes.

At the time of construction, specific provisions for mass timber were not available in the National Building Code (NBC). Instead, the building had to be designed and constructed under the combustible construction category, mid-rise wood buildings.[7] As discussed further in Section 4.3, the building did not initially align with prescriptive requirements of the codes and standards, so code consultants were engaged to support the design of alternative solutions.

2.2.2 The Support Facility

This new two-storey mass timber facility has a gross building area of 4,800 m^2.[8] It is a maintenance and manufacturing facility that supports world class research. It contains a two-storey fully open timber workshop area, welding shop, paint booths, and carpenter's shop. The building has two storeys of offices, meeting space, and supporting amenities.[9] Figure 2 provides an inside view of the facility.

Figure 2. The Support Facility

The offices are on Level 2, which forms an "L-shape" along the north and west sides of the building, and is adjacent to the high-volume space of the Level 1 workshop. The southwest portion of Level 2 contains workshops open to Level 1.

The building was constructed with CLT floors and roof panels supported by glulam purlins, beams, columns, and glulam bracing to resist seismic loads. The design offers openings above the dropped beam and between the purlins, tucking away building services such as heating, ventilation, and air conditioning, (HVAC) ducts, plumbing, electrical conduits, and sprinkler pipes.

2.2.3 The Minwamon Building

This new two-storey facility has a gross area of 5,100 m^2.[10] The building is the first point of contact for many incoming staff and guests. It supports site security, staff check-in, logistics truck screening and loading docks for loading and unloading trucks and is equipped with offices, meeting rooms, office support and a small conference centre that allows staff to meet clients outside of the secure zone.The building supports operations and employee services. It serves as a secure entry point for the facility and includes meeting rooms and support facilities for security and warehouse employees as well as a large warehouse. The building followed the same construction approach as the Science Collaboration Centre and the Support Facility.

Figure 3. Minwamon Building (formerly called "Logistics Warehouse")

7 *National Building Code of Canada (NBC), Division B, Article 3.2.2.58*, National Research Council Canada (2015)

8 *Supplier Document: Whole Building Life Cycle Assessment for Conventional New Builds B703-20000-REPT-004,* Athena Sustainable Material Institute (2022)

9 *Supplier Document: Support Facility Code Compliance Report B750-20000-REPT-001,* Morrison Hershfield (2019)

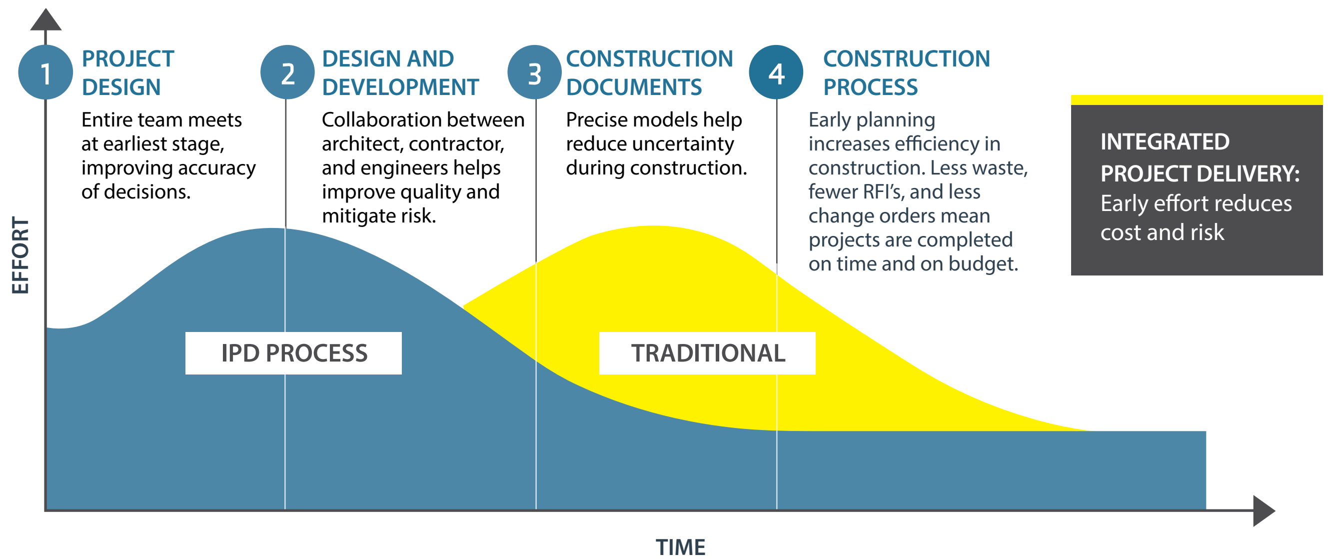
10 *Canadian Nuclear Laboratories Support Facility Profile V-03k,* WoodWORKS (2021)

2.3 Project Approach

These facilities are one of the first federal government projects to use mass timber, and demonstrates a new approach to erecting industrial and institutional buildings in terms of materials, construction, and design processes.

Since many elements of the project were innovative and their use unprecedented in government projects, an integrated project delivery (IPD) process was selected to create a team environment from the early stages of the project to maximize collaboration. IPD integrates construction processes, practices and systems, enabling owners, architects, engineers, contractors, fabricators, trades persons and building consultants to work collectively and more effectively, solving design problems together in real-time. IPD was seen as a key lever by multiple parties to find co-benefits and ultimately recognize that mass timber could be as cost-effective as traditional materials. See Section 4.1 Integrated Project Delivery and Procurement for more details.

Figure 4. IPD Process



2.4 Project Team

The project team and key contacts from the IPD collaborative firms, including their main disciplines, are shown in Table 2.

Table 2. Project Team

ORGANIZATION	ROLE	INTERVIEWEES CONTRIBUTING TO THIS REPORT
CNL and AECL	Owner	Mark Bruce: Project Director (CNL) Steve Innes: Deputy VP, Capital Projects (CNL) Garry Yaraskavitch: Chief Security Officer (AECL)
HDR	Architect	Donald Chong: Design Principal Susan Croswell: Project Principal and Architect
LEA Consulting	Structural Engineer	John Ford: Vice President - Building Structures
Nordic Structures	Timber Fabricator	Louis Filion-Cloutier: Project Lead
Integral Group	Mechanical Engineer	Keith Davidge: Mechanical Designer & Building Analyst
Morrison Hershfield (MH)	Code Consultant	Dana Scherf: Principal & Senior Code Consultant Trisha Ashworth: Principal & Senior Code Consultant
Other Project Team Members (Not interviewed for this report)	**Contractors:** Sullivan Chandos Joint Venture SCJV **Concrete Contractor:** Bellai Brothers Construction **Electrical/Civil Engineer:** Jp2g Consultants **Drywall Contractor:** Marcantonio Constructors	**Building and Controls:** Siemens **Office Furnishings:** ABI Office Furniture **JMR:** Mechanical Electrical subcontractor **Flynn:** Envelope subcontractor

LOW CARBON BUILDINGS

Major improvements and innovation in the construction sector are needed to achieve Canada's carbon reduction targets. Approaches successfully demonstrated in the design and construction of the new buildings at Chalk River can be used broadly on future projects to support this important transition.

Buildings are major contributors to carbon emissions. Building energy use and materials contributed to 37% of global energy-related CO_2 emissions in 2020. A building's energy consumption is often the central focus of emissions in buildings. However the emissions from material production and construction are often overlooked but contribute significantly to total emissions. The manufacturing of building materials like concrete and steel account for 10% of global CO_2 emissions alone.[11] To decarbonize the built environment, buildings require both lower carbon energy sources and solutions for accessible low carbon materials. As demonstrated by the projects at CNL, the adoption of technologies like mass timber can be part of the solution.

3.1 Emissions Sources: Operational and Embodied

There are two primary categories of emissions from buildings: operational emissions and embodied emissions. Operational emissions refer to greenhouse gas (GHG) emissions arising from the ongoing use of energy to maintain building operations, such as heating, cooling, and lighting. Embodied emissions refer to the carbon emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of building materials.[12]

11 *2021 Global Status Report for Buildings and Construction*, Global Alliance for Buildings and Construction (2021)

12 *Embodied Carbon 101*, Carbon Leadership Forum

Historically, the building industry and government policy has focused on reducing building operational emissions. As technology improves and energy systems become greener, operational emissions from new construction are reduced and embodied carbon is becoming a larger share of a building's total carbon emissions. Embodied carbon can represent over 90% of new high performance building emissions between 2022 and 2050 according to Canada Green Building Council.[13]

The majority of embodied carbon impacts (70-90%) in a building occur before the building is occupied, known as upfront embodied emissions. These emissions are a result of the enormous amount of resources required to extract, manufacture, transport, and install construction materials.

