Nexii Deconstruction Case Study

January 2022 *Revised February 2022*

Prepared for Nexii
by Light House Sustainability Society

We would like to thank Temple Vision, Rob Sianchuk, Pacific Institute for Climate Solutions (PICS), the District of Squamish, Sea to Sky Removal and the Nexii team for their contributions to and support of this work.

Title page photo credits: Nexii Building Solutions

Table of Contents

1. Introduction

This case study provides a comparison of the construction and disassembly of a small building, the *Discovery Centre*, constructed with Nexii building panels, with the construction and demolition of conventional wood frame and steel stud buildings of the same size. The *Discovery Centre* previously operated as a show room in Squamish, BC, and will be shipped to and reassembled on Salt Spring Island as a residential building.

The study showcases the successes and challenges of disassembly, along with the differences in environmental impact between traditional construction/demolition and the deconstruction of the panelized Nexii building system. The case study results are coupled with findings from Light House's latest research on Design for Disassembly, construction and demolition waste.

Nexii, a green construction technology company, engaged Temple Vision to complete the disassembly; Rob Sianchuk to provide Life Cycle Assessments (LCAs) for the various scenarios; and Light House, an environmental non-profit, to capture the information needed for this case study, with the assistance of an intern funded by PICS. Jeff Wint from the District of Squamish, and Sea to Sky Removal provided information on the regulatory context and typical waste management practice in the region.

The Nexii Discovery Centre

Size: 700 square feet
Number of stories: 1
Site location: Squamish, BC

The *Discovery Centre* was built as a demonstration project for Nexii in their original Manufacturing Plant in Moose Jaw, Saskatchewan. The building was assembled in Squamish in 2019. It was disassembled in September 2021, over a period of six days.

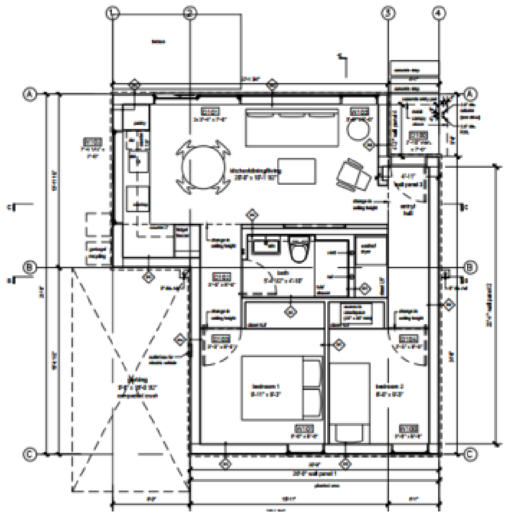

Figure 1 Discovery Centre Floor Plan

Design

Nexii Building Solutions uses a proprietary concrete mix, Nexiite, that is extremely strong, allowing for minimal amounts of the concrete to be used compared with other precast concrete panels. The *Discovery Centre* was constructed with a prototype Nexii panel. This system has evolved since this installation, reducing panel weight while balancing structural, thermal resistance and design needs. The benefits of this building system include the following:

1. Nexiite, a more sustainable, innovative alternative to Portland cement concrete, results in reduced end-to-end carbon emissions.
2. Buildings are precision manufactured off-site and rapidly assembled on-site. This significantly reduces build times, construction waste and community impact.
3. Nexii panels form a highly insulated and airtight building envelope which greatly improves energy efficiency and reduces overall operational costs, for the lifecycle of the building.

Building Assembly

After the foundation was poured and set, and services were run to the building, the panels were ready to be installed. During construction of the building, the panels were assembled on-site starting with the floor panels, followed by the wall panels, and finishing with the roof panels. Once all the panels were installed, the windows and doors could be installed. The sequence of panel installation is pre-determined (see Figure 10), the panels are shipped to site in the order that they will be installed (first panel to be installed is the last panel on the truck). The blueprint for installation becomes the plan for disassembly when it is reversed.

Scope of this Case Study

This study focuses on the structural disassembly of the building panels including the disassembly of the interior, as well as the mechanical, electrical and plumbing components. The Light House team attended two site visits to observe the disassembly process. Note that some proprietary information has been omitted from this report.

Background

The construction industry, as it stands today, has significant impact on land, air quality, and water supply[1]. It is standard practice to dispose of building products or a building at its end-of-life. While some municipalities and regions have construction waste bylaws, nationally, an average of only 16% of construction and demolition waste is diverted[2] from landfill or incineration, with most being 'downcycled' to a lesser use. The construction industry and the real estate sector consume the largest amount of raw material globally while also being the largest waste stream contributors (by weight)[3]. "Approximately 40% of global materials are used for construction"[4], and in our current linear system, construction, renovation and demolition waste makes up one third of our region's waste[5]. This results in increasing pressure on landfills to manage this waste, especially considering the global construction industry is expected to grow 35% more from 2020 to 2030 as compared to the decade from 2010 to 2020[6].

Locally, the Squamish Regional District is experiencing this issue firsthand with the landfill nearing the end of its lifespan. Solutions are being implemented to try and extend its life for as long as possible. The Squamish District has implemented a Demolition Waste Diversion Bylaw that came into effect in June 2021 to help curb the impacts of construction and demolition waste (see the 'Context' section for more information).

When considering the impact of construction, it's important to take into consideration the extraction, production, transportation and end-of-life of the materials (embodied carbon). These processes have immense impacts on the planet in terms of greenhouse gas (GHG) emissions. As of 2018, as reported in the 2019 Global Status Report for Buildings and Construction, 36% of final energy use and 39% of upstream GHG emissions globally are building-related, 11% of which resulted from manufacturing building materials and products such as steel, cement and glass [7].

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[1] Construction and Demolition Waste Reduction and Recycling Toolkit. Metro Vancouver. October 2020.

[2] *GUIDE FOR IDENTIFYING, EVALUATING AND SELECTING POLICIES FOR INFLUENCING CONSTRUCTION, RENOVATION AND DEMOLITION*, https://www.ccme.ca/en/res/crdguidance-secured.pdf

[3] Rep. Making the Business Case for Advancing a Low-carbon, Circular Built Environment. World Circular Economy Forum. October 2021.

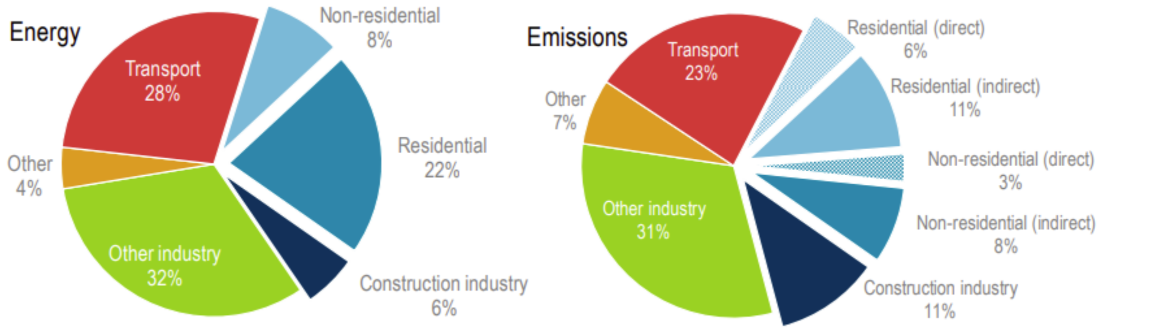
[4] Scaling the Circular Built Environment. World Business Council for Sustainable Development and Circle Economy.

[5] http://www.metrovancouver.org/services/solid-waste/wte-and-disposal/construction-waste/Pages/default.aspx

[6] 'Construction growth to outpace manufacturing this decade, says new global forecast.' Global Construction Review. November 10, 2021.

[7] 2019 Global Status Report for Buildings and Construction. Global Alliance for Buildings and Construction. 2019.

Figure 2 Global Share of buildings and construction final energy and emission, 2019 Global Status Report for Buildings and Construction



In Metro Vancouver, 78% of Construction and Demolition waste is recycled[8] and there is currently no official reporting on salvaged materials in the region. However, the 78% does not distinguish between materials that are recycled into comparable products to the original, and materials that are "downcycled" into inferior products that either serve a lower purpose (like grinding lumber into mulch) or have limited or no ability to be recycled again. This is not the highest and best use for these materials.

