Design of Zero Carbon Buildings
Analytical Portfolio

THE JOYCE CENTRE FOR PARTNERSHIP & INNOVATION (JCPI)
Mohawk College of Applied Arts & Technology,
Hamilton, Ontario, Canada

Building Type:	Educational
Approx. Site Area:	8,919 Square Meters
Approx. Gross Internal Floor Area (GIFA):	8,981 Square Meters
Number of storeys:	5
Date of Construction:	2018

THE JOYCE CENTRE FOR PARTNERSHIP & INNOVATION (JCPI)

Figure 1: Pierre G. Bordeaux Mohawk College – JCPI 2019)

Awards

- Zero Carbon Building - Performance Certification
  Canada Green Building Council
- Inspired Educator - Leadership
  Canada Green Building Council
- Award for Excellence Innovation in Architecture
  RAIC - Royal Architecture Institute of Canada
- Outstanding Post-Secondary Institution Award of Excellence
  Canadian Network for Environmental Education and Communication
- Institutional (Built) Category of Rethinking the Future's Architecture - 3rd
  Construction & Design Awards 2018
- Award of Merit for New Institutional
  Hamilton/Burlington Society of Architects (HBSA)
- Zero Carbon Building - Design Certification
  Canada Green Building Council
- Engineering Project of the Year - 2018
  Ontario Society of Professional Engineers
- Environment Leadership Award
  Hamilton-Halton Home Builders' Association
- Sustainable Project of the Year 2018
  Ontario Sustainable Energy Association
- Environmental Sustainability Award 2018
  Alectra Energy Evolution Summit
- Innovation in Sustainability Award 2017
  Canada Green Building Council