Embodied emissions are often measured and represented using a metric called global warming potential (GWP). GWP is an environmental impact indicator used to measure the impact emissions have on trapping heat in the atmosphere relative to carbon dioxide (CO_2), and is measured in carbon dioxide equivalents (CO_2e).

3.2 Embodied Emissions in Traditional Construction

Traditional construction materials like concrete and steel are the largest source of embodied emissions in construction. Concrete has a significant impact on global embodied carbon emissions because it is the most widely used construction material in the world. More specifically, concrete's emissions are generally from cement, the active ingredient that binds and strengthens concrete. The total impact of embodied carbon depends on many factors like the site location and building type. However, specific levers to reduce embodied carbon include minimizing the total volume of materials used and selecting materials with lower GWPs. Options for reducing embodied carbon in concrete are available with little impact to schedule or cost.[14] When permitted, CNL sought low carbon concrete mixes in their projects.

3.3 Mass Timber and Biogenic Carbon

Mass timber has numerous benefits (discussed in Section 3.4 - Why Wood?) but one of the most significant is its superior environmental performance over alternative building materials. Mass timber buildings typically have lower upfront embodied carbon emissions than typical concrete or steel buildings. Wood products also have the unique benefit of being able to sequester and store carbon. Sequestered carbon, sometimes referred to as biogenic carbon, is carbon removed from the atmosphere and stored in bio-based materials. As a tree grows, it uses the process of photosynthesis to pull CO_2 from the atmosphere and store it as wood.[15] In this way, mass timber buildings become long-term carbon sinks, storing carbon and keeping it out of the atmosphere for as long as the building is in service and even beyond if the mass timber elements are re-used. Mass timber also has the benefit where it can be designed for disassembly (DfD), where older wall assemblies can be adapted for new projects.[16]

However, the carbon may not stay out of the atmosphere in the long run. The end-of-life scenario of the bio-based material ultimately determines whether or not biogenic carbon will return to the atmosphere. Potential end-of-life scenarios for wood products include salvaging, recycling, landfilling, or burning.[17] Salvaging or recycling wood (into wood pellets, for example) can renew use for the wood product, and postpone wood being sent to landfills where it decomposes and releases some of the carbon back into the atmosphere. Furthermore, some of this carbon from decomposed wood would remain stored in the soil.

Opportunities to capture and reuse the emitted carbon exist. Carbon can be captured from incineration, a treatment process that burns waste materials at high temperatures. If carbon can be captured, it can be converted into biofuels like renewable natural gas. In some cases, like in landfills, incineration can be preferable to decomposition if carbon capture and reuse are present. However, most situations will lead to the eventual release of CO_2 emissions when burning these fuels. It is also worth noting that recycling mass timber does not necessarily translate into a reduction for the demand for virgin wood.

13 *CAGBC releases embodied carbon primer*, CAGBC

14 *Strategies for low carbon concrete: primer for federal government procurement: low carbon assets through life-cycle assessment (LCA)² initiative*, Zizzo, R. Masoudi, R. Cooney, Rob (2022)

15 *Regulating Embodied Emissions of Buildings*, Zizzo, R. Doran, K. (2022)

16 *There is life after demolition*, ArchDaily, (2021)

17 *Cross-Laminated Timber Info Sheets*, Tallwood Design Institute (2019)

Biogenic carbon is often reported separately from the total reported embodied carbon emissions due to the end-of-life scenario uncertainty. This conservative approach undervalues the benefits of carbon removal and storage because it does not consider carbon, like money has a time-value proposition. There is environmental merit in postponing the introduction of new carbon emissions until a later date means that current emissions concentrations can be delayed, enabling more time for further climate adaptation and mitigation activities. One possible method to account for biogenic carbon is to assign value to carbon temporarily removed from the atmosphere.

3.4 Why Wood?

Mass timber's benefits go well beyond carbon. Some of the benefits highlighted by the project team included shorter construction timelines, reduced construction risk, the reduction of on-site labour, biophilic properties, aesthetics, and cost-neutrality when all these factors are considered in the budget.

Mass timber offers project schedule reductions by having structural components prefabricated off-site. It also permits the use of a high efficiency inventory management system where structural elements are manufactured and shipped according to the assembly sequence, and are used as soon as they arrive on site. This is known as just-in-time (JIT) inventory management. Another advantage is that mass timber does not need time to cure like concrete does, meaning there is no wait time required for the material to gain its full strength.

The scheduling and prefabrication benefits allow high quality factory-assembled systems to be installed on site in a shorter time frame which, for some projects, can mean minimizing or even avoiding winter and/or rainy seasons. The prefabrication also reduces the amount of management, labour, and equipment needed on site to perform the work, resulting in lower project costs.

The use of mass timber can also reduce the budget for interior finishes since the exposed surfaces can perform architecturally as well as structurally. Rather than adding dropped ceilings or drywall to cover the structural elements, mass timber components can remain exposed since the wood finish is already aesthetically pleasing. This avoids the material, labour, and schedule costs to add these finishes.

Mass timber can be an important component of a biophilic design, leading to positive outcomes for building occupants including increased productivity, reduced stress, and reduced anxiety.

On-site quality control can also be reduced when mass timber is used due to the rigorous quality assurance of standardized prefabrication processes within manufacturing facilities.

Perhaps surprisingly, mass timber has physical attributes that enable it to perform extremely well in a fire event. When exposed to fire, mass timber burns slowly and forms a carbon layer on the exterior of the member called char.[18] The char layer provides protection to the member, insulating it against additional damage by preventing oxygen and therefore the fire from migrating deeper into the structural element, helping it to maintain its structural integrity. This inherent fire resistance can leave the structural performance relatively unaffected by the heat and in some cases, it can exceed the performance of non-combustible construction materials like steel and concrete. The burning rate will depend on the timber's species, moisture content, dimensions, and exposure; the material can be specified with extra thickness to meet fire resistance requirements and ensure structural integrity under fire conditions.

Wood also has natural insulating properties. A mass timber building has inherent thermal resistance that can reduce the overall amount of insulation required and enhances the building's energy performance reducing its energy consumption over its life cycle resulting in cost and emissions life cycle savings.

3.5 Federal Strategies and Objectives

Canada is warming at twice the global rate.[19] The frequency and severity of extreme weather events have increased for wildfires, floods, and heatwaves.

These events are correlated to the changes seen in climate, with the majority of the scientific community linking it to human-made activities.[20] As a result, the Government of Canada has developed the Greening Government Strategy to transition to net-zero emissions and climate-resilient operations by 2050.[21]

The government's net-zero commitments target the reduction of both embodied and operational carbon emissions.

18 *Mass Timber*, Nordic Structures, 2023

19 *Greening Government Strategy: A Government of Canada Directive*, Government of Canada (2020)

20 *Climate change widespread, rapid, and intensifying* – IPCC, International Intergovernmental Panel on Climate Change (2021)

21 *Net-Zero Emissions by 2050*, Government of Canada (2022)

Some objectives designed to reach this goal for buildings of new construction buildings are as follows:

Embodied Emissions

- Disclose embodied carbon from structural materials of major construction projects by 2022.
- 30% reduction in the embodied carbon emissions of structural materials in government projects by 2025.
- Complete a whole building life cycle assessment for major buildings and infrastructure projects by 2025.

Operational Emissions

- Absolute reduction of direct and indirect operational emissions[22] by 40% by 2025 and 90% by 2050 from a 2005 baseline.
- Government departments will use 100% clean electricity by 2022, where available. By 2025, produce or purchase renewable electricity.
- Government-owned buildings over 1,000 m^2 and considered to have "significant energy consumption" require energy metering by 2022.
- Net-zero operational emissions by 2050 for all government-owned and leased real property.

Operational carbon is expected to decrease drastically over the next 30 years due to the government's considerable effort to green the electrical grid, phasing out fossil fuels, derivatives, and natural gas[23] in favour of renewable energy sources such as hydro, solar, and wind.[24] Moreover, Canada aims to increase the amount of electricity generated from nuclear facilities.[25]

To reduce embodied carbon, the Government of Canada initiated the Low-Carbon Assets through Lice Cycle Assessment (LCA^2) initiative, which raises awareness of low-carbon materials and provides guidance to assess and reduce embodied carbon through a life cycle assessment (LCA).[26] The current construction landscape puts mass timber in a uniquely advantageous position since it offers an alternative solution that provides an excellent opportunity to reduce the embodied carbon of new construction.