By looking toward circular economy solutions to keep materials out of the landfill and circulate them back into resource loops, communities will see benefits such as better air quality, better land management, job creation, more secure supply chains and economic savings:

- Designing for construction waste reduction and reusing or selling material at the end-of-life, could potentially save the owner an estimated \$100/m² of gross floor area[9].
- "Studies suggest that deconstruction produces five-to-eight jobs for every one job in demolition, a potential opportunity for skilled labour displaced in the transition to a greener economy"[10].
- With global insecurity in supply chains due to COVID-19, turning toward a circular economy can be, "a great opportunity to improve raw material resilience and decouple material consumption from financial growth."[11]
- By diverting more material for reuse and recycling, it will extend the life of landfills, allowing for land to be protected from future landfill expansions.
- Air quality can be improved with deconstruction and disassembly practices where materials are disturbed to a lesser extent, especially in a panel disassembly where walls remain undisturbed. Materials that typically cause air quality issues in a demolition are drywall, wood, and contamination with mould (common in humid environments), insulation, and

[8] Metro Vancouver Recycling and Solid Waste Management 2018 Report. Metro Vancouver
[9] Watching Our Waste. Light House, National Zero Waste Council, December 31, 2020.
[10] Hannah Teicher, A Canada-wide deconstruction industry should be part of our 'build back better' recovery, Vancouver Sun, January 31, 2021
[11] Brown, A.B. "Gartner: 51% of Supply Chain Pros Expect to Increase Circular Economy Focus." Supply Chain Dive. Supply Chain Dive, September 28, 2020. https://www.supplychaindive.com/news/gartner-survey-supply-chain-circular-economy/585962/

dust that collects in the building over time[12]. By using a backhoe in demolition, these contaminates are released into the air causing decrease in air quality and a risk to both workers as well as the public.

Prefabricated Panels

Nexii buildings are comprised of a system of panels that are designed to be built off-site and assembled on-site in a quick and efficient way. These panels are prefabricated units, built on an assembly line in a plant and transported to the construction site. Prefabricated, panelized or modular building systems can have advantages over traditional on-site construction[13]:

- Site work can happen at the same time as panels being built, which can reduce overall construction time;
- Units can be built when weather does not allow outdoor construction;
- Efficiencies and lean manufacturing principles realized on the assembly line can result in savings;
- Because units are built indoors and closely supervised, they can be of higher quality than construction on-site.

Figure 3 Nexii Manufacturing Facility

Design for Disassembly

Not all modular buildings can be easily disassembled at their end-of-life. Nexii is one of the few companies that have invested research and development to make this possible. They put this thinking into developing a new panelized construction system that will easily allow disassembly and eventual reassembly on a new site. Select wood panel SIPs (structurally integrated panels) and mass timber construction companies are also researching and piloting building disassembly and reuse, a practice that is more common in Europe than North America on the whole. This type of consideration is called Design for Disassembly (DfD). It is a strategy to design and build a structure with its end-of-life in mind. In addition to considering the decommissioning of the building, DfD also considers the end-of-life of products installed in the building and their replacement during the life of the building, including ongoing maintenance and renovations.

[12] Jule, Jesse. Interview by Christina Radvak. Telephone Interview. November 22, 2021.
[13] Modular and Prefabricated Housing: Literature Scan of Ideas, Innovations, and Considerations to Improve Affordability, Efficiency, and Quality. (2014) BC Housing.

During the design phase, the changes over time of the programming of the building are anticipated and accommodated, as well as the deconstruction of the building itself to allow them to be "reversible". DfD principles cover all building components including structural elements, finishing products as well as mechanical, electrical, and plumbing systems (MEP).[14] These reversible buildings are designed so that there can be deconstruction between different 'levels' (see Figure 4).

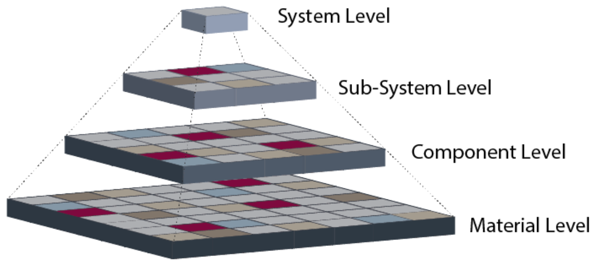


Figure 4 BAMB Reversible Building design guidelines' hierarchy of levels of technical decomposition of reversible buildings.

Design for disassembly has a number of environmental, social, and economic benefits. By designing for end-of-life, it extends the useable life of the materials, allowing for these to be diverted from the landfill either by being reused beyond their original purpose or being easily separated to properly recycle the different components. DfD also promotes jobs by supporting a deconstruction and reuse industry in local communities[15] and allows for a building to have economic value at the end of its life so that the materials can be sold and reused rather than the owner paying for the building to be disposed of.

For the *Discovery Centre*, disassembly was mostly focused on the structure of the system (floor, walls and roof) since there were minimal finishes in the building. The electrical and mechanical systems were integrated into the panel design to allow for easy disassembly and pre-planned penetrations of the envelope to enhance the performance of the envelope and future reuse.

Nexii DfD Strategies:

- Access to bolt connections for panels
- Panelized wall assembly to allow for easy disconnection and assembly
- Labeling of panels to provide information to teams in the future
- Using durable materials, like Nexiite, that withstand deconstruction processes

Applying DfD principles to concrete building foundations has remained a gap in most circular design case studies from across the industry. The highest and best use of the concrete foundation for this project would be on-site reuse. Alternatively, the foundation can be crushed, and the rubble reused as aggregate or landfilled.

Context

The District of Squamish, where the *Discovery Centre* is located, has developed the Community Climate Action Plan to collectively reduce greenhouse gas emissions. The city aims to reduce CO_2 emissions by 45% against a 2010 benchmark and reach net-zero emissions by 2050[16]. These plans are aligned with federal and provincial actions that support a circular economy in the construction waste industry. National building standards such as the Canadian Construction Association's standard document CCA 81-2001 "*a best practices guide to solid waste reduction*"[17] have been successful in increasing material recovery rates.

[14] Design for Disassembly Report (2021). https://www.light-house.org/wp-content/uploads/2021/04/DfD-Report-Final.pdf
[15] The business case for circular buildings. World Business Council for Sustainable Development. October 27, 2021.
[16] District of Squamish Community Action Plan. District of Squamish. April 2020.
[17] A best practices guide to solid waste reduction. Canadian Construction Association. 2001.

End-of-life management strategies for the District of Squamish include policy-driven incentives and enforcements. This includes the development of recycling targets as part of the construction, renovation, and demolition permit process that is supported by fee and rebate incentives. Material separation is also enforced for construction materials that enter the landfill. Further policies in the future will be supported by a working group that will assess wood waste and explore avenues for resource recovery.

District of Squamish Demolition Waste Diversion Bylaw[18]:

Based on their current engagement and research, the District of Squamish has implemented a Demolition Waste Diversion Bylaw, that was put into effective June 16, 2021. The bylaw will require a permit application fee of $2 per square foot to be paid to the city that will be reimbursed in full when the project team has proven, through documentation, that at least 80% of the construction is diverted (by volume) and a partial refund if over 40% is diverted.

The Community Climate Action Plan identifies the level of difficulty and timeline for the strategies that are outlined within the document. Their goals to divert wood waste through different strategies involved a medium-high cost to implement to engage sustainability professionals and provincial authorities to develop forestry wood waste plans.

Table 1 District of Squamish - Community Climate Action Plan excerpt

STRATEGY: Manage wood waste				
Assessment of strategy	Actions, and level of difficulty (green/blue/black)		Type	Timeline
• Financial cost: High • Degree of impact: High • Leverage: Medium	■	Enforce construction materials separation at the Landfill.	Direct	Short
	■	Develop recycling targets as part of the construction, renovation and deconstruction/demolition permit process. Support the processes with policy, fee/rebate structures and possibly a bylaw amendment.	Direct	Medium
	◆	Partner with the Province and others to explore strategies to manage current forestry wood waste in Squamish (e.g. from log sorts, mills).	Partner	Short
	◆	Develop a working group/project to assess existing buried wood waste and determine options for resource recovery.	Partner	Medium

[18] "Construction and Demolition Waste." District of Squamish.

