CITY OF VANCOUVER'S GASTOWN CHILDCARE CENTRE: A PASSIVE HOUSE ZERO EMISSIONS PROJECT

CASE STUDY

As part of the Zero Emissions Building Plan, the City of Vancouver committed to designing all new City-owned buildings to the Passive House or an equivalent standard and eliminate the use of fossil fuels. In 2018, the City started the development of a childcare centre on the roofs of a pair of adjacent parkades in downtown Vancouver to provide much-needed childcare spaces in the neighbourhood. Partial prefabrication techniques are used to expedite on-site construction and to facilitate building a high-performance envelope. In addition to Passive House, the project also pursued LEED v4 Gold certification.

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PREPARED BY

zebx

THE UNIVERSITY OF BRITISH COLUMBIA

CITY OF VANCOUVER

QUICK SUMMARY

INCREASED INSULATION

in the exterior walls contributes to a designed R-value of R45 and R60 in the two buildings. Both buildings are estimated to be over three times more effective than the minimum effective thermal resistance required in the B.C. Building Code - **page 8**

EMBODIED CARBON ASSESSMENT

estimated the total embodied GHG emissions of the structure and envelope of the two buildings to be 701 kg CO_2eq./m^2 over a 60-year building life. This makes up 94% of the building's total life cycle GHG emissions, and about 85% of it is released in product and construction phases - **page 7**

REDUCED ENERGY USE

of the two buildings, according to the project's energy model, 72% lower than an equivalent conventional childcare building - **page 6**

EFFICIENT FENESTRATION

including high-performance triple-glazed, thermally-broken windows and doors with pre-formed aluminum frames with designed effective U-value of 0.85 W/m^2K - **page 8**

PARTIALLY PREFABRICATED

panels for the floor, roof and exterior walls expedite the on-site construction timeline - **page 4 & 5**

THERMAL BRIDGING

is minimized by prefabricated insulated wood cassette exterior walls and roof assemblies as well as treated timber thermal breaks between transfer structure and floor - **page 8**

PASSIVE COOLING STRATEGIES

including natural ventilation and fixed shading on the south facades, mitigate overheating from solar and occupant heat gains - **page 9**

MINIMAL HEATING & COOLING

required is provided by air-to-water heat pumps with hydronic fan-coil heating and cooling distribution systems with individual temperature control in each space - **page 9**

ENERGY RECOVERY VENTILATORS

with an efficiency of 86% capture heat and moisture from indoor air to preheat and humidify incoming fresh air - **page 9**

HEAT PUMP DOMESTIC HOT WATER

with electric resistance back up increases the DHW system's efficiency and reduces carbon emissions - **page 9**

RENEWABLE ENERGY

is generated on-site using photovoltaic (PV) panel array that provides approximately 10kWh/m^2 electricity per year - **page 6**

HEALTHY MATERIALS

such as low-VOC adhesives and sealants, low-emitting carpets, and formaldehyde-free millwork, safeguard occupant health - **page 4**

Render credit: Acton Ostry Architects, solar PV panels are added based on information provided by the City of Vancouver.

GENERAL OVERVIEW

The Gastown Childcare Centre project is one of the first facilities owned by the City of Vancouver that is designed and built to the Passive House standard to demonstrate the feasibility of the City's Zero-Emissions Buildings Plan's targets.

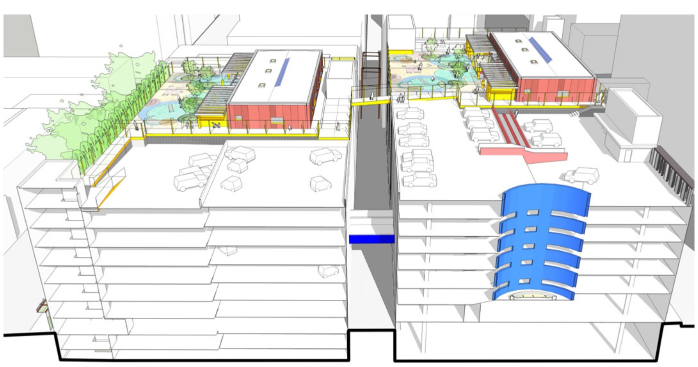
Project Overview

Building Type	Childcare Facility
Climate Zone	4: Cool-Temperate
Location	Gastown, Vancouver, B.C.
Zoning	HA 2 - Gastown Historic Area
Gross Floor Area of Conditioned Space	Each building: 465 m² / 5,005 ft²
Building Height*	5.11 m / 16.75 ft
Number of Storeys	1
Construction Start Date	September 2019
Projected Move-in Date	January 2021

**Excludes the height of parkades on Water St. and Cordova St. : 20 m / 66 ft and 21 m / 69 ft*

Project Team

Owner	City of Vancouver
Architect & PH Consultant	Acton Ostry Architects Inc.
Structural Engineer	Fast + Epp
Construction Manager	Heatherbrae Builders Co Inc.
Mechanical & Electrical Engineer	Integral Group
Sustainability Consultant	Stantec
PH Certifier	Passive House Institute
Code Consultant	GHL Consultants
Cost Consultant	Altus Group



The building on the left is located in Water Street and the building on the right is located in Cordova street.
(Render credit: Acton Ostry Architects, solar PV panels are added based on the information provided by the City of Vancouver.)