22 Direct emissions in this document are known as Scope 1 emissions that occur from sources owned or controlled by an organization. Indirect emissions, or Scope 2 emissions, result from indirect emissions from purchased electricity, heating, and cooling.

23 *Government of Canada Delivers on Key International Climate Commitment to End New Public Support for the International Unabated Fossil Fuel Energy Sector*, Government of Canada (2022)

24 *A clean electricity standard in support of a net-zero electricity sector: discussion paper*, Government of Canada (2022)

25 *Market Snapshot: The Potential Role of Nuclear in Canada's Energy Future*, Government of Canada (2022).

26 *Low-carbon assets through life cycle assessment initiative*, Government of Canada (2022)

4

PROJECT INNOVATION

This chapter discusses the project innovations and solutions, as well as challenges. The goal is to build upon existing knowledge and facilitate further developments in mass timber projects in the following areas:

- Integrated project delivery and procurement
- Mass timber construction
- Compliance, safety, and durability
- Non-structural performance

Information from this section was obtained through eight interviews with six key project team members. Interviewees are noted in Section 2.3 - Project Team.

4.1 Integrated Project Delivery (IPD) and Procurement

The CNL project required a highly collaborative team environment because new ideas needed to be developed to address the site's unique considerations and objectives. One major concern was the remote, rural location, which was a potential barrier due to the limited availability of specialized trades. Furthermore, though CNL's leadership had interest in using mass timber, several assumptions had to be tested to see if the project team could address potential barriers like costing, durability, moisture, and fire resistance. CNL elected to use integrated project delivery (IPD), as means to address some of their challenges.

> *"Contracts need to be examined, and building a team by turning opponents into proponents is a great way to develop a robust process."*
>
> — MARK BRUCE, CNL

IPD is a holistic approach to construction project delivery in which all project stakeholders, including architects, engineers, construction managers, contractors, and owners, work together in highly collaborative relationships. This project also included several specialists from the beginning, including the mass timber fabricator, mechanical and energy specialists, and many others.

In contrast to conventional construction methods, the IPD methodology creates an agreement that binds all parties together in a single, multi-party contract that outlines estimated costs, project scope, and shared risk/rewards, creating a greater incentive to collaborate. The teams are convened in the same room to work together in person through project design. The CNL project team once calculated there was over 1000 years of experience between all the specialists they had brought together.

Though each session may appear expensive up front, collaborative design processes help identify opportunities to reduce costs and risks later in the project. Numerous project team members highlighted that IPD enabled the team to uncover opportunities that they would not have been able to identify and take advantage of if they had been working in silos. Design challenges and site-specific considerations were identified early which prevented scope changes and change orders later on. The project team reports that an essential part of this project was that the project vision and objectives were set together and egos were checked at the door.

> *"IPD allowed the team to focus on the big picture problems, support bigger and even "courageous" ideas, while supporting each other to turn these ideas into a reality. Many traditional contract formats prioritize the lowest cost. Templatized contracts can stifle big ideas before they are even fully flushed out. Though mass timber was a unanimous decision by the team, I'm not convinced we could have gotten there without the IPD process. Innovation requires collaboration. We need collaborative-centric contracts. IPD is a format that enables collaboration, which we certainly need more of."*

— DONALD CHONG, HDR

For CNL's project team, this type of project organization provided a number of key benefits. First, every member of the project team understood the larger context of the project, which allowed them to think beyond their traditional scopes to challenge existing perceived barriers. The shared context also helped the team reduce errors and create more accurate scheduling during the initial stages to prevent scope creep and enhance cost certainty. Another advantage was that problems were identified early and with more precision and cost-smart decisions with a team of experts available. Efficiencies leading to time and cost-saving opportunities were also identified early to manage the budget and schedule.

> *"The collaborative hands-on nature of the project's execution, from design through construction, promotes a culture where each team member can contribute, thereby reducing guesswork and assumptions."*

— JOHN FORD, LEA CONSULTING

IPD ultimately served as a framework for finding opportunities for more efficient construction, improved budgeting, and enhanced scheduling. IPD also identified design components that did not initially comply with codes and standards so the team could work with code consultants to create alternative solutions.

As discussed further in Section 4.2, the design team members reported that IPD was critical not only for the project design, but also for pre-planning the delivery of the mass timber, a product that some team members did not have extensive experience with. Mass timber requires more precision for both construction and scheduling than other structural materials.

The IPD process benefited from having a broad number of participants present from the early stages. This included Nordic Structures, the mass timber manufacturer and supplier whose extensive contributions helped the team understand the impacts the use of mass timber would have on construction processes and scheduling. Mass timber is relatively new to the Canadian construction market, so IPD served as an avenue for on-the-job training where material specific considerations were addressed in real time.

By having the team in the same place, they could also use building information modelling (BIM) to examine different scenarios and permutations of the building design together.

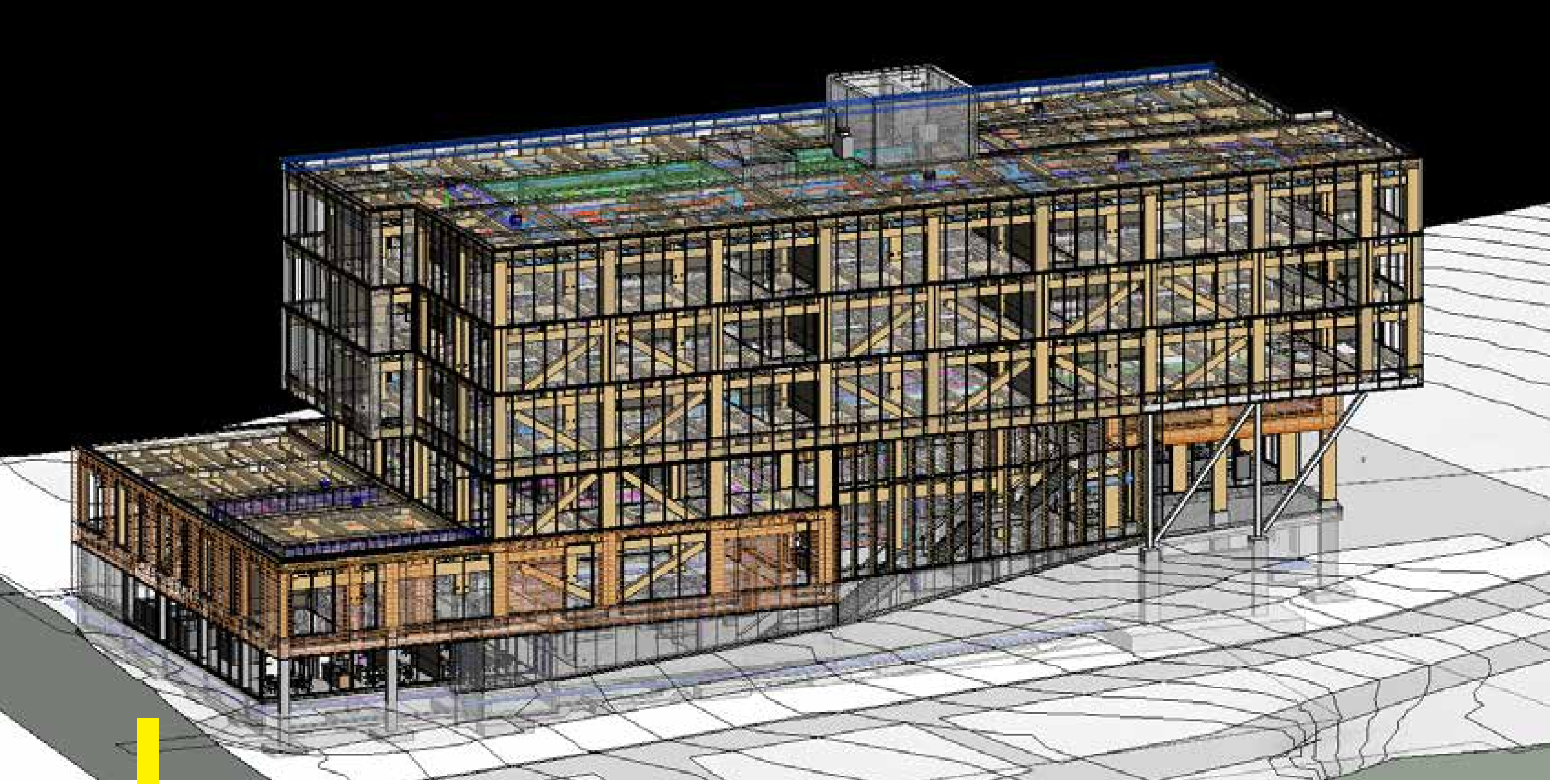


Figure 5. **Building information modelling (BIM)**

4.2 Considerations for Mass Timber Construction

The material properties of mass timber differ from traditional construction materials such as steel and concrete. As a result, some of the construction processes for mass timber also deviate from traditional construction methods. IPD helped to uncover some of these challenges and enabled the design team to make adjustments for the mass timber construction process. The IPD team conducted a cost-benefit analysis and ultimately arrived at a unanimous decision that mass timber was the best choice from a cost, schedule, and risk management perspective. Furthermore, it aligned with higher level sustainability objectives and supported the well-being of CNL staff through its biophilic properties, two outcomes that were highly valued.