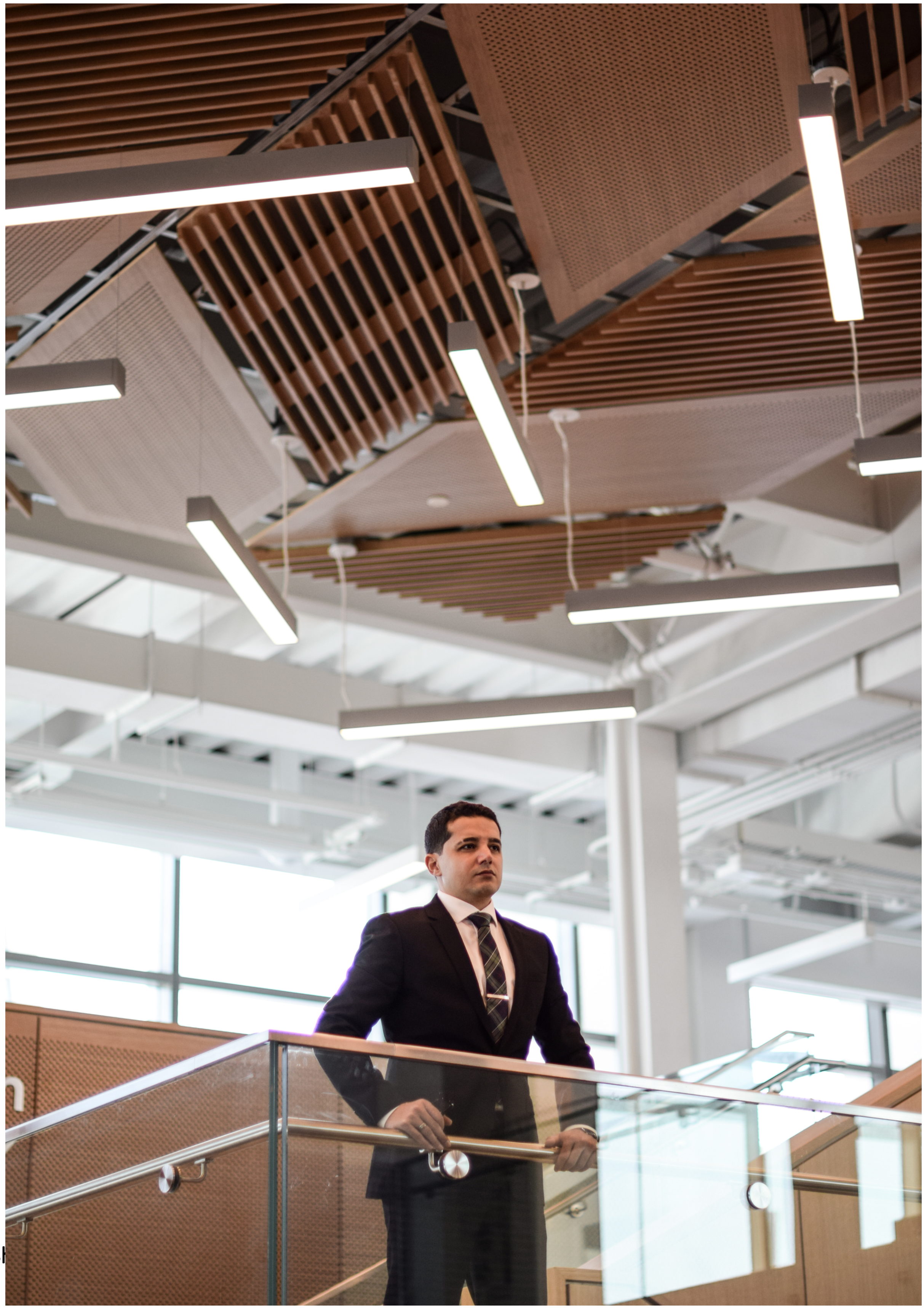

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Figure 2: Pierre G. Bordeaux Mohawk College – JCPI 2019)

The Joyce Centre for Partnership & Innovation (JCPI) at Mohawk College's Fennel Campus in Hamilton, Ontario, is one of the region's first and largest net-zero institutional buildings. As both a national and global pilot project, the building helped determine the requirements and standards for the Canadian Green Building Council (CaGBC) Zero Carbon Buildings Framework and is contributing to the World Green Building Council's (WGBC)"Advancing Net Zero," initiative, a global project which aims to ensure that all buildings are net zero carbon by 2050, with all new buildings being net-zero carbon by 2030.

This all-electric building is designed to meet rigorous net zero energy and carbon performance targets and incorporates the latest in energy-efficient materials and processes. The Joyce Centre features solar-powered, state-of-the-art labs, workshops, open study spaces and flexible lecture theatres. The mechanical and electrical spaces, as well as the green roofs, are accessible to all and intended to be part of the learning environment.

Section 1: Stakeholders

Stakeholder Group	Includes	Notes
Project Owner/ Developer	Mohawk College of Applied Arts and Technology Notes: Mohawk College is recognized as a leader in sustainability, as it was the first college in Ontario to introduce a comprehensive environmental management plan that sets carbon reduction targets by addressing key areas of college operations including buildings, energy use, transportation, waste management and food. Since then, Mohawk has succeeded in reducing its direct carbon emissions by 63% from the 2007 baseline year. Mohawk manages over 30 programs and initiatives each year that are dedicated to increasing the sustainability of Mohawk's campus, community and neighbourhood.	
Design	▪ McCallum Sather Architects and B+H Architects – Architects in Joint Venture ▪ RDH Building Science - Energy ▪ Mantecon Partners – Structural ▪ The Mitchell Partnership – Mechanical ▪ Mulvey & Banani – Electrical ▪ N-Sci Technologies – Photovoltaics ▪ Geo-Xergy Systems – Geothermal Notes: B+H Architects is an international player and a leading sustainable architecture designer in located in Canada with more than 60 WELL, Green Mark, China 3-Star, Net Zero, LEED certified projects supported by more than 50 LEED AP staff. RDH Building Science is a leading firm in North America that work with governments and utilities in assessing and designing energy saving programs with over 20 years in the industry and over 2,000 reports.	
Construction	▪ WalterFedy – Civil: a leading integrated architecture and engineering firm in the Waterloo Region and Southwestern Ontario. Walterfedy have extensive experience in educational building as they have contributed their expertise to a number of post-secondary institutional solutions in Ontario. For instance; University of Waterloo and University of Toronto.	

	▪ Ellis Don – Contracting: has provided technical guidance and support to over 160 green building projects in Canada and internationally, with a total construction value of over $13 billion	
Commissioning Authority	▪ C3PX Engineering	
Regulatory Bodies	▪ Canada Green Building Council (CGBC)	
Neighbours / Community	The Joyce Centre for Partnership and Innovation is located at the Fennel campus of Mohawk College in Hamilton, Ontario, Canada. Regionally, it is located at the Great lakes area between Canada and the US.	