2. The Process

Nexii's high-performance envelope and structural solution integrates the following design aspects that are important in deconstruction and design for disassembly principles:

1. Nexiite

The panels are built with a thin layer of Nexiite as the exterior that completely encapsulates EPS insulation, Nexiite 'ribs', and additional structural elements running through to provide support. Panels of various dimensions make up the entirety of the envelope of the building. For this early iteration of Nexii panels, windows and doors were not installed in the manufacturing plant due to transportation logistics (preventing breakage). In later versions, windows and doors are integral to the panels.

2. Mechanical, Electrical and Plumbing Systems

The degree of MEP integration (in particular the plumbing) varies greatly from project to project. For this installation of the prototype Nexii panels the MEP systems were embedded into the panels. This allows for less material needed in finishing. Typical concrete walls require bulkheads, chases or false walls to hide these systems, however, in the case of Nexii's panels the plugs are integrated into the wall for a more seamless system.

Steel stud interior partitions were connected directly to the exterior wall panels to create interior spaces. The interior of the space had no drywall, reducing the amount of construction waste produced.

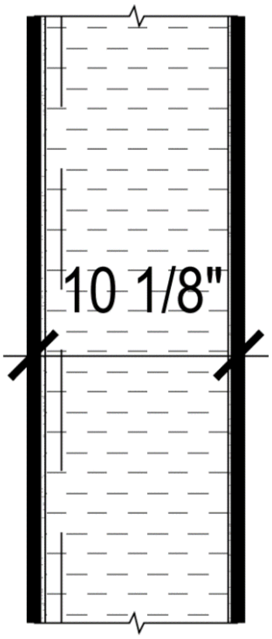


Figure 5 Typical 10" Insulated Wall Panel w. light texture finish

3. Bolt-in-place connections

The panels are connected through bolt details at the bottom and top of the panels. The bolt connections secure the neighboring panel together as well as to the foundation. The bolts are housed in a metal casing that is big enough for appropriate access for tools to allow for the connection and disconnection of the panels. The panels are also periodically connected to the foundation at intervals that are unique to each panel design.

Figure 6 Connection detail at exterior corner

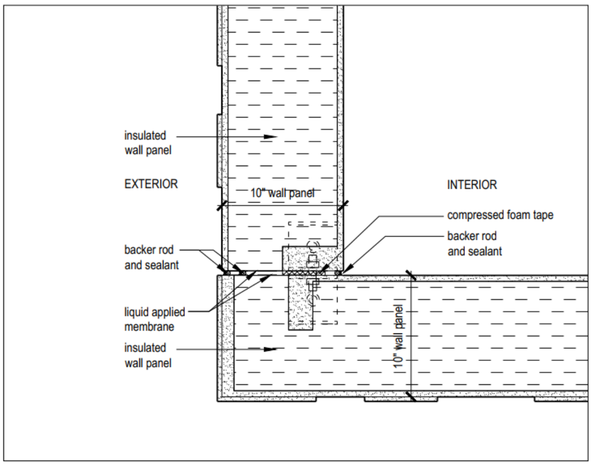


Figure 7 Plan of typical exterior corner

Figure 8 Connection detail at exterior, not at a corner

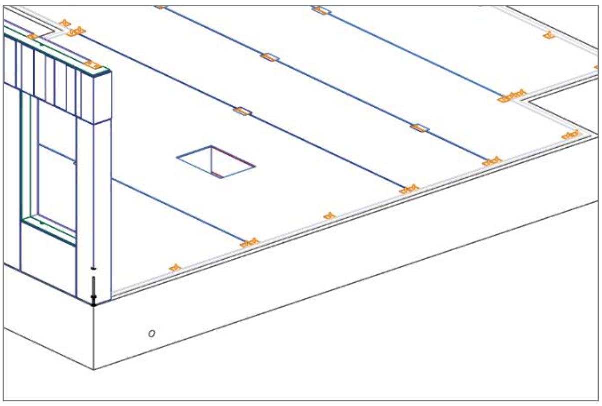


Figure 9 Excerpt of wall panel assembly detail

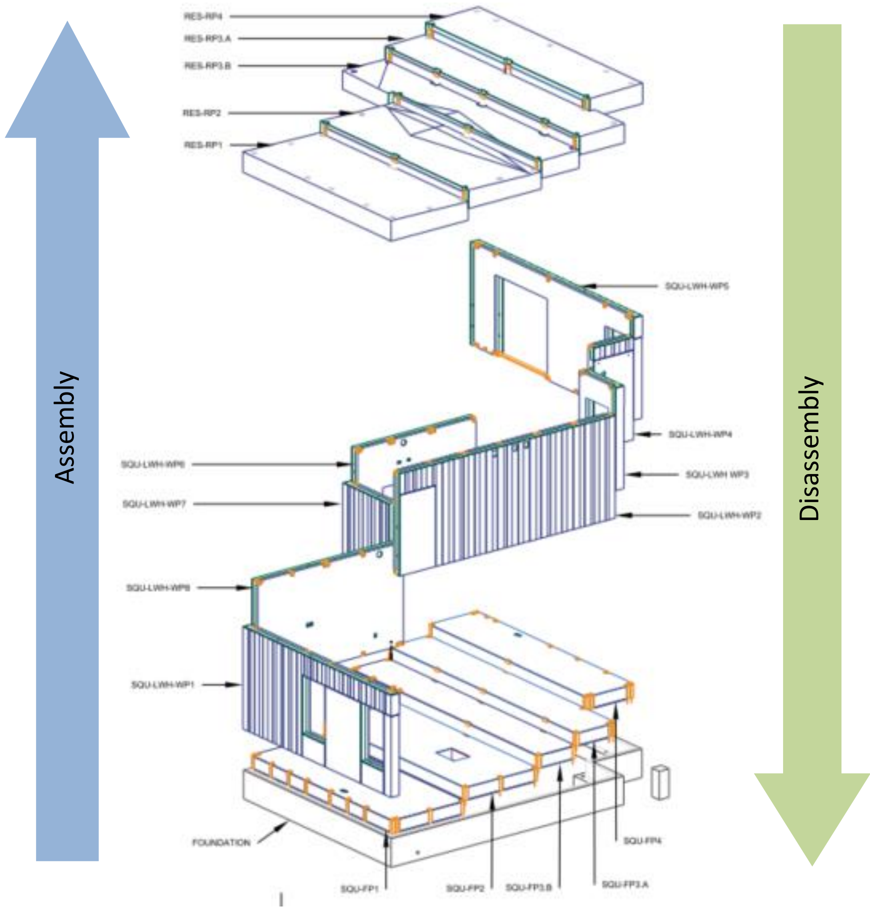


Figure 10 Nexii panel assembly and disassembly diagram

The Discovery Centre Disassembly

At the end of the Nexii *Discovery Centre*'s use in its Squamish location, the building was deconstructed into its component panels to be reassembled on a new site. Because its future deconstruction was considered during design using DfD strategies, the disassembly was simple and on schedule.

The method of the disassembly was done in the reverse order of the assembly (see Figure 10). The team started with the removal of the interior of the building, including the mechanical and electrical systems. Then, the team could begin the panel disassembly, starting with the roof. The windows and doors were protected and secured so that the wall panels could be removed and flat packed for transportation. Finally, the floor panels were removed, leaving the foundation intact.

Figure 11 Member of the crew breaking sealant between panels

The panels were separated from one another by disconnecting bolts at the top and bottom. Sealant also had to be broken, this was done using a reciprocating saw (see Figure 11). Once the panels were separated from each other, the bolt locations doubled as anchors for a crane to lift the panels. When the panels were lifted in the air and away from the building, they could be placed on a flat bed truck (in the case of the roof panels, which were already horizontal) or, in the case of the wall panels, they were laid onto the ground on EPS dunnage for the crane to readjust anchor points and then lifted onto the truck.

Below is the Nexii Panel Disassembly Schedule that remained on time and took 6 days in total.