Project Context

The City of Vancouver developed the Zero Emissions Building Plan (ZEBP) in 2016 to address global climate change concerns by developing a roadmap for all new buildings to achieve zero operational GHG emissions by 2030. In 2017, the Province of British Columbia enacted the B.C. Energy Step Code to incrementally move toward net-zero energy ready buildings in 2032.

Vancouver is demonstrating the feasibility of these targets through the integration of energy-efficient and low-carbon design approaches in City-owned and managed building projects. Gastown Childcare Centre is the first Passive House certified and zero-emissions City-owned childcare facility, serving as a model for other communities looking to increase the energy and emissions efficiency of their buildings.

Gastown Childcare Centre is in downtown Vancouver, in a historical neighbourhood that is a mix of commercial and residential buildings. The two single-story buildings, located on the roofs of two underused parkades and connected by a dedicated walkway, have a combined area of around 10,000 ft² of indoor conditioned space, and around 11,000 ft² of outdoor space. The Centre will provide 74 much-needed childcare spaces, accommodating 24 infants/toddlers and 50 preschool-age children.

Vancouver, like many urban areas, is facing a shortage of childcare facilities. The unusual parkade location was proposed to respond to this need in the dense city center by repurposing underutilized real estate space. The use of partially prefabricated panels simplifies the construction logistics on the parkades and expedites the schedule.

Both buildings are designed to achieve Leadership in Energy and Environmental Design (LEED) v4 Gold, which is the requirement for all City-owned projects. As per the ZEBP, the City also committed to achieving Passive House certification and eliminate the use of fossil fuels for the operation of the facility. The design was also required to be compliant with the City of Vancouver's Childcare Design and Technical Guidelines.

This case study aims to provide an overview of the design process and share transferrable learnings from the design and early construction phases. The information in this case study is based on the project design phase modeling and not the actual performance.

DESIGN HIGHLIGHTS

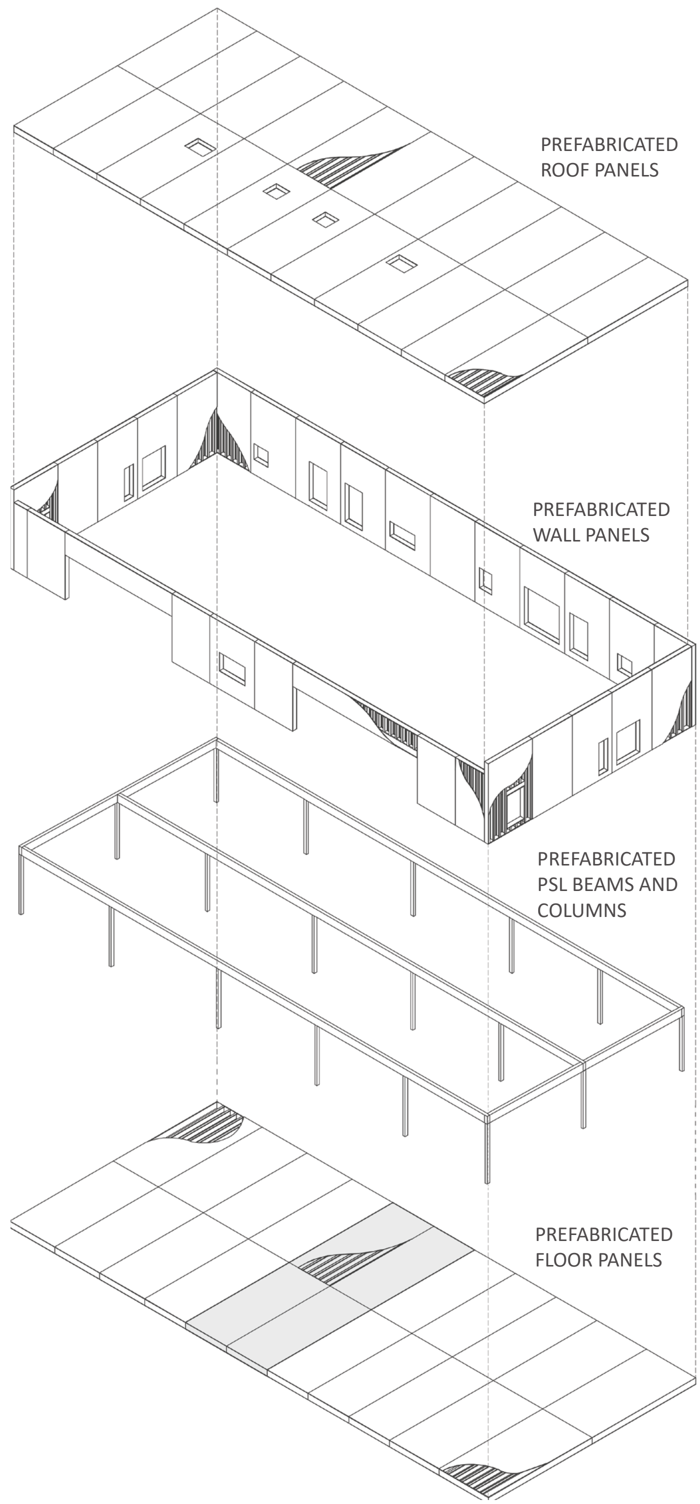
The design of the Gastown Childcare Centre focused on minimizing energy use and GHG emissions, prefabrication of the panels to simplify the construction process and providing a healthy and comfortable indoor space.