Section 2: Site Analysis

Hamilton Climate is facing few challenges to be tackled. A new city report says that a shift to greener transportation along with more environmentally friendly buildings and more carbon "sinks" are needed for Hamilton to mitigate and adapt to climate change.

1- Hamilton' Solar Power

The average solar power system in Ontario will produce approximately 1166 kWh of energy per kW per year. Hamilton would produce 1,152 kWh/yr (Energy Hub, 2020).

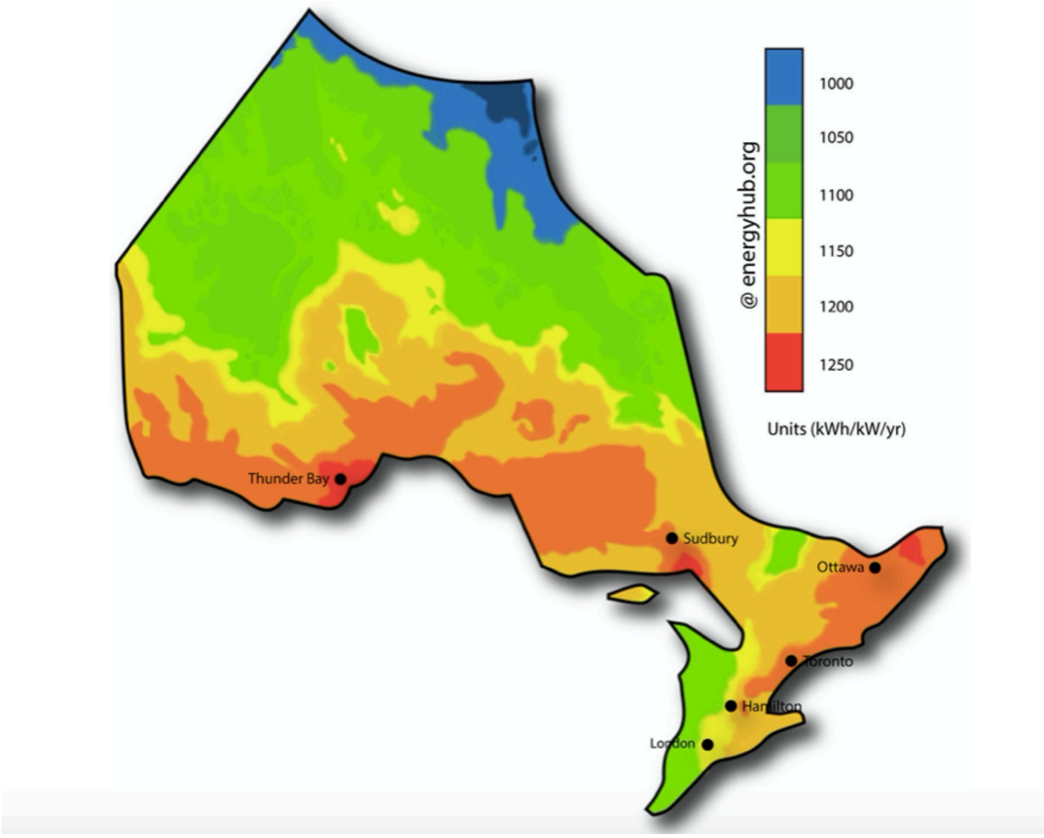


Fig 3: Source: https://energyhub.org/wp-content/uploads/2019/01/Solar-Power-Map-Ontario.jpg

2- Greenhouse gas emissions

Hamilton had the highest per capita emissions in 2017 — about 19 tonnes per person — compared to a regional Greater Toronto Hamilton Area (GTHA) average of 6.9 tonnes (The Atmospheric Fund, 2017).

Hamilton's greenhouse gas emissions have decreased since 2006 by a third, with its 2017 estimate at 11,569,045 tonnes carbon dioxide equivalent. It needs to further reduce by 3 million tonnes to reach a 50 per cent drop. The city wants to achieve net zero carbon emissions before 2050.

The industrial and steel industries are the city's major greenhouse gas sources, but both have reduced their emissions by 33.5 per cent and 47.8 per cent since 2006. Commercial and transportation, however, have increased.

3- Infrastructure

Hamilton has been battered in recent years as climate change continues to damage infrastructure via extreme storm events. Both extreme heats leading to drought and increased precipitation leading to flooding, along with higher lake levels, are impacting Hamilton's shoreline and escarpment through erosion.