Table 2 Nexii Panel Disassembly Schedule

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Interior finishes removal	Roof panels	Prep windows/doors	Wall panel removal	Wall panel removal	Floor panels

Panel labeling system

When the panels were initially built, they were identified with standard labels before being transported to the site and assembled. The labels include a unique panel identification number, the type of panel (roof, wall, floor), the size and weight. These labels are located on the ends of the panels which are covered up when another panel is connected. The labels were not in perfect shape; although they were legible, this discovery highlighted the need to improve the durability of the panel labelling system.

Figure 12 Nexii Label

3. Analysis & Reflections

Based on information extracted from interviews, site visits, and research, both qualitative and quantitative comparisons were made when analyzing the benefits of disassembly of Nexii panels in contrast to typical wood frame and steel stud demolition. Findings from this analysis provide the reflections of how Nexii panels compare overall.

Qualitative Comparison

According to Jesse Jule, the builder with Temple Vision who led the disassembly of Nexii panels,[19]

"I would say the differences are almost incomparable, they are night and day in their system of construction. The building solution that Nexii is offering is the future and it's here now!"

Some of the variations observed between demolition and Nexii disassembly, where the results are important, but could not be quantified within the scope of this study were:

- **Site Disturbance**: The site is significantly less disturbed by disassembly than demolition. There is less soil compaction and erosion, which occurs when heavy construction vehicles are driven over a site area. Soil compaction reduces water infiltration and root vegetation growth potential (i.e., stunted tree growth). Loss of topsoil through erosion reduces soil quality and increases sedimentation in neighbouring waterways. Traditional demolition typically uses heavier machinery moving over the entire site, however, in the case of the Nexii disassembly, a single relatively stationary crane was used to access exterior walls and roofs. Using a crane can reduce site disturbance by avoiding site soil and vegetation disturbance. Soil compaction can also occur from storing heavy materials directly on site for longer periods of time. In the case of the Nexii disassembly, the roof panels were removed by crane and directly placed on a truck, which transported the panels to a warehouse for storage. The wall panels were placed on the ground, reconnected to the crane to change their orientation and immediately stacked on the truck. Observations from the Nexii disassembly methods suggested there tends to be minor site disturbance compared to traditional demolition methods.

- **Air Quality:** Airborne dust from construction and demolition activities can impact environmental and human health. Fine dust particles from dust generated on-site can enter airways and lungs, causing long-term health issues. Currently, more construction workers die from exposure to these airborne contaminants than die from all construction site accidents combined.[20] These pollutants also enter water bodies, changing PH levels, among other impacts. Traditional demolition takes a destructive "knock and crush" approach where residual materials can be mixed into surrounding soils and made airborne. Demolition causes disturbance of dust, mould, drywall particles, and other air quality contaminants. In the case observed from the Nexii disassembly, very little to no airborne dust was generated.

- **Safety and Health**: Construction safety is critically important for those working on a site, as is the long-term wellbeing of construction workers. Compared to wood frame deconstruction, the removal of Nexii panels is less physically strenuous. The crane does the heavy lifting, moving the panel from the building to a truck, reducing the physical labour needs and strains. The physical impact on a crew is minimal, compared to more physically demanding work that takes a toll on the crew's bodies and affects how long an individual can stay within their line of work. When

[19] Jule, Jesse. Interview by Christina Radvak. Telephone Interview. November 22, 2021.

[20] Based on statistics published by WorksafeBC. Annual reports vary from year to year but are relatively consistent in workplace disease due to prolonged chemical/toxin exposure causing more deaths in construction than are caused by accidents.

considering the deconstruction of a wood frame building for a similar sized building, a crane is often not used because of cost.

With demolition, where material movement is only “semi-controlled”, there is a greater risk of debris or collapsing structures causing harm or damage when compared with greater control in the removal of the Nexii panels, with the caveat that the panels themselves are very heavy, so if an accident were to occur, more harm may result than might be typical with demolition debris.

- **Environmental & community benefits:** Some of the quantitative benefits resulting from disassembly are discussed later in this report; other environmental and community benefits are more difficult to quantify but are equally as important. Demolition is noisy, messy and disruptive. The process to deconstruct the *Discovery Centre* reduced all three issues. While both demolition and the disassembly of the Nexii panels involve the use of heavy machinery (excavator or backhoe and crane plus flatbed truck respectively), there was significantly less noise from the mostly stationary equipment used on the *Discovery Centre* site compared to the knocking down and crushing that occurs on a demolition site. Repeated exposure to noise at 85 decibels or above puts one at risk for serious hearing loss, and demolition is one of the loudest phases of construction, and frequently reaches this noise level.

  Another consideration is that of landfill lifespans and environmental impacts. These impacts include altering soil chemical composition; leeching of these chemicals into adjacent soil; high concentrations of ground level ozone and unpleasant odours[21]. Keeping demolition waste out of the landfill is of particular concern for the District of Squamish. Future landfills impact local residents’ health, reduce land value, degrade the land, and reduce land availability in areas where new landfills are built[22]. The type of deconstruction that Nexii’s panel design allows supports the District of Squamish’s sustainability goals, where deconstruction is a key part of their circular economy strategy”[23], and is a means of transferring this practice from single-family residential to the commercial sector, which is one of Nexii's core markets for building products.

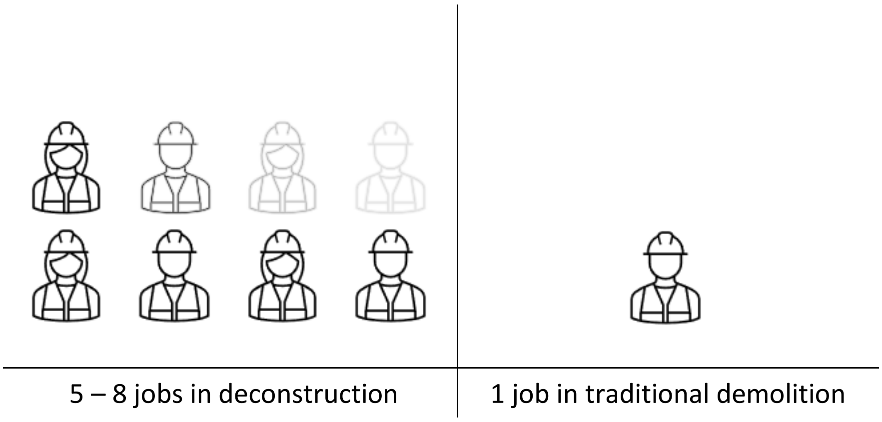
"Deconstruction is going to be a key part of our circular economy strategy, and seeing how it can work with ICI [industrial, commercial and institutional] buildings is an important step in that [process]." – Jeff Wint, District of Squamish

[21] ‘Environmental and socio-economic impacts of landfills.’ Maheshi Danthurebandara et al., January 2013.
[22] Ibid.
[23] From correspondence with Jeff Wint, Outreach Sustainability Coordinator, District of Squamish

- **Time & Jobs**

  Deconstruction has been shown to "produce five to eight jobs for every one job in demolition."[24] This was demonstrated in the Nexii disassembly where three people were employed over six days[25] compared to a demolition project where one to two people are employed for three to five days for a typical size project. The disassembly also provided training for installation of Nexii panels, which will be completed by the same company that provided deconstruction, Temple Vision. Nexii provided an estimated 124 hours in training the crew during the disassembly (roughly 1/3 of the total labor time spent on site).

Figure 13 Panel Disassembly vs Traditional Demolition Job Creation



Quantitative Comparison

This section looks at embodied carbon using Life Cycle Assessment (LCA), waste management and waste composition, as well as the cost for the disassembly of the *Discovery Centre*, and the value of the recovered material.

Discovery Centre, Life Cycle Assessment

- **What is LCA:** Life Cycle Assessment, or LCA, quantifies the potential environmental impacts of products, from the extraction and harvesting of the raw resources, through manufacture, transportation and use, and finally to disposal; it is a process based on natural sciences that considers the entire value chain. Similarly, LCA can be applied to buildings to help designers focus their efforts on reducing the environmental footprint. When the entire building project is considered holistically in an LCA study it is called "whole-building LCA". In a whole-building LCA, all the flows between processes and nature at each life cycle stage are inventoried – that is, the resources consumed, and the substances or wastes emitted to air, water and land are calculated for every stage of the building life cycle. Next, those environmental flows are assessed for their likely consequential impact on the environment, such as global warming, ozone depletion and acidification. For example, in the context of its use in building design, LCA compares the impacts of different types of insulation, structural materials, and building techniques, drawing on a range of data resources such as Life Cycle Inventory (LCI) databases, impact assessment methods, other LCA studies and EPDs.