Gastown Childcare Centre's sustainability targets in the design included a strong emphasis on exceptional energy performance and low operational GHG emissions. The project has rooftop PV arrays to provide low-carbon energy for the building operation and offset GHG emissions from the grid.

The design was also tailored to the unique project setting on the top of two parkades in the dense downtown core. Each building is designed in a simple, rectangular form to facilitate the use of prefabricated panels and simplify structural loading. The compact square massing also reduces both energy gains and losses through the envelope. The buildings are placed on steel base structures that distribute the loads to the existing structural shear walls and columns of the parkades.

The project team also carefully considered the safety, comfort, and wellbeing of children and care providers. They specified healthy materials, such as formaldehyde-free millwork, low volatile organic compound (VOC) adhesives and sealants, and low-emitting carpets. The building systems monitor pollutants, such as carbon dioxide, and allow individual temperature controls between various activities and nap rooms. Removable carbon filters can be used for the supply air of the ventilation systems to reduce odours and particulates when the outdoor air quality is poor, for instance during forest wildfires. Lastly, particular attention was given to the acoustic design to manage exterior noises such as traffic and mechanical equipment, as well as interior noises of playing children.

The City of Vancouver Childcare Design Guideline requires direct sunlight in outdoor play areas for at least two hours each day. However, the solar and shadow modeling of the project showed that because of the shadows from a nearby building, the desired solar insolation was not achievable. The play areas receive two hours of direct sunlight but only to about 30-40% of their total area. However, the site gets an abundance of ambient light and has a great view, since the project is at the rooftop. Additionally, at the time, this site was the only option available in the area. Thus the project received a relaxation from Vancouver Coastal Health's Childcare licensing.



Gastown Childcare Centre axonometric drawing showing the prefabricated elements (Credit: Acton Ostry Architects)

CONSTRUCTION HIGHLIGHTS

Partial prefabrication of the wood cassette panels reduced the complexity of construction on the unique site location on the roof of two parkades in the dense downtown core. However, the complex site location contributed to the higher cost of the Centre compared to typical childcare facilities in Vancouver.

The project was designed within the structural capacities of the existing parkades. Both parkade buildings are seismically sound as they both have been upgraded in the past 20 years. However, the project faced construction challenges due to the logistical complexities of the site location in a constrained inner-city site, located 20 meters above ground on the roof of the parkades. This led to the decision of using a prefabrication construction method.

The buildings' structural panels, including floors, walls, and roofs were partially prefabricated wood cassette panels with I-joists, plywood, and OSB sheathing. The panels are built in the factory before being transported to the site for rapid assembly. The prefabricated structural panels are lifted by a crane from the street to the parking rooftops, where they are stored until assembled in the buildings. The walls and roof panels are overlaid with insulation, moisture-proof membrane, and gypsum board on-site, whereas the floor panels already have the exterior insulation installed in the factory. All panels are also filled with dense-pack cellulose applied on site.

The panelized construction allows for a faster framing time, requires a smaller on-site crew, produces less construction waste compared to traditional on-site construction, and minimizes disruptions to the surrounding Gastown neighbourhood.

Project Cost

The Gastown Childcare Centre project cost is higher than the average childcare facilities in Vancouver because of the innovative solutions used to reduce operational GHG emissions as well as the challenges faced by the unique and complex construction site.

This project is partially funded through a City of Vancouver Community Amenity Contributions grant, as well as grants from the provincial government from the Childcare B.C. New Spaces Fund.