4.2.1 Cost and Schedule

Though mass timber will often have higher material upfront costs than steel or concrete, the total project cost can be neutral when the entire budget is considered holistically and reduced construction schedules are accounted for. Initially, before starting the construction work, the project team assumed the entire project would be roughly 20% more expensive. However, this estimate did not consider the broader benefits. In the early stages of work, the IPD team created a cost/benefit matrix comparing their structural options, estimating that if mass timber was used for this project, the benefits later in the project would negate the upfront cost. Mass timber was cost-neutral.

Though the material costs for mass timber were higher than traditional structural materials, budgeting the project holistically allowed the project team to uncover numerous time savings and risk management benefits which neutralized the cost premium. Mass timber created two key time saving benefits. The first is that mass timber building components can be pre-fabricated off-site. Pre-fabrication provides numerous benefits, including that structural components can be manufactured indoors in specialized controlled environments meeting high quality assurance requirements. This lengthened the construction season so more work could be mobilized in tandem during winter. Second, unlike concrete, mass timber does not need curing time on site to meet its full strength.

In the context of this project, the total schedule was reduced by omitting the time needed to wait for floor slabs and structural members to cure.

Beyond the savings related to the schedule, the project benefited from reduced labour costs, improved quality, and savings on finishes, equipment, structural costs, and storage costs.

For a remote site like Chalk River, prefabrication reduced the number of out-of-town tradespeople who would have been required to commute and stay on the site.

Figure 6. **Exposed Timber Interior**

Figure 7. **On-Site Installation**

Instead, more work was done in the factory. When components were brought to site, local trades were trained to support the assembly, which helped stimulate the local economy.

Quality assurance costs decreased because there was less variability in the manufacturing process for prefabricated components. This is for a variety of reasons, such as protection from weather events, the use of scalable processes, and the use of the same quality assurance team.

The cost of finishes were reduced because mass timber surfaces are meant to be exposed and do not require covering. While steel and concrete buildings would require dropped ceilings and drywall, mass timber's surfaces have natural appeal as an architectural finish and the biophilic properties of the material contribute to a positive indoor environment, so the costs and schedule impacts of installing additional finishes were avoided in many locations.

Equipment costs were reduced because many critical processes that would have otherwise required heavy equipment on-site were already accomplished during the prefabrication process.

Mass timber also has less mass than concrete or steel so it reduced the building weight, which in turn decreased foundation costs and reduced seismic loading.

With coordination of the project team supported by the IPD process, mass timber construction enabled just-in-time inventory management. Once components and materials arrived on-site, they were installed immediately and reduced the need for storage.

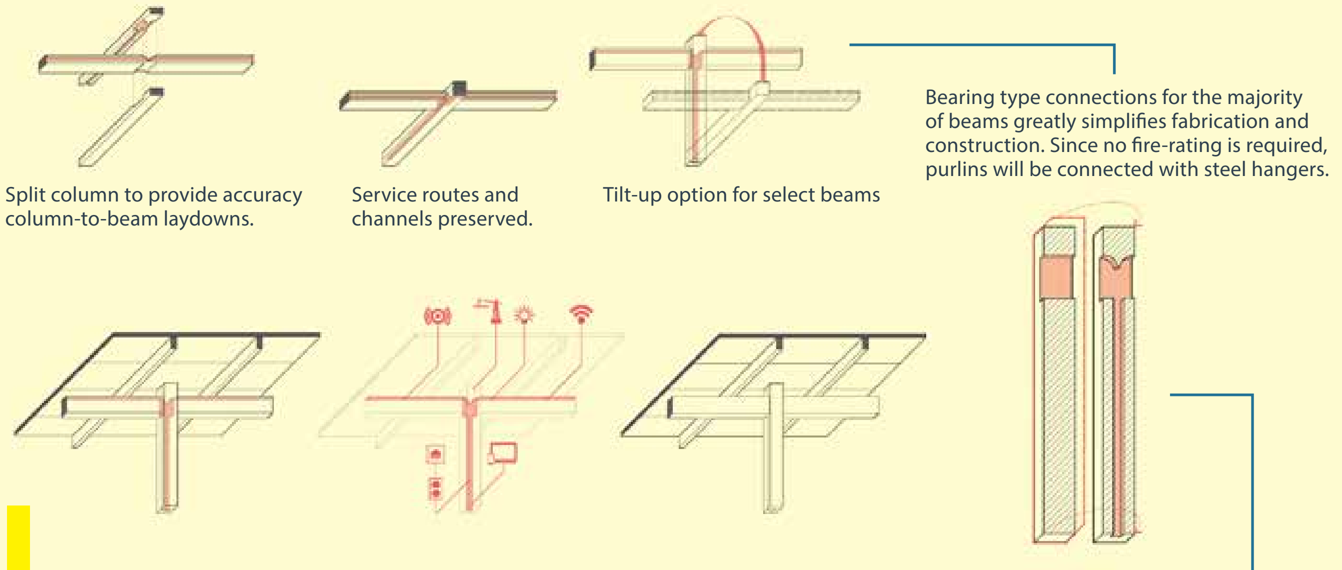


Figure 8. **Mined and Chased Beams, Columns, and Mullions**

This column strategy, which affords a realistic, replicable, and standardized unit structural component also offered scheduling advantages, and more opportunities for trades that would be involved. Along with the fire-safety advantage, this column is one that will be continually improved upon.

4.2.2 Structural Systems

The team constructed the facility's mass timber structural system using CLT floors and roof panels supported by glulam purlins, beams and columns.

Using the CLT floor and roof slabs as diaphragms is a critical element of the structure's lateral force-resisting system (LFRS). The ductile glulam timber braced frames provide additional lateral stability. Timber bracing components use steel plate connections to deliver ductility and seismic performance.

The design incorporated a unique feature, a small section of the dropped beams, mullions, and columns were manufactured to create chasing routes. Since the design did not have a dropped ceiling or drywall covering the structural elements, these chasing routes allowed the design team to run the electrical, plumbing, mechanical, sprinkler telecommunications and other services within the structural network of the beams and pillars. The mined and chased columns and beams illustrated in Figure 8 allowed for a clean and exposed finish throughout the interior.

The building's CLT floor slabs were topped with an acoustic membrane and non-structural concrete topping to mitigate noise transfer and improve the acoustic performance of the facility. The solution's success, including the mass timber floor structures, was modelled during design and verified after construction.

The team utilized mass timber winter protection for CLT roofs using an exterior peel and stick waterproof membrane applied over to the wood decking, which was applied before the snow started. The protection limited snow and ice freezing to the wood decking and improved roofing system application. This helped prevent water from penetrating the wood joints which can cause staining on the exposed timber decking on the interior.

4.2.3 Risk Management

The project team conducted a risk analysis to evaluate the strengths and weaknesses of the three proposed structural solutions (steel, concrete or mass timber). The team concluded that mass timber reduced risks in four significant areas.[27]

4.2.3.1 Availability of Trade Professionals

Chalk River is located in a remote area that is a sizable distance away from urban centers and potential workers. Procuring trades and resources was deemed a potential challenge and potentially expensive for both travel and housing. The off-site fabrication of the mass timber components helped significantly reduce on-site labour requirements. The mass timber assembly crew consisted of five to eight installation professionals. In comparison, a steel structure would require twice as many people to assemble, and a primarily concrete structure would need three times as

27 Cost benefits, schedule & risk management report, *WoodWORKS*

many people. The majority of work was completed in a controlled prefabrication facility, which ensured a safer construction site, reduced safety risks, and decreased the overall on-site hours required.