[24] Hannah Teicher, A Canada-wide deconstruction industry should be part of our 'build back better' recovery, Vancouver Sun, January 31, 2021
[25] Hours logged by Nexii team.

The European Standard, EN 15978, specifies the calculation method based on LCA and other quantified environmental information, to assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment used in the *Discovery Centre* LCA, prepared by Rob Sianchuk.

- **Scope of the LCA:** For this case study, whole-building LCA includes the assessment of the environmental impacts of the building materials, construction, building use, deconstruction or demolition of the structure, and the consequences of the material disposal, or material recovery (known as cradle-to-grave, and cradle-to-cradle respectively). Three scenarios were studied in the LCA: Nexii *Discovery Centre*, Steel Stud building, and Wood Stud building. The hypothetical steel stud and wood stud buildings are of the same size, thermal and structural performance in order to set a baseline of comparison to the *Discovery Centre*.

  As seen in Figure 14, below, the Nexii design assumes reuse of all elements, except for the foundation. The steel and wood stud designs assume demolition of all elements, with limited separation of materials for recycling. Demolition waste from steel stud, and wood stud scenarios is assumed to be disposed of in landfill, with the exception of steel and drywall, which are typically locally recycled, based on our research of waste management practice in the region. At the time of the disassembly, the site owner intended to reuse the concrete foundation, however this was later demolished to return the land to its original state. A sensitivity analysis, summarized in Figures 14 and 16, highlight the differences in LCA results with and without on-site reuse of the foundation.

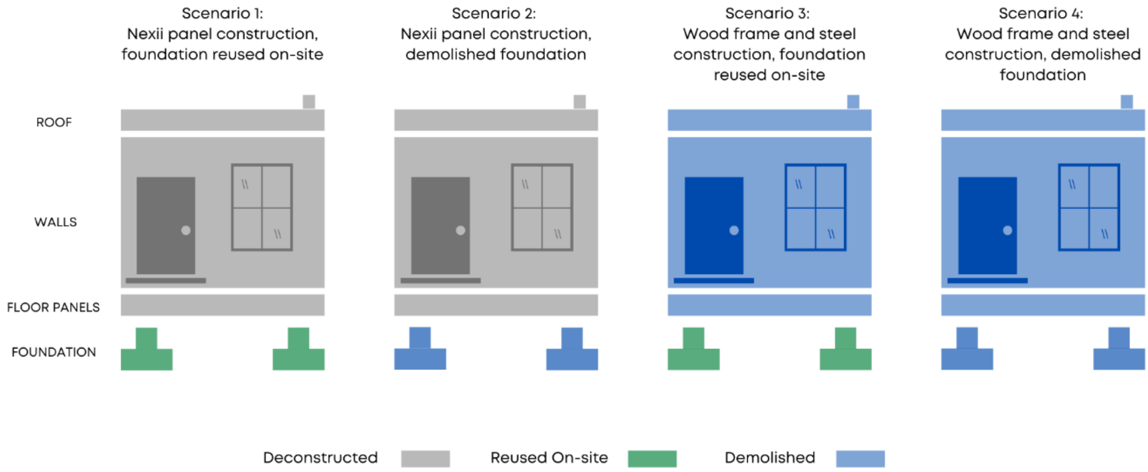
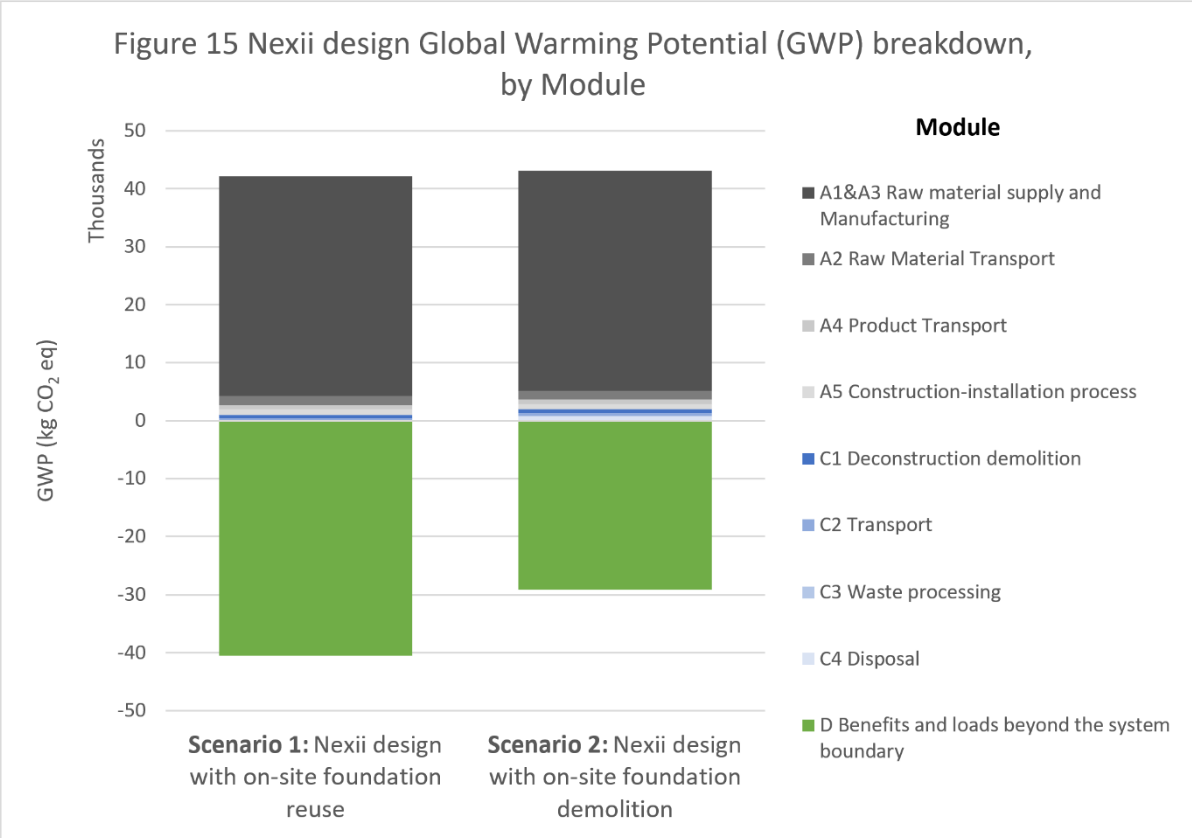


Figure 14 LCA Scenarios for Nexii, Steel Stud and Wood Stud designs, with/without foundation reuse