Right: Wooden structure raised above the steel base structures which distribute the loads to the existing structural columns and wall of the parkade.
Bottom: Prefabricated wooden wall panels assembled on site to be filled with rigid insulation and exterior airtight membrane.
(Credit: City of Vancouver)

ENERGY AND CARBON PERFORMANCE

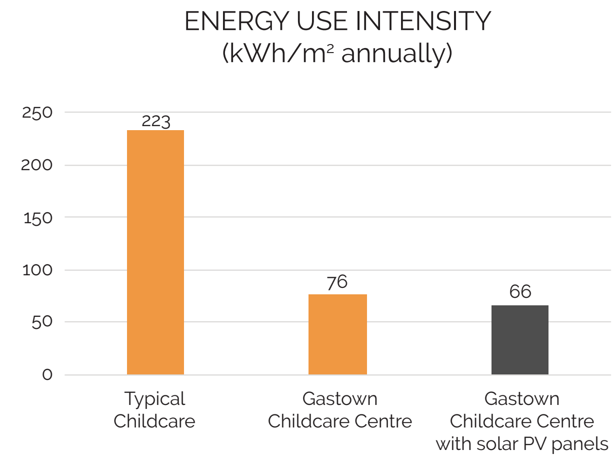
The Gastown Childcare Centre aims to achieve LEED Gold and Passive House certifications. The energy use intensity of the Centre is estimated to be 66 kWh/m² yr. Additionally, the project is complying with the ZEBP's GHG reduction target with an operational GHG intensity of 0.7 kg/m² yr.

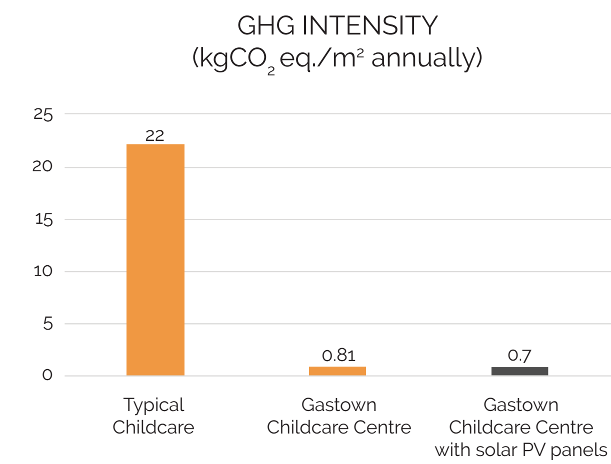
The City of Vancouver sets higher energy targets for City-owned buildings to show leadership. As part of the 2016 Zero Emissions Building Plan (ZEBP), the City committed to designing all the new City-owned buildings to Passive House or an alternative zero-emissions standard and eliminate fossil fuels in the operations of these buildings. They also retained the requirement to achieve LEED Gold certification.

The predicted average Energy Use Intensity (EUI) of the Gastown Childcare Centre is 66 kWh/m² yr, which is about 72% lower than a typical equivalent existing City-owned childcare facility.

The project also followed the ZEBP's requirement for minimizing operational GHG emissions, with a predicted GHG Intensity (GHGI) of 0.7 $kgCO_2eq./m^2$ yr, which is about 97% below a typical equivalent existing City-owned childcare facility.

This amount of reduction in GHG emissions is achieved by using electric mechanical systems and offsetting some of the GHG emissions through the on-site generation of renewable energy. Renewable energy is generated using PV panels on each building with a combined estimated energy generation capacity of 10 kWh/m² yr., taking into account the shading from adjacent buildings.





Right: Comparison of the operational energy use intensity and carbon emissions per building of Gastown Childcare Centre for three design scenarios, showing the final project choice to employ solar PV panels (Source: project team presentation at CaGBC 2019 conference)
Bottom: Partially prefabricated structural wood cassette panels stacked on the site (Credit: City of Vancouver)

EMBODIED CARBON EMISSIONS

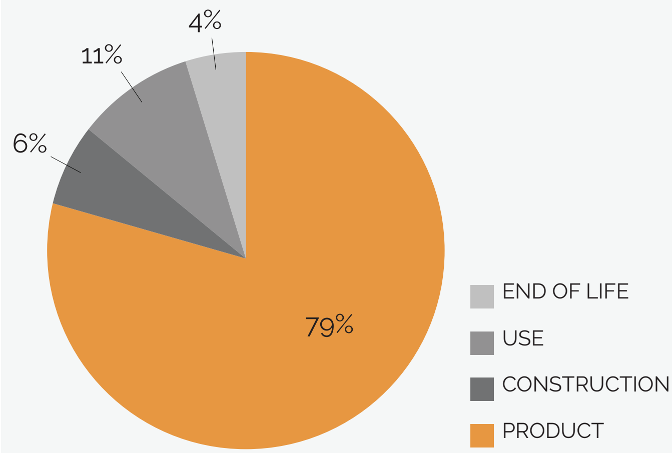
The estimated embodied GHG emissions are 709 kgCO_2eq./m² for the structure and envelope, assuming a 60-year building life. With nearly zero emissions from building operations, the embodied emissions come into greater focus; about 85% of these emissions are emitted before the building starts operating.