In its pitch, the report references recent data estimating that an annual investment of $5.3 billion is needed across Canada for municipalities to adapt to climate change.

the city should look at material reuse and recycling when it comes to demolitions, best practices for green building, financial incentive and award programs, and fee rebates.
It also asks that the city update its emissions target and corporate energy policy to ensure city-owned buildings are built to better standards and retrofit existing ones.

Figure 4: Dan Taekema/CBC

To improve the city's resiliency to extreme weather and minimize future damages, the report asks for a city-wide climate vulnerability and risk assessment to be completed.

4- Transportation

Two goals are dedicated to transportation, including looking at strategies to increase trips taken by "active and sustainable transportation" versus single use occupancy vehicles — which is 67 per cent of all trips in Hamilton — and moving up plans for low and zero emission transportation.
The task force points to promotion of existing programs to alleviate pressure, like Smart Commute, and mileage reimbursement policies. It also raises the option of having city services like parking enforcement act on foot or by bicycle.

The city would accelerate several master plans, including one for cycling that addresses a bike share and bike parking. The others look at street design, a car share, and parking pricing. It would also look at expanding electric vehicle infrastructure and changing city-owned vehicles to low or zero emission options.

Section 3: Building Description

Site layout

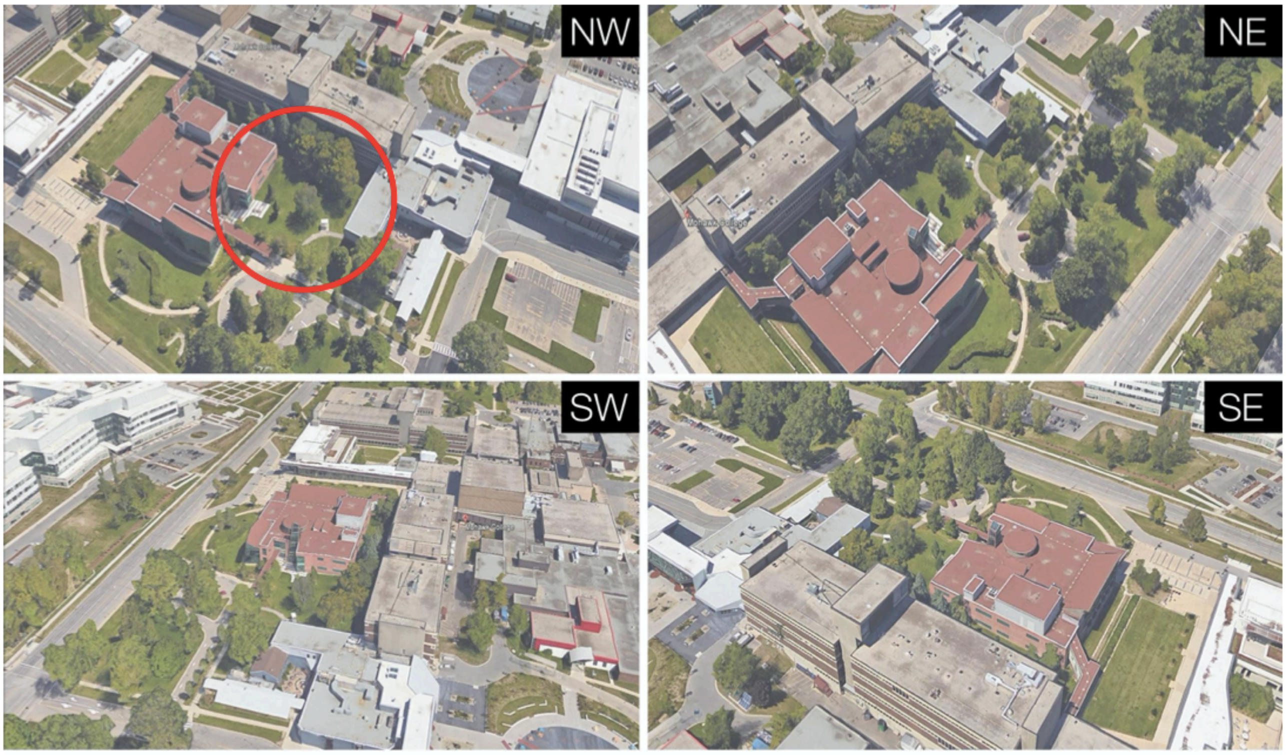


Figure 5:, Mohawk College Site Layout, 2017, by Pierre G. Bordeaux

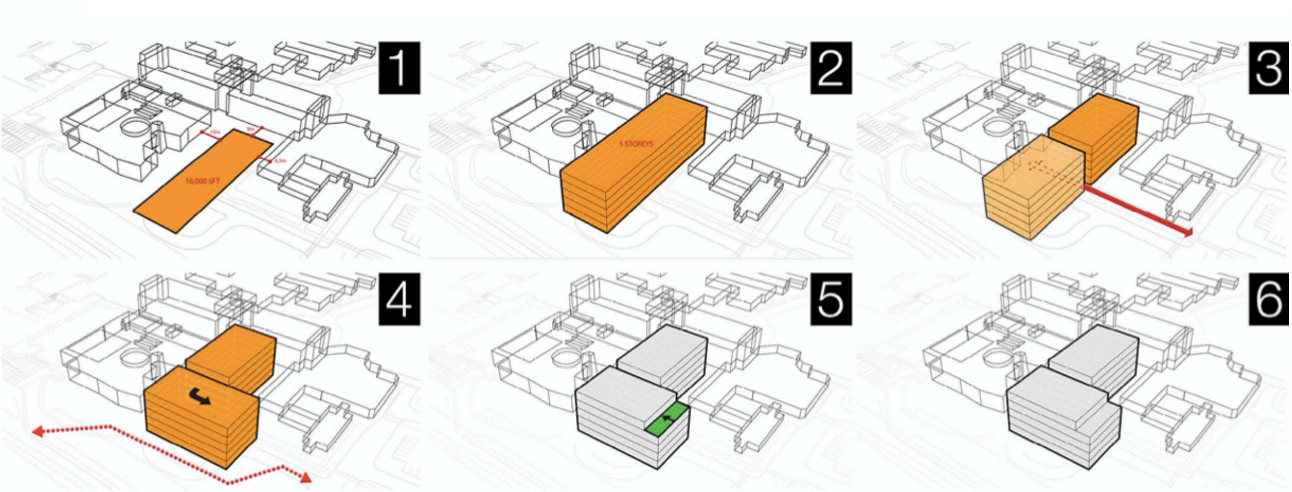


Figure 6: Illustration of the proposed building within the site layout by Pierre G. Bordeaux

The Philosophies behind the Design:

#1: Strategic integrated design

"High performance enclosures drive high performance systems."

– Steve Kemp, RDH Building Science

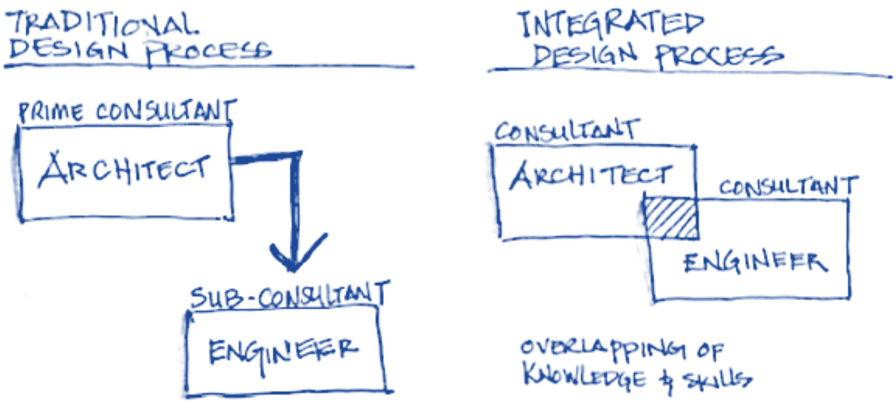
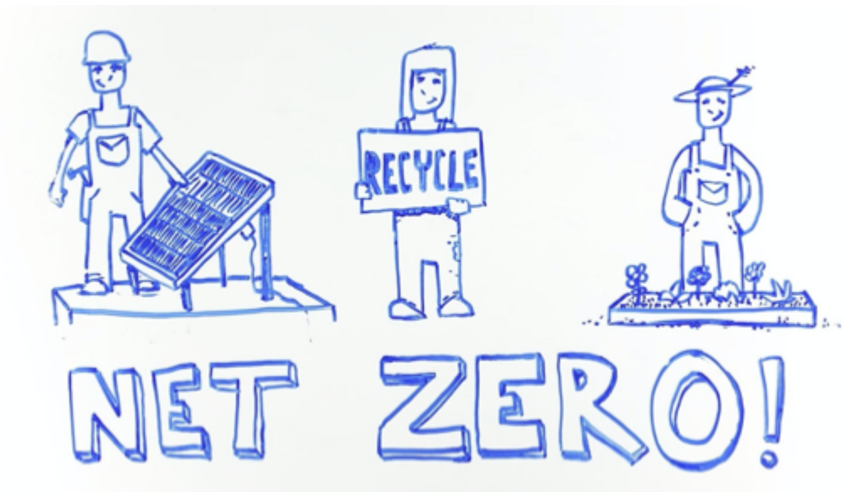