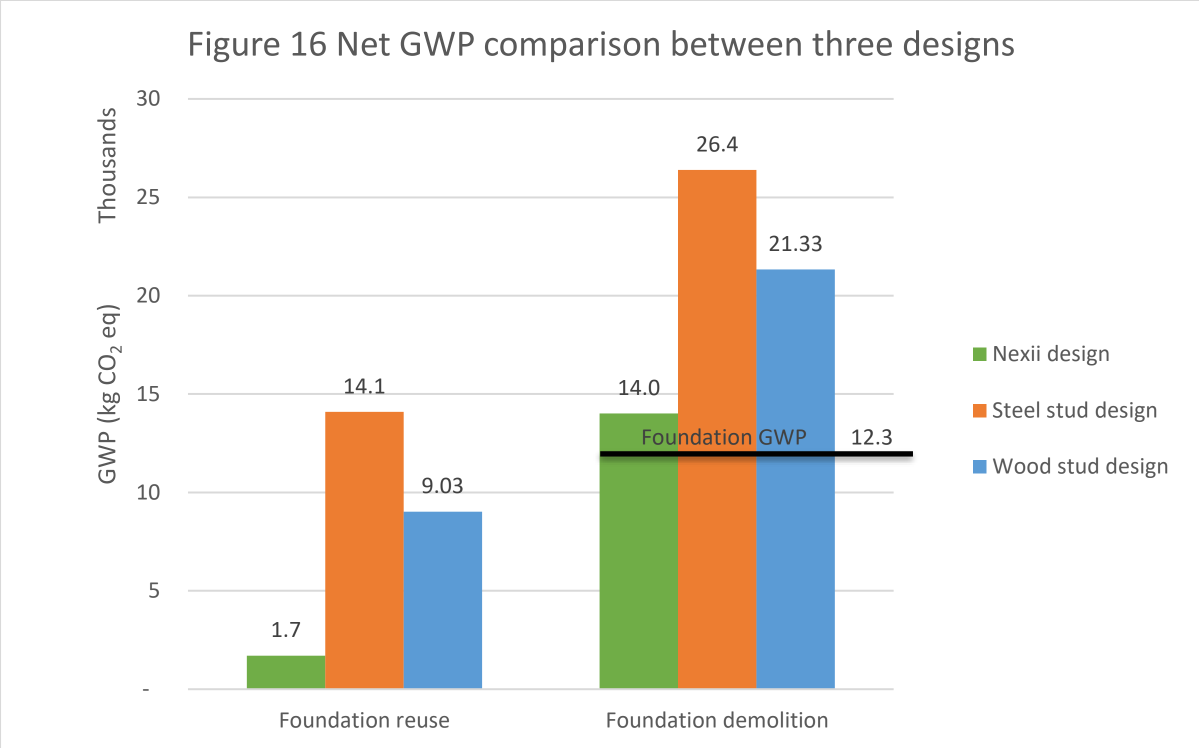
- **Exclusions:** The LCA study focuses on the environmental impacts of the materials; operational energy and water use are not considered and are assumed to be similar or identical in all three scenarios. The study also does not extend to the reassembly of the panels, although it includes the transportation to their new location. Emphasis for the scenario comparison was on walls above grade, roof and lowest floor construction. The foundation was assumed to be identical across Nexii, steel stud and wood stud design. The prototype panels used in the construction of the *Discovery Centre* were early concept designs with higher embodied carbon than Nexii's current panel products. Nexii's evolved panel design, customized to end-use and lighter weight while balancing structural, thermal resistance and design needs, was not considered for this study.



See Appendix 1 for a description of LCA Modules

The bar chart, as seen above in Figure 15, shows the Global Warming Potential (GWP) distribution of Scenario 1 (foundation reuse on-site) and Scenario 2 (no foundation reuse) by LCA Modules. It is noted that Module D has negative values which indicates the benefit from recycling, recover or reuse of building materials. In Scenario 2, the majority of the reused building materials is Nexii panels. The ability to deconstruct the Nexii panels intact, ready to be installed in a new location, offsets much of the cradle-to-grave GWP impact as the need to manufacture new panels is avoided – up to **96%** for Scenario 1. This is largely a result of the significant CO_2e emissions savings in material manufacturing for the next use of the panels that is reflected in Module D, and waste disposal savings in Module C4.

Figure 16 below highlights Net GWP (cradle-to-cradle) comparison between the three designs, with and without foundation reuse. For Scenario 1 (foundation reuse on-site), the Net GWP of the Nexii design is **81%** lower than wood frame and **88%** lower than the equivalent steel stud construction. In Scenario 2 (no foundation reuse) the Nexii design has a **34%** lower embodied impact than wood frame and a **47%** lower impact than the equivalent steel stud construction (see Figure 16).



Waste

When a building approaches its end-of-life, it will typically either be demolished or deconstructed. This section investigates the waste generated after the *Discovery Centre* building finished its service life in its original location, including the breakdown of materials reused, recycled, and sent to the landfill.

There are a few considerations to note regarding the management of waste and how it informed the studies:

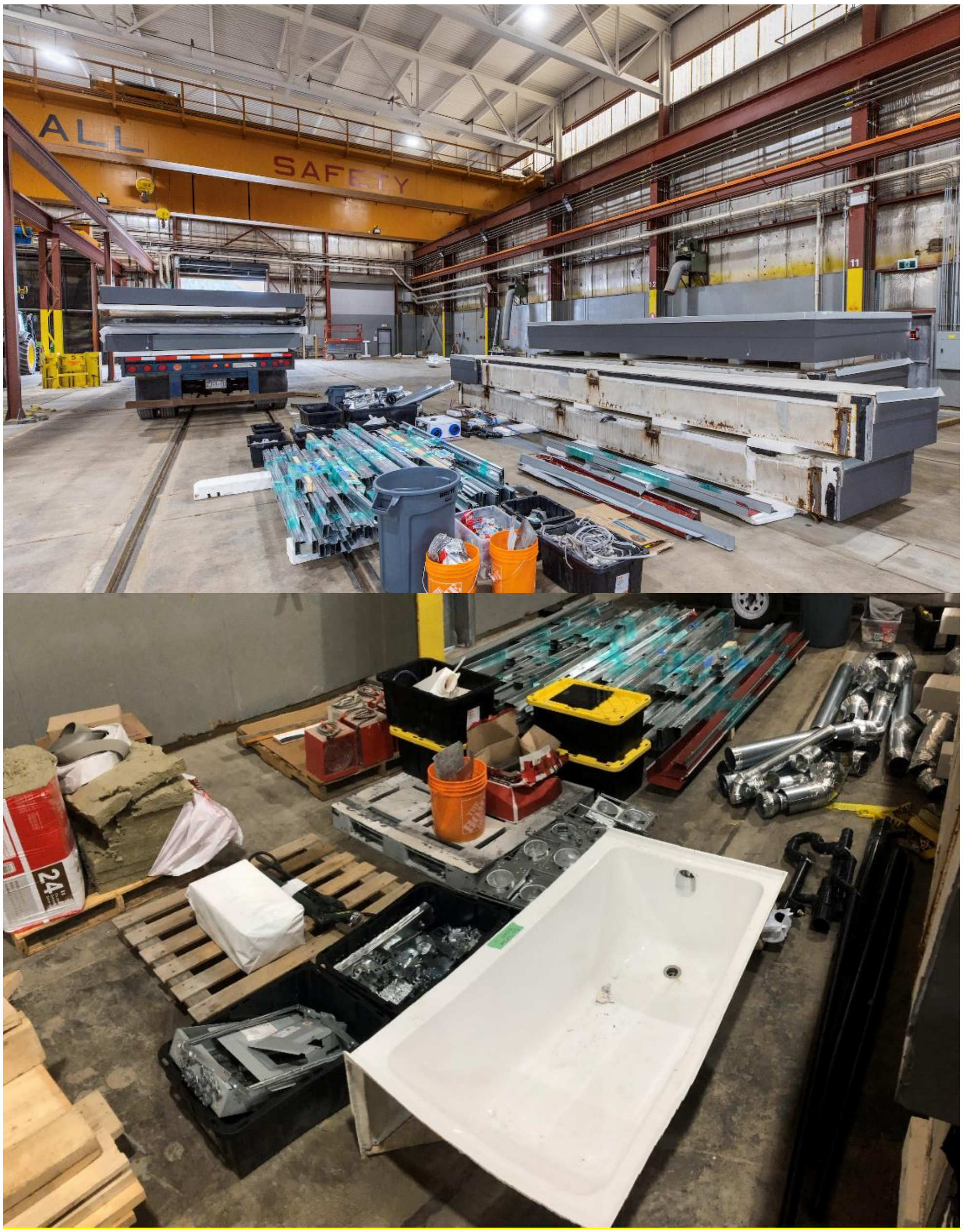
- The building foundation of the *Discovery Centre* was not excavated as part of this project. At the time of disassembly, discussions were still being held as to whether the foundation would be reused for a future application on-site, therefore, the foundation is not included in the waste calculations.
- Due to the benefits of the Design for Disassembly of Nexii panels, the following building components will be reused as part of the reassembly project: wall panels, roof panels, floor panels, windows, doors, steel framing, wiring, ducting, plumbing, downspout, and other hardware.