The City of Vancouver commissioned Scius Innovations to conduct a Life Cycle Assessment (LCA) to assess the GHG emissions of the building materials of a number of recent City-owned projects, including the Gastown Childcare Centre. The study aimed to identify and assess preliminary opportunities for reducing the GHG emissions of building materials also referred to as embodied carbon. The LCA was conducted using the Athena Impact Estimator for Buildings tool and based on the bill of materials generated from the project drawings. The study quantified the building structure and envelope, which encompass the majority of the building materials. In the envelope, cladding, insulation, fire protection, vapor and water barrier, windows and doors are included. The scope of the study included the production, construction, use (that is maintenance and replacement) and end of life (that is deconstruction, waste processing, and disposal) stages.

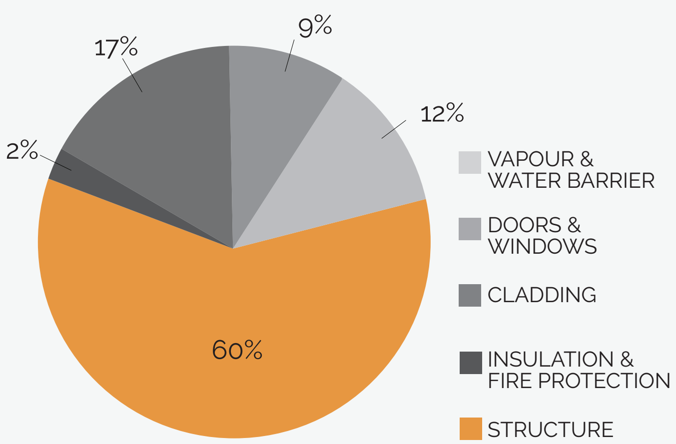
The study reports the embodied carbon of each building of the Gastown Childcare Centre separately, but here the results are presented for the whole Centre as one. The estimated total embodied carbon emissions of the structure and envelope are about 659,500 kg CO_2eq. or 709 kg CO_2eq./m² for the total gross area of 930 m². Because the building design has significantly reduced the operational carbon emissions, this amount of embodied carbon is even more significant. This makes up 94% of the building's total GHG emissions over its assumed 60-year lifetime. Additionally, 85% of the embodied carbon is released before the building starts its operation. Therefore, future zero-carbon buildings must explore potentials for minimizing their embodied carbon emissions as well as their operational carbon emissions.

The structural elements constitute about 60% of the total embodied carbon. The additional steel structure required to support the two buildings and the child play areas on the roof of the existing parkades significantly contributed to the embodied emissions of the structure. Steel elements alone cause 45% of the total embodied emissions.

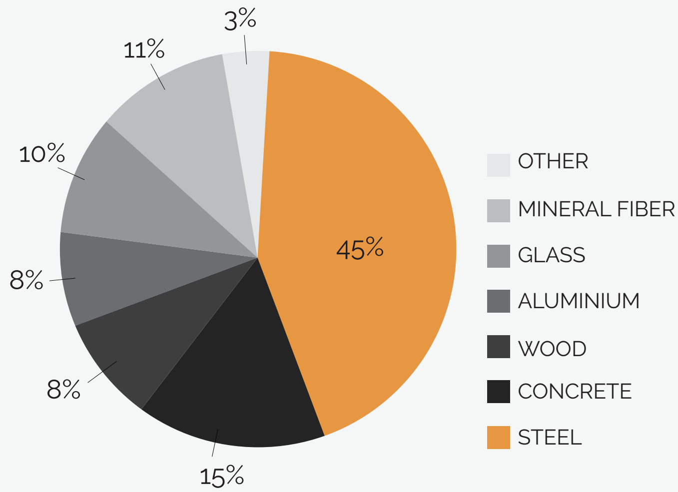
GASTOWN CHILDCARE CENTRE POTENTIAL EMBODIED CARBON EMISSIONS BY LIFE CYCLE PHASE