Additionally, trades were trained on-site to help them become more familiar with mass timber construction, and supplemented the on-site mass timber labour. This was particularly important for mechanical, plumbing, and electrical trades whose work is typically concealed by a dropped ceiling, but in this project, was exposed.

4.2.3.2 Quality

The mass timber supplier, Nordic Structures, improved overall project quality through precision manufacturing and strict quality control at the fabrication plant, boosting the building's overall fit, precision, and performance.

> *"Mass timber is a high-quality, high-end product. The mass timber precision through perfect cuts, shapes and robust connections done by the computer numerical control (CNC) machines and staff mitigated almost any re-work or refitting during the on-site installation."*

— GARRY YARASKAVITCH, AECL

4.2.3.3 Schedule

The mass timber option reduced the schedule by 20% to 25% compared to concrete or steel structural options.

4.2.3.4 Weather

Weather protection is a consideration for any mass timber project. Located adjacent to the Ottawa River, Chalk River has a harsh winter climate. During the erection of the timber members for the Support Facility, the team endured severe winter conditions, including snow and freezing temperatures between -10 to -30 degrees Celsius.

Mass timber is relatively uninhibited by winter construction since it is a factory-built component that arrives on-site ready to assemble.

Once the concrete slab foundation was poured and cured, mass timber construction was able to proceed without interruption despite these conditions, a benefit that proved to reduce delay risk that conventional concrete and steel structures are subject to. In these winter conditions, along with a remote location such as Chalk River, the productivity of a large concrete workforce can drop by 40% to 50%. Steel construction suffers a similar drop in productivity.[28]

4.2.4 Material Efficiency

Another reason that mass timber was selected was due to its significant embodied and biogenic carbon emissions benefits over steel and concrete. It also presented an opportunity to use components of trees that would otherwise be waste material by creating large structural elements through the combination of smaller timber pieces. Additionally, leaving the timber exposed means fewer finishes and materials, reducing cost and carbon.

> *"Many mass timber elements in our project were fabricated from a waste output from dimensional lumber manufacturing. By reclaiming the dense wood from upper tree sections, our project was able to incorporate what was once understood to be waste as a core element of our buildings' structures."*

— KEITH DAVIDGE, INTEGRAL GROUP

4.2.5 Mass Timber Procurement and Logistics

Nordic Structures, the project's mass timber supplier and timber fabricator, is a vertically integrated company that is part of Chantiers Chibougamau,[29,30] a sawmill eight hours north of Montreal. As a subsidiary of a sawmill, Nordic Structures was able to avoid a middle person, eliminating the supply chain risk that the dimensional lumber required to make the CLT and glulam for the project would not arrive at the manufacturing facilities on time, and disrupt the production schedule.

> *Communication and sharing needs and goals is a key to establishing a reliable mass timber procurement process.*

— LOUIS FILLION-CLOUTIER, NORDIC STRUCTURES

Nordic Structures prefabricated the mass timber structural system elements while the project schedule was progressing, which needed to be precise for the project to maintain its pace.

28 *Cost benefits, schedule & risk management report*, WoodWORKS

29 *Nordic Structures* (2023)

30 *Chantiers Chibougamau* (2023)

Figure 9. **Nordic's Sawmill, photography**
Photo: Stephane Groleau

One of the lessons learned through the IPD process was that mass timber construction moves quicker than other forms of construction because so much of the project is prefabricated off-site. A benefit of using the IPD process was that Nordic Structures could provide the manufacturing context and set the pace of the mass timber construction, which required other trades like mechanical, electrical, plumbing to move faster and more precisely than on a traditional project to keep up with the accelerated schedule. Accelerated procurement of other hardware, like screws, nails, and bolts was also critical to remain on schedule.

4.2.6 Aesthetics

> *"It was evident when the clients went and saw the timber buildings; they would go and touch it. I've never seen clients have quite the same reaction to steel or concrete buildings."*

— JOHN FORD, LEA CONSULTING

The aesthetic of the material impacted the project in different ways. The project team elected to keep the walls and ceilings of the structure exposed rather than covering the surfaces with a dropped ceiling or drywall. This meant mechanical, electrical, and plumbing contractors needed to conduct cleaner work because it would also remain exposed to the tenants.

4.3 Performance: Adaptability, Durability, and Safety

4.3.1 Adaptability and Durability

The project team aimed to create a space that could be used by various CNL teams in different capacities. The Science Collaboration Centre was designed to permit 400 workstations in different configurations to support CNL's growing needs and remain adaptable to future changes. Everything inside the structures was designed to be flexible (removed, configured, and adjusted as required), with only a few exceptions for fixed spaces like janitor closets and washrooms.

> *"In our site master plan, we had mapped out that no buildings were to be demolished in the foreseeable future. They have to be built to last, even if CNL's operations change. This meant that buildings like the Science Collaboration Centre had to be designed for CNL's current capacity while easily being adaptable for the needs of their future operational needs."*

—SUSAN CROSWELL, HDR

High-quality materials were used throughout the entire project to support the building's longevity. Prefabricated Kingspan insulated sandwich panels in simple shapes were used on the warehouse building. These materials also were utilized on the curtain walls and front facade.

> *"Mass timber provides the same strength as different materials in the long term. However, some external columns were switched to steel (galvanized) when there was a lot of exposure against the elements."*
>
> —JOHN FORD, LEA CONSULTING

4.3.2 Safety

A misconception about mass timber is that it poses a higher fire risk than other common building materials. Widely available results of recent Canadian studies have shown mass timber meets or exceeds required fire resistance levels, irrespective of the structural systems used.[31] As building codes articulate, all structures are expected to perform to the same level of fire safety.

Large dimension wood sections, such as those used in mass timber construction, have an inherent resistance to fire. Wood burns slowly at approximately 0.6 mm/minute. The char created on the wood surface as it burns helps to protect and insulate the unburnt wood that remains below the charred layer. The unburnt portion of a thick member of wood retains at least 85% to 90% of its strength.[32] Structural engineers design for this and provide additional wood as a "sacrificial char layer."

4.4 Codes, Regulations, and Permitting

The project team had some unique code and standard considerations. The site, although located in Ontario, supports a federally regulated industry, meaning the project had to align with national codes and standards. There was no formal municipal permitting process, but rather third-party reviews and other due diligence processes were applied.

Elements of the project design did not conform to applicable codes and standards because parts of the design were breaking new ground for the use of mass timber construction in Canada. To support these compliance considerations, code consultants from Morrison Hershfield (MH) were engaged to address issues identified during the IPD process. As challenges were uncovered, MH guided and supported the project team through developing alternative solutions. These alternative solutions were also analyzed and documented to ensure that the building's performance met or exceeded the performance required by the codes and standards.

For each instance that the design challenged or did not fit prescriptive provisions in codes and standards, MH and the design team analyzed options and how performance could be achieved in other ways, to find ways to prove that the building met or exceeded the required level of safety.

> *"Keep an open mind when applying the code, and don't limit yourself to the prescriptive path but don't jump right away to the performance path since maybe there is another solution under the prescribed path. When needed, apply the performance path through using alternative solutions as they have existed in the code since 2005."*
>
> —DANA SCHERF, MORRISON HERSHFIELD

4.4.1 Codes

The buildings were required to meet the 2015 National Building Code of Canada (NBC) and the 2015 National Fire Code (NFC).

At the time design and construction commenced, mass timber construction was inherently addressed by the NBC within the definition of combustible construction. The recent encapsulated mass timber construction (EMTC) provisions in the 2020 NBC were not yet adopted but were also not contemplated as an alternative solution during design since the design team wanted to feature the exposed surfaces of the wood.

For this particular project, the construction requirements dictated by the code are the same as would apply to light frame wood buildings of the same occupancy and size. The construction requirements prescribe required fire separations and ratings, and give the designer flexibility in how to demonstrate how the ratings will be achieved.

The design teams considered that mass timber has charring properties that insulate and protect structural wood in comparison to light frame wood construction.[33] When designed properly, mass timber can tolerate fires as well or better than structural steel and concrete.