Waste Diversion

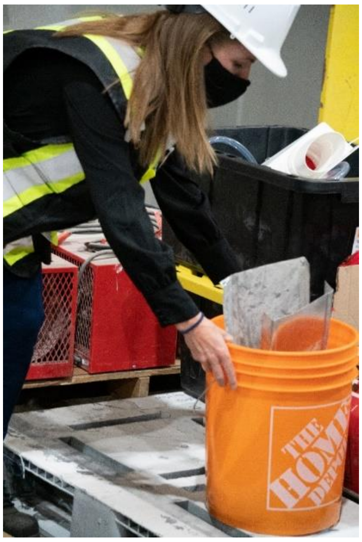
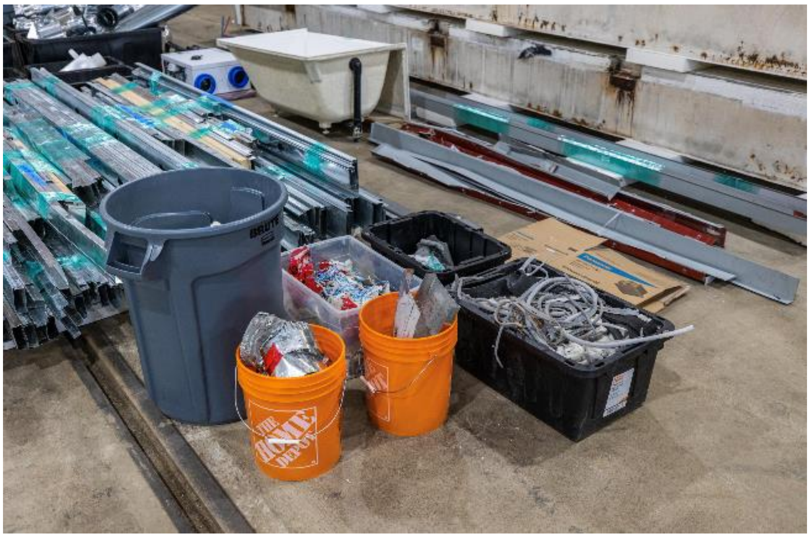
The *Discovery Centre* has a high diversion from landfill rate with the reuse of the building panels and the interior totalling 99.83% of all materials. Materials such as EPS scraps and other miscellaneous items were recycled (0.11%). Only 0.06% of the materials ended up in the landfill, amounting to approximately 2 small buckets of waste (as can be seen in Figures 17-20). This consisted of sealant that was scraped from the panels as well as other miscellaneous items that were not able to be recycled. Please see Appendix 3 for the end-of-life building materials waste diversion breakdown.

Table 3 Discovery Centre end-of-life diversion in weight

Material diversion	Weight (kg)	By Percentage
Reused	34,084	99.83%
Recycled	36	0.11%
Landfill	21	0.06%



Figures 17 & 18 Reused and recycled materials produced from disassembly

Figures 19 & 20 material sent to landfill (foreground)

Cost

The cost of the Nexii disassembly was paid for by the new owner of the building panels and material, who covered transportation, security, and crane time, as well as labour costs of the Temple Vision team (to include reassembly of the panels on Salt Spring Island). The labour of the Nexii team was covered internally by Nexii as training time for Temple Vision and a learning opportunity overall. The labour and minor material costs associated with reconditioning of the panels in the plant have yet to be determined.

Discovery Centre Removal and Reassembly: Total estimated project cost ~ $70,000

This includes the disassembly, transportation, crane, storage, and installation costs at the new site. Panel reconditioning costs are to be determined and excluded from the estimate.

New Nexii Panels: Estimated value of an equivalent new build ~ $100,000

This includes panels, transportation, crane, project management, and installation costs.

Cost to the Owner: While the savings associated with disassembly and reuse of Nexii panels compared to a new build for a small project such as this may be moderate, a reduction of 30% in construction cost remains significant. For this case study, the upfront panel production costs savings were largely offset by the labour, transportation, equipment, storage and panel reconditioning (materials and labor) required for reuse. A decrease in labour, which is the primary cost, should occur with experience and with the efficiencies one might expect on larger projects. This would further increase the proportionate savings. Other qualitative and quantitative benefits of panel reuse should be considered in addition to cost when assessing the value of a disassembly project.

Barriers and Challenges

Identification of the key challenges in the deconstruction process. Potential areas of observation are:

Storage: The disassembled panels need to be stored until the new site is ready. Nexii is storing the panels at their 50,000 square foot R&D facility for the four-to-six-months while the new site is prepared. This differs from “just-in-time” manufacturing, and, depending on the locations where the dismantling and reassembly takes place, would require additional planning, and may add costs for storage. This has prompted a broader discussion with Nexii around the ownership, overall process for panel assessment, remediation for reuse, and panel take-back in general.

Insurance: The insurance process is different during a disassembly than during the demolition of a typical project. Additional insurance is needed for panels during the disassembly, remediation, transportation, and reassembly process. Nexii is covering insurance until end of storage, where the new owner will cover the insurance during transportation and construction at the new site.

Re-assembly: The site on Salt Spring Island where the panels will be reassembled is more constrained. It is a rural area that has narrower roads in poorer condition. The team will be required to unload the panels onto a smaller truck when they arrive at Salt Spring to have the maneuverability to unload the panels at the final destination. Had the construction used new panels, these panels could have been sized to suit the constraints.

Quality Control: Inspection of disassembled panels is required to ensure the panels are in good shape to be reinstalled. Some surface-level rust was discovered in the roof panels that was likely caused by the original installation taking place on a rainy day, with the interior side of the roof panels sealed before the exterior side, allowing water to be trapped in the panel seams. This will be verified, and preventative measures taken as part of the assessment and remediation process to ensure that future projects don't have the same issues. Current panel composition ensures that all metal is protected from the elements, either through encasement in Nexiite or by using moisture resistant coatings. Wet weather conditions can be hard to avoid, and Nexii wants to ensure that buildings can be built in any weather. Additional install procedures are being added to remove moisture in the building before the final sealing is completed.
Preparation for the panels to be reinstalled at the new site will be required, include painting, relabelling, and scraping of sealants from the panels where they were connected to other panels, so they can be properly resealed during reassembly. Sealant is one of the few materials that ended in the waste stream from the disassembly of the building. As Nexii moves its sealant system to dry seals, this will further reduce the amount of material wasted.

Access regionally: Access to this technology is something that Nexii is actively addressing through its growth strategy. Currently, Nexii operates two corporate plants in Canada and is working with licensees, Nexii Certified Manufacturers (NCMs), to open additional plants across the U.S. and Canada. The first NCM plant in Hazleton, Pennsylvania, commenced operations October 2021 with an official opening slated for early 2022. A range of other North American NCMs are at various stages of development with plans to open in 2022 and beyond.

Advantages & Recommendations

Overall advantages of Nexii's panel design for disassembly and deconstruction:

Waste: Because the panels are durable and designed and built to allow for disassembly and reuse, this technology approaches 100% waste avoidance. The environmental benefits of waste avoidance include land use benefits (as the lifespans of our landfills are extended, postponing or eliminating the need to appropriate more land for this use), and eliminating the environmental impacts discussed earlier in this study of landfills and waste.

Avoidance of New Material Use and all the associated environmental impacts including GHG and pollution production, extraction of raw resources, water use and the waste production associated with manufacture.

Economic: While there are cost advantages to the existing building owner with the recovery of value from the building materials, and cost benefits to the buyer, who will receive a significant discount over the price of purchasing new, perhaps the greatest economic benefit observed is that the design for disassembly process shifts investment from material to people. Rather than purchasing new materials, which are generally resource intensive with high environmental impact, that money goes towards labor, boosting the local economy and creating jobs. Over 350 employment hours[26] were created during this project, including Nexii staff.

Health and Wellbeing: The virtual elimination of airborne contaminants during deconstruction, and the reduction of noise over a harmful decibel level contribute to the health and wellbeing of the deconstruction workers, as well as others who are proximal to the site. The reduced physical demands as compared to other types of deconstructions helps to protect workers from injury and potentially extend their careers.

[26] Hours logged by Nexii team.

Conclusion

The Nexii deconstruction case study models true circularity in the built environment. The Nexii disassembly process illustrated the many opportunities and advantages that designing for disassembly and planning for the end-of-life of a building in an environmental, social, and economical way can provide.

Ideally it would be the goal of every development to improve the community in which it is built. This case study demonstrates that we can move into an era where this benefit doesn't end with the deliberate destruction of the development (what we have referred to as demolition). The benefit can extend beyond the first use, to subsequent uses, and can also extend beyond its existing location to new sites. Making this shift towards deconstructing our built environment will create a system where the long-term sustainability of resource use can be prioritized without compromising quality, incurring additional costs, or sacrificing jobs. This strategy is part of the answer of how to create a regenerative and circular built environment.