GASTOWN CHILDCARE CENTRE POTENTIAL EMBODIED CARBON EMISSIONS BY ELEMENT



GASTOWN CHILDCARE CENTRE POTENTIAL EMBODIED CARBON EMISSIONS BY MATERIAL TYPE



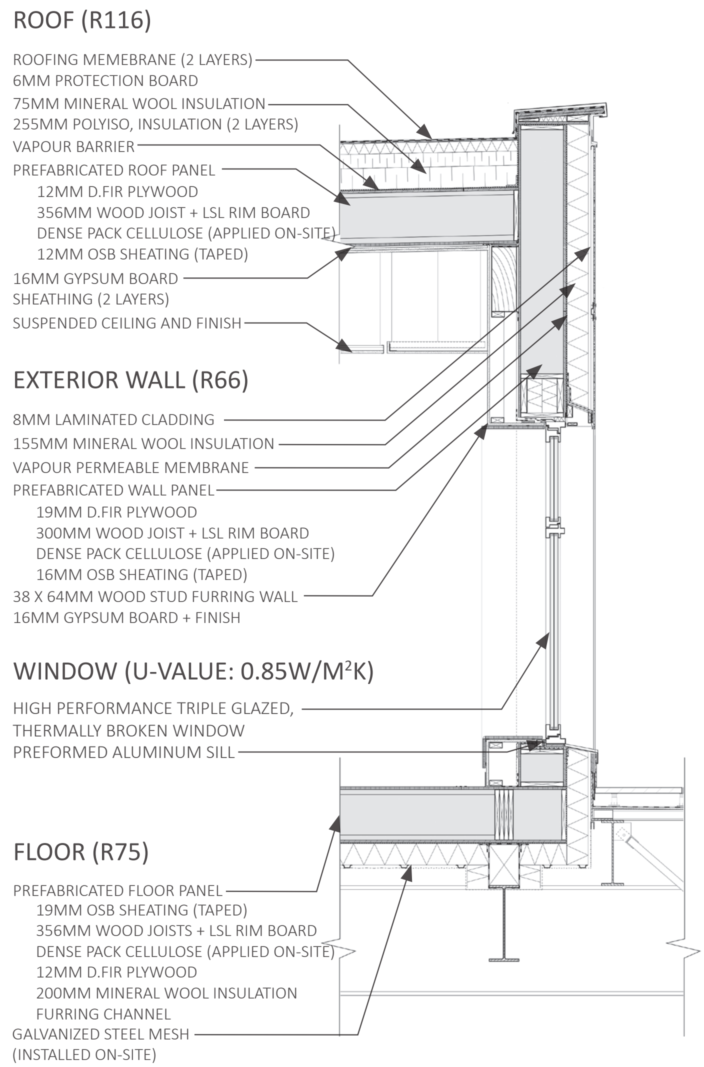
(Data source: LCA report by Scius Innovations for the City of Vancouver, 2019)

HIGH-PERFORMANCE ENVELOPE

According to the energy model for the Gastown Childcare Centre, the two buildings' energy demand is effectively minimized through a partially prefabricated highly insulated, airtight, and thermal-bridge free envelope with Passive House certified doors and windows.

The project team took an envelope first approach to the design of the buildings to ensure energy demands are reduced as much as possible before sizing the mechanical systems. To meet the Passive House envelope performance requirements, the buildings' exterior wall assembly consists of a hollow cassette panel filled with dense-pack cellulose insulation on the interior side, and rigid insulation with a self-adhered vapor-permeable membrane on the exterior side. All fenestrations are Passive House certified, with high-performance triple glazing, and thermally broken windows with pre-formed aluminum sills. Wood was favored for the panels because of its lighter weight relative to concrete or steel, higher thermal performance, and lower embodied carbon emissions.

The high-performance roof assembly is similar to the exterior wall assembly, with an additional two layers of polyisocyanurate insulation below the rigid insulation. Since the floors are raised above the parkade deck, they effectively act as an exterior wall and therefore are part of the building envelope. As such, the floor assembly also utilizes a split-insulated approach whereby the floor panel is insulated on the exterior with rigid insulation attached to the infusion-treated exterior-grade plywood, and with dense-pack cellulose inside the cassette panel frames. This approach improves assembly durability by keeping the moisture sensitive materials at a warmer temperature, thus minimizing moisture related risks.



Right: Gastown Childcare Centre floor, wall and roof sections
Bottom: Thermal performance of exterior components of Gastown Childcare Centre
(Credit: Acton Ostry Architects Inc.)