31 *Fire Safety of CTL Buildings,* NRC (2018)

32 *Fire Safety & Performance report,* Wood *WORKS!* (2021)

33 *Fire Performance of cross-laminated timber assemblies*, Chapter 8, CLT Handbook, American Wood Council (2013)

> *"At the time of design and construction, mass timber was not explicitly a construction type in the NBC. However the existing combustible construction provisions provided the flexibility needed to accommodate the design team's approach, with the exception of the alternative solutions. Future design teams for similar buildings should remember that the new EMTC provisions do not need to be used for all mass timber buildings!"*

—TRISHA ASHWORTH, MORRISON HERSHFIELD

Elements of the NFC apply to the design of the building, such as aisle layout in open floor areas, and to the use and operations within the building such as the storage of flammable and combustible liquids, storage of compressed gasses, and hot works operations. The NFC also requires a fire safety plan at the time of occupancy.

4.4.2 Standards

Together with the codes, referenced standards establish the required fire performance of building elements. For example, CAN/ULC S101: Standard Methods of Fire Endurance Tests of Building Construction Materials is the prescribed fire test for columns, beams and floor and roof assemblies to show adequate resistance to fire. The design team stated that additional care was required to demonstrate the fire resistance ratings for the mass timber structure and assemblies, relative to conventional construction where "off-the-shelf" listings are more readily available.

Though this site serves Chalk River's nuclear facilities, the design team noted that these facilities would not contain radioactive materials beyond the exemption limits by the Canadian Nuclear Safety Commission (CNSC), so nuclear safety standards like "CSA N393 Standards - Fire Protection for Facilities that Process, Handle, and Store Nuclear Substances" were not applicable to the project.

4.4.3 Permits

The project was constructed on federal land, so it did not need to go through traditional municipal/provincial permitting processes. The only area where permitting needed to be considered was for the approval of the proposed alternative solutions.

4.4.4 Challenges and Alternative Solutions

CNL's Chalk River site has its own Authority Having Jurisdiction (AHJ), which helped enable real time feedback. When iterating through alternative solutions, CNL's AHJ was a valuable source of information, innovation, and enabled quick internal feedback while maintaining the highest level of safety.

4.4.4.1 Height Limitations, Exposed Wood, and Moisture Management

The initial proposed design for the Science Collaboration Centre building exceeded the NBC height requirements for combustible construction, which had to be addressed by the design team.

Rather than reducing the height of the design, the alternative solution proposed a compensating measure by making the first two levels out of concrete and the rest with timber. The design team had initially designed only the slab on grade and foundation walls of concrete.

Interestingly, the initial proposed building height challenged the National Building Code but would have conformed to Ontario's Building Code (OBC) if it were not a federal site. The Science Collaboration Building was constructed on a sloping site. The OBC allowed establishing grade as an overall average of the perimeter ground elevation, whereas the NBC required grade to be established based on the lowest ground elevation around the building. As such, the building height had to be measured from the lowest elevation per the NBC, making the height to the uppermost floor exceed the criteria for using combustible construction. The compensating measure of the first two levels made of concrete, provided a means to effectively reduce the mass timber structure to four storeys.

Other measures and features of the building were relied upon for the confirmation of overall performance level related to building height. One compensating measure is that the sprinkler density otherwise required by National Fire Protection Association (NFPA) 13 was increased by one hazard classification throughout the building.

Another compensating measure is that the building had two main entrances, at the lowest level of the site (level 1) and at the second level, to provide firefighting access into the building. The Fire Department access route required by the NBC is provided to the level 2 main entrance at the west end of the building, ensuring that the access route is within 3 to 15 meters of 25% or more of the building perimeter and located 20 meters or less from the floor of the top storey, which reflects the prescriptive code requirements.

Since the total number of floors made out of mass timber were reduced, this also helped avoid other code related issues stemming from the design, like

Figure 10. **Science Collaboration Centre Cross Section**

the exposed members and walls. One of the key design features of the building was that the mass timber walls, ceilings, and structural elements were to remain exposed. Most office spaces have drywall on their walls and dropped ceilings to conceal the mechanical, plumbing, and electrical networks. The CNL buildings were designed to showcase the warmth and natural beauty of wood. Furthermore, the exposed wood is an aspect of biophilic design, the concept where exposure to natural material can enhance occupant health and connectivity (discussed further in Section 4.4.3.1 Biophilic Design). The exposed wood design came into question when it was uncovered through the IPD process that the NBC required combustible construction over six storeys to encapsulate all the exposed walls with drywall or other materials. It was no longer an issue as the updated design meant that it did not exceed six storeys.

The project team also developed a Moisture Management Plan and tool which was used during construction. The tool included a pre-delivery checklist to prepare the site for mass timber deliveries, a daily checklist, and instructions on required actions after a wetting event.

4.4.4.2 Hot Works

The Support Facility building houses some workstations where staff can perform tasks that require open flames (e.g. welding and soldering). Open flame work is often referred to as "hot works."

NFC requires combustible and flammable materials within a 15 meter distance from the hot work to be protected against ignition.[34] The initial configuration and design of the Support Facility did not satisfy these requirements, so an alternative solution was needed.

The intent of the design is that the mass timber members function not only as the structure, but also as interior finishes wherever possible. The support facility includes manufacturing and large welding work areas that are located within 15 m of mass timber columns and the underside of the mass timber roof assembly. The requirement of the NFC to cover all of the mass timber within a 15 meter radius with noncombustible materials conflicted with the project desire to showcase the exposed wood surfaces.

The resolution to meet both aesthetic and safety objectives was an alternative solution to apply a flame-retardant treatment to the exposed timber on the ceiling, and also to the exposed surfaces of columns and beams more remote from the hot works. Stainless steel cladding was added to the lower portion of the columns to reduce ignition risks where the columns were closer to the hot works. Additional positive features were the noncombustible floor surface and welding curtains to optimize operations and minimize the risk of sparks.

4.4.4.3 CLT Floor Products

The flooring used in the project is 89 mm CLT decking. The product is particularly cost-effective because it meets structural requirements with a minimal thickness which reduces material costs. The CLT 89mm thick decking was new to Canadian markets so there were no previous firestopping system listings for CLT decking floors, unlike

34 *2015 National Fire Code (NFC),* Division B, Sentence 5.2.3.1.(2)

the traditional firestopping products that have many listings for concrete and steel floor assemblies.

The project team worked with industry experts to design engineered judgment details for all firestop details at the building perimeter and slab openings. They then engaged a third party consultant to inspect installation on site. This maintained the required 45-minute to 1 hour fire rating between storeys. The process was successful and the approved use of the product enabled the 89 mm CLT to be used in other subsequent projects in Canada.

4.5 Energy Performance and Internal Comfort

4.5.1 Building Envelope

The architecture team worked closely with the mechanical lead to determine the best orientation for the building envelope to meet the project's energy and carbon targets, and to increase the occupants' comfort level.

The design optimized solar gains with double glazed south facing windows and mitigated thermal losses by selecting triple glazing on the north face. Through developing the design, the team integrated high-resisting fenestrations and building envelopes for better thermal performance and reduced energy leakage. Timber enhanced the buildings' thermal performance. Its natural insulating properties result in much less thermal bridging than steel or concrete buildings, meaning less heat is lost in the winter.

The architectural team also maximized daylight, security, and safety emergency evacuation features. The project also followed guidelines and principles from whole-building sustainability and wellness targets and programs, adapted from ASHRAE guidelines and green building design standards, including LEED, WELL, and Fitwel, and other industry best practices.[35]

4.5.2 Mechanical and Electrical Systems

Mechanical equipment can often represent one of the heaviest loads within a building, so careful consideration is required when deciding where to place these components within a building. On a traditional design-build project, for example, a structure's design might be 80-90% complete before the mechanical engineer starts work. IPD discussions that included the mechanical engineer from the outset helped optimize building design harmony levels, leading to a better design approach, early clash detection, fewer errors, and enhanced collaboration and problem-solving.

> *"The mechanical team exchanged information about the weights of major pieces of equipment while the structural team was generating the first set of structure scheme options, contributing to reduced design changes in later project stages."*

—KEITH DAVIDGE, INTEGRAL GROUP

4.5.3 Occupant Health and Well-being

4.5.3.1 Biophilic Design

To improve the health and well-being of inhabitants, architects incorporate elements of the natural world into the built environment. This practice is known as "biophilic design." Architects design environments that speak to our inherent connection to the natural world by offering outdoor views, direct access to nature, and by utilizing natural construction materials such as wood, and other features that reflect and preserve the local ecology.