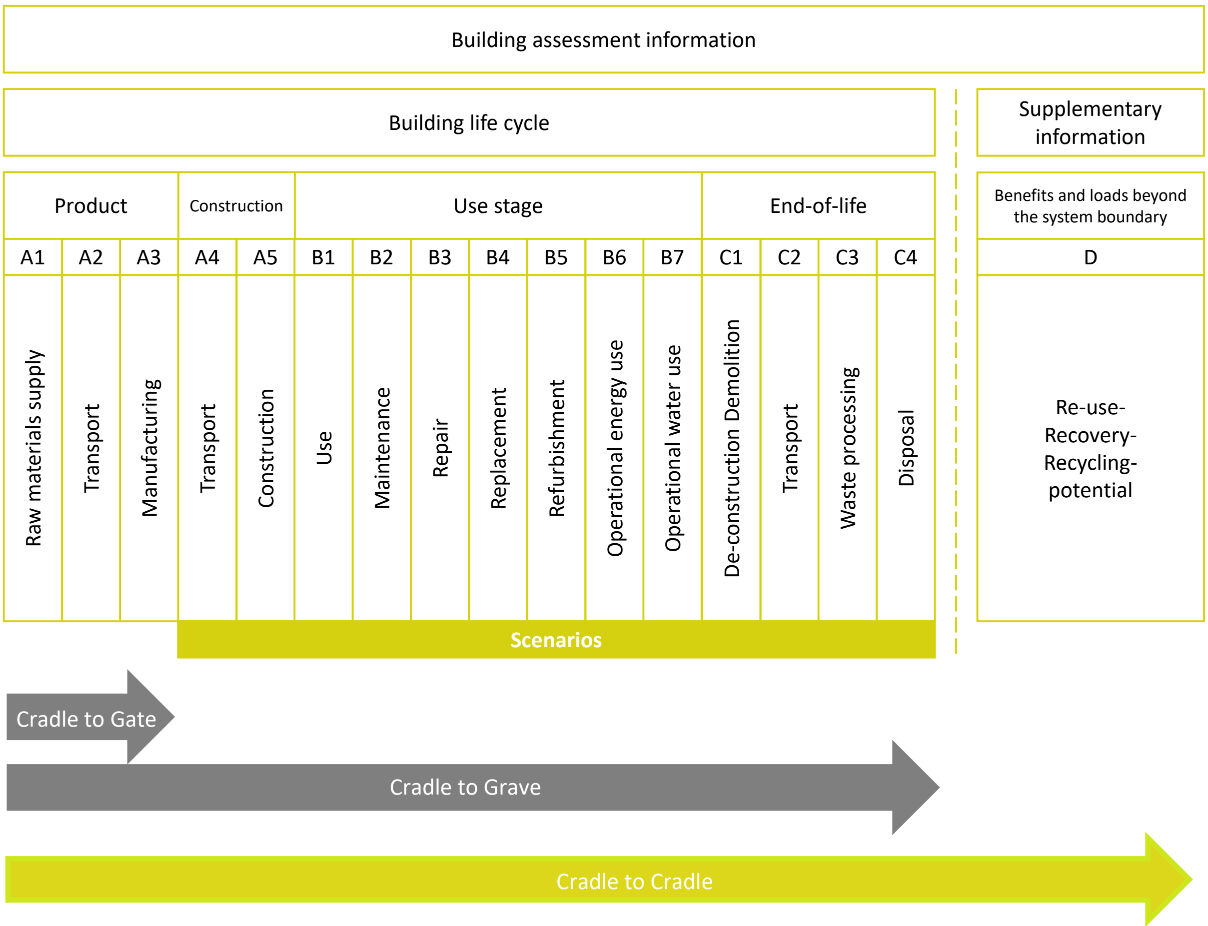
Appendix 1: Life Cycle Analysis System Boundary

LCA system boundary

The LCA compartmentalizes different life-cycle stages, allowing each stage to be compared in isolation with other projects. These different stages are considered "modules" for the purpose of the LCA.

- Modules A1 to A3 include the environmental impacts of extraction, manufacturing and all the processing that occurs before it is transported to site including processing of secondary material (ie. recycling processes).
- Modules A4 and A5 include the impacts of the transportation to the construction site and the impact of the construction process.
- Modules B1 to B7 cover the operation of the building which was excluded from this LCA study to focus the study on the embodied carbon emissions of the building rather than operational emissions that can include energy consumption like electricity, gas, etc.
- C1 to C4 include the impacts of the deconstruction or demolition of the building and disposing of the materials or recycling them.
- Module D provides the net benefits relating to exported energy and secondary materials, secondary fuels or secondary products resulting from reuse, recycling and energy recovery that take place beyond construction and deconstruction/demolition activity.

Building life cycle, adapted from Figure 6 in EN 15978



Appendix 2: LCA Building Physical Characteristics

Building Physical Characteristics
Life Cycle Assessment of the Discovery Centre by Rob Sianchuk

Building Element[1]	Nexii design	Steel Stud design	Wood Stud design
Foundations	25MPa foundation walls, concrete strip footings, steel reinforcement, 6 mil polyethylene, XPS insulation.		
Lowest Floor Construction	14" HPE floor panels, steel connectors.		
Roof Construction	20" HPE roof panels, steel connectors.	Steel joists, "5/8 plywood decking.	I-joists, "5/8 plywood decking.
Walls Above Grade	10" HPE wall panels, steel connectors.	2 layers of 1 5/8"x 3 5/8" 20Ga steel studs @ 16oc, ½" OSB sheathing, 5/8" type-X gypsum board, 10" thick EPS insulation, fiber cement cladding.	2 layers of 2" x 4" wood studs @ 16oc, ½" OSB sheathing, 5/8" type-X gypsum board, 10" thick EPS insulation, fiber cement cladding.
Windows and Entrances	Aluminum frame windows with triple glazing. Exterior aluminum frame doors with glazing.		
Roof Covering	"5/8 gypsum fiber board, modified bitumen membrane.	"5/8 gypsum fiber gypsum board, modified bitumen membrane, 6 mil polyethylene, "5/8 fire-rated type X gypsum board, 18" EPS insulation.	

Appendix 3: Discovery Centre End-of-life Waste Diversion

Discovery Centre End-of-life Building Materials Waste Diversion

Building Components	Weight (kg)	End of life	Material	Assembly Type	Note
Hardware - Steel	40	Reused	Metal	Various locations	Nexiite Panel Component
Hardware - Shims	28	Reused	Wood	Various locations	Nexiite Panel Component
Frame	5	Reused	Wood	Various locations	Nexiite Panel Component
Electrical	69	Reused	Metal	Mechanical	Nexiite Panel Component
Ducting	47	Reused	Metal	Mechanical	Nexiite Panel Component
EPS Srcaps	2	Recycled	Insulation	Various locations	Nexiite Panel Component
Metal flashing	32	Recycled	Metal	Unable to identify	Non-Nexiite Panel
Garbage	21	Landfill	Commingled	Unable to identify	Non-Nexiite Panel
Recycling	2	Recycled	Commingled	Unable to identify	Non-Nexiite Panel
Plumbing – ABS	24	Reused	Plastic	Mechanical	Nexiite Panel Component
Plumbing – PEX	8	Reused	Plastic	Mechanical	Nexiite Panel Component
Life breath HRV	18	Reused	Various materials	Mechanical	Non-Nexiite Panel
Down spout	2	Reused	Metal	Mechanical	Non-Nexiite Panel
Steel framing	776	Reused	Metal	Various locations	Nexiite Panel Component
Nexiite Wall Panel	10255	Reused	Various materials	Wall	Nexiite Panel
Nexiite Roof Panel	10988	Reused	Various materials	Roof	Nexiite Panel
Nexiite Floor Panel	12823	Reused	Various materials	Floor	Nexiite Panel

Note: Nexii panel components, i.e. steel corner connections, embedded structural elements, are integral to the design and overall weight of the Nexii panels and were therefore not separated out for waste diversion calculations.