Envelope Component	Component Description	Thickness (cm/inch)	Average U-value (W/m²K)
Exterior Wall	Prefabricated closed-wood cassette panel with fully taped joints, externally insulated, rain-screen with high-pressure laminated rain-screen cladding	54/21	0.086 (R66)
Floor	Prefabricated closed-wood cassette panel with fully taped joints, externally insulated, rain-screen with metal rain-screen cladding	59/23	0.075 (R75)
Flat Roof	Prefabricated closed-wood cassette panel with fully taped joints, externally insulated, roofing membrane	74/29.5	0.049 (R116)
Windows	Triple-glazed, thermally broken, preformed aluminum sills	-	U value: 0.79 SHGC: 0.5
Exterior Doors	Insulated exterior doors with insulated and thermally broken frames	-	Effective U-value of glass & framing: 0.85

ENERGY-EFFICIENCY STRATEGIES

Efficient energy recovery ventilators are employed to reduce heating and cooling demands and to control indoor air quality. Space heating and cooling are provided through air-to-water heat pumps with hydronic fan coil distribution systems. Domestic hot water is provided through heat pump water heaters.

Heating and Cooling

The design of the Gastown Childcare Centre maximized passive strategies to optimize internal and external heat gains and losses. The buildings have south-facing glazing to capture the solar heat in the winter months and horizontal shading to control excessive solar heat gain in the summer months.

The modeling showed that shading from surrounding buildings limited the potential amount of sunlight and optimal solar heat gain, so additional insulation was used in the envelope to reduce the heat loss in the winter. Given a large number of occupants and their activities, the energy modeling showed significant internal heat gains. Children are more sensitive to overheating, so during the design, the team was careful to minimize potential overheating from excessive solar and internal heat gains.

The City of Vancouver's Childcare Technical Guidelines call for a low-carbon energy source for heating and domestic hot water, and where appropriate, allowance for existing or future district energy connections. Space heating and cooling are supplied via an air source heat pumps with a hydronic fan coil distribution system in each building. Each system has one air-to-water heat pump and nine indoor fan coil units with Electronically Commutated (ECM) motors that are located in the back of the rooms or in the storage cupboards to reduce noise in the rooms. The conditioned air is supplied to the interior spaces via ducts and grills.

Using multiple fan coil units allows independent temperature control in each zone depending on their need. Heat pump systems are more energy efficient than conventional boilers and chillers. Electric heat pumps also have very low carbon emissions thanks to British Columbia's low carbon electric grid.

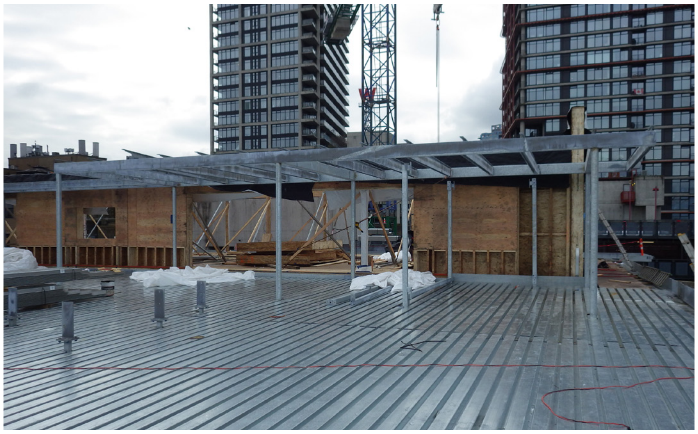
Domestic hot water is supplied by a 275-litre hot water tank in each building, heated by air-source Rheem heat pumps along with a supplementary electric resistance heater for peak loads.

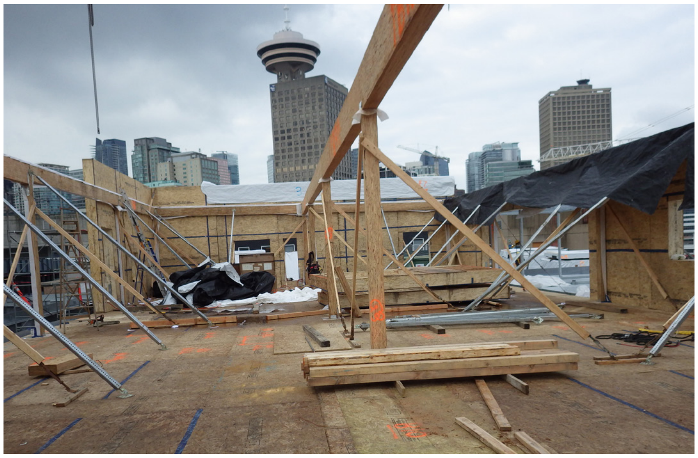
Even though district energy was available for this project, it was not a requirement for this project to connect to it. This was allowed by the City because the energy demand in the project was minimized by pursuing Passive House certification. Therefore the buildings would have been more efficiently heated by smaller, on-site heat pumps rather than by pumping hot water from the district energy system up to the parkades' rooftops.

Ventilation

Gastown Childcare Centre uses Swegon RX Gold energy recovery ventilator (ERV) systems with a rotary wheel heat exchanger to provide 86% efficiency, for ventilation and air conditioning in each building. The ERVs conserve energy by transferring heat and moisture from the indoor stale air into the fresh air stream coming from outside. The building is also equipped with operable windows in the living spaces to facilitate natural ventilation.