In the case of CNL's project, the buildings were designed to prioritize natural lighting and to keep natural materials exposed.

Biophilic design has been studied and shown to provide a number of physical and mental health benefits. Recovery rates are higher in hospitals that apply biophilic design concepts, cognitive function is better in classrooms, and productivity is higher in workplaces.[36] For example, in its simplest form in this project, when the client sees the timber buildings, it elicits a tactile response. They will interact directly with the building by touching it, unlike steel or concrete.

The building occupants not only benefit from the wood's demonstrable, positive effects, but also from the careful consideration given during the design phase to accessing natural views, improving air quality and ventilation, and providing natural lighting and improved acoustics.

> *"We knew about the biophilic properties of mass timber before engaging in this project but were still pleasantly surprised by how it changes the feel of the work throughout the entire space. Our teams agree that the space feels natural and bright; some people even describe it as relaxing."*

— MARK BRUCE, CNL

35 *CNL - Sustainability and Wellness Performance Memo,* Integral Group (2021)

36 Zhong, W., Schröder, T., & Bekkering, J. Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. *Frontiers of Architectural Research,* 11(1), 114–141. (2022). https://doi.org/10.1016/j.foar.2021.07.006

Figure 11. Mass Timber Construction

4.5.3.2 Indoor Environmental Quality

Acoustic discomfort can lead to employee dissatisfaction. Designing to mitigate sound transmission and protect speech privacy can improve productivity and decrease stress levels by minimizing acoustic distractions within the workplace. The design carefully considered that conference rooms and offices meet the standards illustrated in Table 3.

Noise Criteria (NC): Defines acceptable background noise levels by specifying the maximum noise levels present in each octave band. Lower NC values indicate spaces with less ambient background noise.

Sound Transmission Class (STC): Is a measure of how a material transmits sound. Higher STC values indicate materials and assemblies that more effectively isolate noise.

Reverberation Time (RT): This measures how long a sound takes to fade after the source of the sound has stopped. It's preferred to have lower RT values in rooms used for speech; an RT of around 1s is desirable for open offices, while values below 0.5s are for conference rooms.

4.5.3.2 Other: No Smoking, Zero Idling, External Views

No-smoking and zero-idling policies implemented onsite were developed from requirements in the Smoke-Free Ontario Act, the WELL Building Standard, and LEED v4. The requirements help to improve indoor air quality by removing sources of air contaminants from within the building and the adjacent site area.

The architecture team prioritized lighting control for occupants, proximity to windows, and high-quality views throughout the design following credits in LEED v4 and WELL Building Standard.

Table 3. Indoor Environmental Quality[37]

LOCATIONS	TARGET NC	TARGET STC (RATING)	TARGET STC (RATING)
Conference Rooms	25 Hz	45 or above	0.5s
Private Offices	35 Hz	40 or above	-
Open Offices	40 Hz	-	0.5s - 1s

37 *CNL - Sustainability and Wellness Performance Memo,* Integral Group (2021)

5

RESULTS AND CARBON IMPACT

CNL's three new buildings at Chalk River were deemed a success by the owners, the project team, and from an environmental targets perspective. The project was delivered on time, and nearly on budget, and with minimized change orders.

The CNL mass timber project has won awards and has been featured in Canadian Architect.[38] It also successfully aligned with Canada's Greening Government targets while supporting AECL's, and CNL's commitments to carbon neutrality by 2040.

The desire for a low-carbon building was a driver for CNL to look beyond traditional methods of construction. The CNL team worked with industry professionals to realize the embodied, biogenic, and operational emissions benefits of the Minwamon Building, Support Facility, and Science Collaboration Centre.

> *"The IPD process helped fold the carbon equation and increased the project's viability and intelligence."*
>
> —SUSAN CROSWELL, HDR

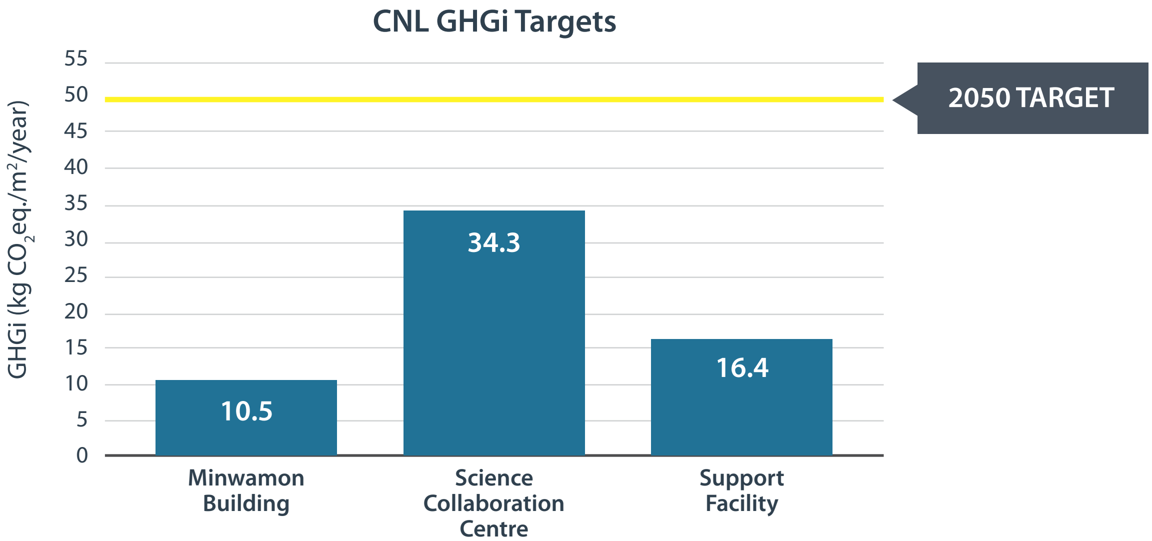
5.1 Operational Carbon Emissions

CNL commissioned Integral Group to develop a sustainability and wellness performance memo.[39] Integral Group assessed the operational emissions of all three buildings to evaluate the buildings' performance and to find opportunities for energy efficiency. A maximum yearly operational carbon emissions target, also called greenhouse gas intensity (GHGi) target, was set to 50.3 kg CO_2eq./m^2/year for each building by 2050. This target was based on an 80% reduction from CNL's 2005 baseline emission levels.

38 *Innovation Hub,* Canadian Architect (2021)

39 *CNL – Sustainability and Wellness Performance Memo,* Integral Group (2021)

Figure 12. **GHGi Targets and Performance**[41]



The Minwamon Building, Support Facility, and Science Collaboration Centre all performed below the specified GHGi target[40] (see Figure 12) and also met the Greening Government Strategy to reduce absolute GHG emissions by 40% by 2025. Moreover, the Minwamon Building and Support Facility have both surpassed the Canadian government's 2050 reduction target to reduce GHG emissions by 90% below 2005 levels.

5.2 Embodied Carbon Emissions

Athena Sustainable Materials Institute completed whole building life cycle assessments (LCA) of the Support Facility and Science Collaboration Centre using the Athena Impact Estimator for Buildings software. LCA is a methodology to assess the environmental impacts of a building throughout its life cycle.[42] The project established itself as an industry leader by satisfying the federal government's Greening Government Strategy by completing a whole building LCA for major buildings ahead of the 2025 target. Additionally, the prominent use of mass timber in both buildings qualified the project to participate in Natural Resources Canada's (NRCan) Green Construction with Wood program, which offers funding to support incremental costs associated with the design and construction of mass timber buildings.

The embodied carbon intensity of total GWP per floor area over the assumed 60 years of the building lifecycle is as follows. The Support Facility and Science Collaboration Centre was 174 kg CO_2eq./m^2 and 283 kg CO_2eq./m^2, respectively (excluding recycling and biogenic carbon). The scope of the assessment for both buildings was the cradle-to-grave impacts from the foundations, structure, and exterior envelope.[43]

Currently, there is little public benchmarking data for embodied carbon facilities, especially in Canada. However, these values represent very low embodied carbon results. Caution should be taken when comparing LCA results to other studies/benchmarking data due to differences in methodology, assumptions, and scope. However, data on these buildings can support benchmarking approaches for mass timber use in future commercial and industrial buildings.

5.3 Whole-life Carbon Emissions

Combining the embodied and operational results provides a more complete picture of the environmental impact of the buildings and is referred to as "whole-life carbon." The annual carbon GHGi performance of the Support Facility and Science Collaboration Centre is multiplied by 60 years to compare with the life cycle embodied emissions. As shown in Figure 13, the operational emissions are 5.4 and 7.3 times greater than the embodied emissions (excluding recycling and biogenic carbon) of the Support Facility and Science Collaboration Centre. The low embodied carbon of the projects is largely due to utilizing mass timber as the primary structural system.

40 The Science Collaboration Centre energy model is undergoing an update. Continued compliance with the specified GHGi target will be confirmed.

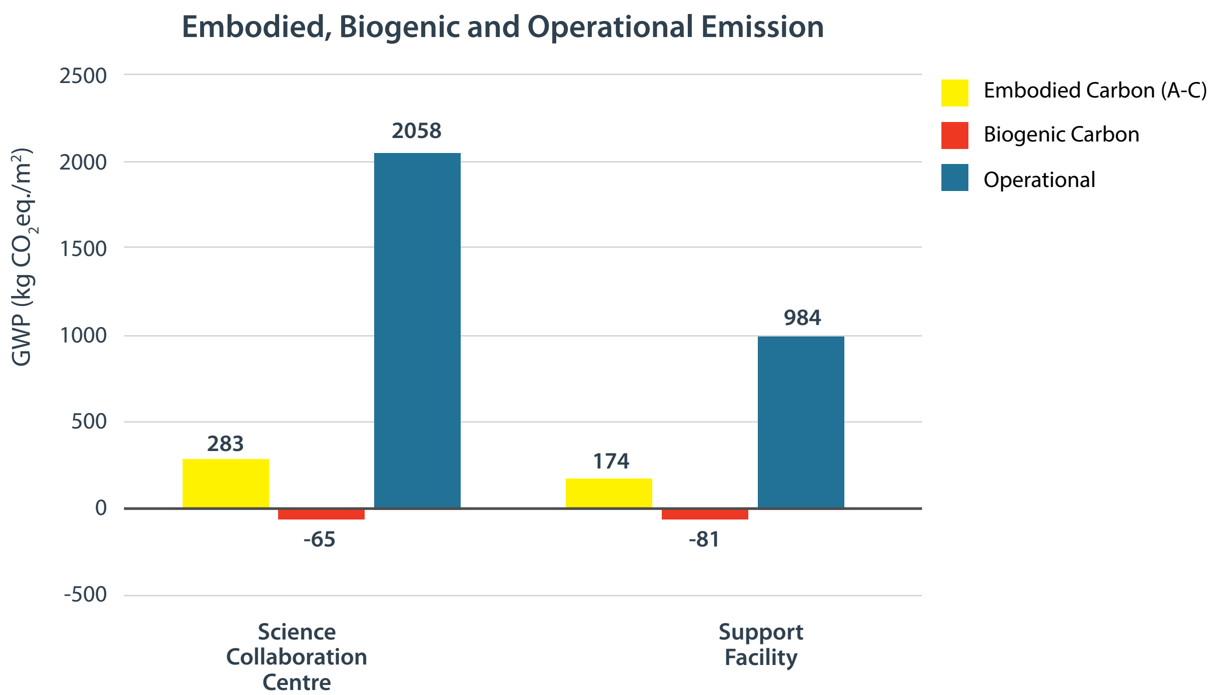
41 *CNL - Sustainability and Wellness Performance Memo*, Integral Group (2021)

42 An LCA for the Minwamon Building was not available during the writing of this case study.

43 *Supplier Document: Whole Building Life Cycle Assessment for Conventional New Builds B703-2000-REPT-004-Revesion 0*, Athena Sustainable Materials Institute, (2022)

Figure 13. Embodied and operational carbon emissions for the Science Collaboration Centre and Support Facility adopted from Athena Whole Building Life Cycle Assessment Report[44] and CNL Sustainability Memo[45]

(Note: The embodied carbon impacts associated with benefits and loads beyond the building life cycle are negligible with the given scale and, therefore, excluded from the figure).



44 *Supplier Document: Whole Building Life Cycle Assessment for Conventional New Builds B703-2000-REPT-004-Revision 0,* Athena Sustainable Materials Institute, (2022)

45 *CNL – Sustainability and Wellness Performance Memo,* Integral Group (2021)

6

LESSONS FOR FUTURE PROJECTS

CNL's three new buildings in Chalk River are considered successful across numerous criteria incuding environmental impact, scope, cost, schedule, and aesthetics.

Much of the success of the project is attributed to a shared vision, collaborative environment, and innovative approach. These pillars ultimately enabled a unified team to address large challenges, find opportunities for efficiencies, and challenge pre-existing assumptions.

Some of the central lessons that can be used for future federal projects include:

- **Establish a shared vision:** Establish a shared vision and values to foster collaboration across the entire project team. This will help the team align, discover efficiencies, and identify potential challenges for project design, delivery, and construction. IPD is a proven procurement contract format that can enable a collaborative environment in federal projects. This vision and values will be used throughout the project for decision making which means decisions will not always be based on financial implications alone. Less financially-tangible benefits, like biophilic design and furthering innovation adoption domestically can be incorporated into the decision making process.
- **Challenge pre-existing assumptions:** The project team challenged their initial assumptions and addressed ongoing challenges in innovative ways. For example, they had initially assumed that by using mass timber, the project budget would increase by 20%. When the team measured the budget holistically, they discovered that mass timber was actually cost neutral.
- **Technology adoption needs collaborative practices:** In this case study, the decision to use mass timber was unanimous across the project team. Collaborative efforts enabled the team to effectively support different facets of the project from design to delivery. The IPD format was central to enabling this collaborative environment and many team members thought it should be used in most projects moving forwards.
- **New material and technology education is a pillar for high performing buildings:** The team relied heavily on the expertise of their mass timber supplier, Quebec-based *Nordic Structures.* A deeper understanding of the innovative material and technology was a catalyst for better design and risk reduction.
- **Mass timber has numerous benefits:** Mass timber provides other project benefits in addition to carbon reductions. When project budgets are holistic and have broader considerations such as schedule improvements, project risk reduction, and reduced interior finishing materials, owners can realize higher performance buildings for the same cost as traditional construction.
- **Building codes and standards barriers can be addressed through alternative design:** Building codes and standards may not always have provisions for new technologies, materials, or techniques. If codes and standards are a barrier, design teams can work with code consultants to prove that the design meets or exceeds the performance objectives of the code's prescribed acceptable solutions and propose a solution through the alternative solutions pathway to Code compliance. In this case-study, the design team worked with their code consultant to show that their design satisfied code objectives.
- **Use whole building life cycle assessments (wbLCA) to support net zero infrastructure strategies:** Achieving net-zero will require a combination of measures that address operational carbon, embodied carbon, on-site renewable energy, and potentially carbon credits. A wbLCA can measure a building's operational and embodied emissions, inform material selection for future projects, and quantify the remaining emissions to inform the offsets through on-site renewable energy and carbon credits.

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CONCLUSION

Achieving Canada's net-zero targets will require a significant pivot from business-as-usual construction practices.

Despite some challenges, Canadian building owners and construction professionals may already have much of the technology, skills, and tools needed to achieve these targets, but lack the supportive, collaborative environment needed to bring about change.

New technologies can have positive and negative cascading impacts throughout a project. For example, in the case of mass timber, a faster schedule also means that it must be more precise. Many contract delivery formats break down project scopes and silo them. This can stifle innovation and lead to challenges being discovered later in the project, at a point when they are more costly to address. Collaborative procurement structures like IPD enable project team members to share both the opportunities and risk. These incentives help project members think of the project systematically and collaboratively to discover efficiencies and mitigate risks. This mechanism also allows the government to reduce its own risks while redirecting it to the people best equipped to manage it, the project team.

Collaborative project delivery and procurement formats like IPD enable on-the-job learning for novel and underserved technologies like mass timber. Using mass timber enabled numerous schedule-related, aesthetic, and environmental benefits. Many members of the project team credit the IPD project delivery method for the decision to use mass timber at Chalk River.

As the Government of Canada pushes the boundaries of Canadian low-carbon construction, case studies like CNL's three new buildings at Chalk River offer a meaningful precedent. This is a compelling success story for both mass timber and Integrated Project Delivery to be used as tools for delivering successful, high-performance buildings.

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