To control the air quality, removable carbon filters are provided in the supply air system to reduce odours and particulates when the outdoor air quality is poor, for instance during forest wildfires. Additionally, a monitoring system that is connected to the building's direct digital control system is used to track the CO_2 content of the indoor air.





Top: Galvanized steel installed on-site to place the floor on top of it
Bottom: Mass-timber beams and columns, prefabricated floor, and partially prefabricated exterior walls assembled on-site (Credit: City of Vancouver)

GLOSSARY

Key terms, definitions, and abbreviations used in this case study arranged alphabetically

Air-to-Water Heat Pumps
A type of Air-Source Heat pump that draws heat from the outside air and uses water to transport the extracted heat. These heat pumps are more efficient as they can provide domestic hot water and central heating/cooling at the same time yet consuming the least energy.

Airtightness
The resistance to inward or outward air leakage through unintentional leakage points or areas in the building envelope. Airtightness is represented in units of ACH and is commonly tested using a blower door test.

ASHRAE 90.1
it is an American National Standard that provides minimum requirements for energy-efficient designs for buildings except for low-rise residential buildings (i.e. single-family, duplexes, townhomes, small apartment buildings, etc.)

BC Energy Step Code
A voluntary provincial standard in British Columbia that provides an incremental and consistent approach to achieving more energy-efficient buildings that go beyond the basic requirements of the B.C. Building Code.

Domestic Hot Water (DHW)
The building system used to supply hot water for kitchen and bathroom sinks, showers and other appliances

Electronically Commutated Motors (ECM)
is also referred to as a variable-speed motor. ECMs are used in HVAC systems to maintain the designed airflow by using electronic controls to vary the speed.

Embodied Carbon Emissions
GHG emissions, measured in equivalent CO_2, associated with building materials during the life cycle of a building, that includes production, construction, use, and end of life (demolition and disposal).

Energy Recovery Ventilators (ERV)
A mechanical device that recovers heat from the exhaust air and moisture to pre-heat the filtered incoming fresh air stream. ERV also transfers moisture between inside and outside air to optimize the humidity level of the indoor space for the residents' comfort. Using an ERV helps reduce the heating load and reduce the energy required to replace the stale inside air with the outside air.

Energy Use Intensity (EUI)
Energy use as a function of a buildings total area. Enables comparison between different sized buildings.

Formaldehyde
is a naturally-occurring, organic compound that is used widely to manufacture wood products, such as particleboard, medium-density fiberboard, etc. They break down easily into the air and exposure to relatively high amounts of the compound is found to poses health risks.

Green House Gas Intensity (GHGI)
A measure of greenhouse gas contributions from a building and its systems.

Leadership in Energy and Environmental Design (LEED)
An internationally recognized green building rating system, that verifies a building or community was designed and built using strategies aimed at improving performance across energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. Buildings are awarded points based on the extent to which the strategies are achieved, and can qualify for four levels of certification starting from Certified, Silver, Gold, to Platinum certification for the highest number of points.

GLOSSARY

Key terms, definitions, and abbreviations used in this case study arranged alphabetically

Passive House
An internationally recognized certification program, developed by an independent research institute based in Germany. The program is intended to result in buildings with extremely low space heating and cooling needs and consequently lower environmental impacts, as well as comfortable indoor temperature and air quality.

Polyisocyanurate Insulation
High-density foam insulation that is most widely used on commercial low slope roofing assemblies. It has a high R-value per inch (R 6-6.5) compared to other insulation products used in commercial construction.

Rotary Wheel Heat Exchanger
It is a type of efficient heat exchanger inside the Energy recovery ventilators that extracts and transfers heat during the rotatory process of an inbuilt wheel, bisected by two parallel ducts. Outside air flows across the top half of the wheel, while inside air flows across the bottom half

R-value
The capacity of an insulating material to resist heat flow. The higher the R-value, the greater the insulating power.

Solar Insolation
The incident solar radiation on a surface, or measure of solar energy incident on an area over a set period of time.

U-value
A measure of thermal performance or heat transfer through a surface due to conduction and radiation. Lower U-Value rates indicate more energy-efficient surfaces. U-value is the inverse of the R-value.

Volatile Organic Compounds (VOCs)
are common organic chemical compounds used in construction, such as paints and other solvents, wood adhesives, sealants, aerosol sprays, etc. that evaporate under normal indoor atmospheric conditions, compromising indoor air quality and contribute to short- and long-term adverse health effects.

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A PASSIVE HOUSE ZERO EMISSIONS PROJECT

Learn more at

https://zebx.org/resources/#case-studies

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