Diagram 01: Integrated Design

#2: Prioritize net zero project mandate



Component	Key Features	Notes
Structure	**The building superstructure** is structural steel, five-storey center and the solar farm spans across the building on wing-shaped structures supported by a combination of structural steel and supports from the solar panel fabricator.	
Architecture	**The design** incorporates high-capacity teaching spaces grouped together around a social hub atrium, converging to allow the flow of students to interact. The laboratories will be flexible and modular, allowing them to develop over time – in tune with advancing technology. The Joyce Centre has a 35/65 window-to-wall ratio to maximize energy absorption and natural light **Building Automation** To restrict energy usage modern controls and system automation systems are in place. The HVAC is demand responsive, with CO2 sensors adjusting ventilation when the facility is occupied. Lighting controls reduce output when daylight is available, and occupancy sensors will turn off lights in vacant rooms.	
Envelope	**High-Performance Envelope** The Joyce Centre's building envelope is designed to be air-tight so that heating and cooling systems work a minimal amount of the time. The roof was also designed to increase thermal performance, with green (planted) areas and surfaces that reflect heat from the sun. consisting of triple-pane glazing and insulated pre-cast sandwich panels, maximizes heating, cooling and natural light.	
Energy	**Solar Arrays** The Joyce Centre is designed to take advantage of natural sunlight! There is a total of 1,980 solar panels installed, projected to generate 730,000 kWh of energy annually. That's enough to power 67 homes for a year! The Centre also uses no natural gas onsite. **Geothermal System** The Joyce Centre generates its own renewable energy using a geothermal system. Energy is generated and stored in 28 geothermal wells drilled to a depth of 605 feet. A geothermal system takes advantage of Hamilton's unique climate by storing heat extracted from the building during cooling season into the ground and by drawing that heat from the ground during heating season for use in the building. **Natural Light** Let the light in! The Joyce Centre uses natural light to reduce energy needed for lighting. Large, insulated windows allow sunlight to illuminate classrooms, labs and hallways. A specially designed central	

	light well allows natural light to flow through five floors. Sensor-controlled LED lighting detects sunlight and will dim, or turn off, when there's plenty of sunshine available. **Electric Generation** The building generates 620,600 Kwh of renewable energy and consumed 537,000 Kwh in the same period (October 2018 – October 2019), producing 115.5% of the energy required for its operation. The generated green power created a surplus equivalent of 154,196 kg CO_2e (the amount of CO_2 that would have the equivalent global warming impact) while registering indirect emissions of 12,305 kg CO_2e, keeping the equivalent to 141,891 kg of carbon dioxide from entering the environment. The peak energy demand for the building was 296 kW in one day. The Joyce Centre uses no natural gas onsite.	
Rainwater Runoff	**Stormwater Harvesting** The Joyce Centre reduces water by using smart water conservation technologies. Two underground cisterns capture 228,000 litres of rainwater runoff. This water is then used in wastewater plumbing and landscaping systems. By capturing and reusing rainwater, The Joyce Centre is helping to manage storm water and reduce clean water consumption.	
Fresh Water Efficiency	**High-Efficiency Fixtures** The Joyce Centre maximizes efficiency and reduces heat and water waste. The average Canadian uses 251 litres of water each day. About 30% of this water is used to flush toilets. Older toilets can use up to 13 litres of water for each flush! To reduce wastewater, The Joyce Centre uses low-flow taps, toilets and urinals.	
Energy Metrics	**Energy Use Intensity (EUI)** JCPI is achieving a 73 kWh/m2/yr (final energy model) compared to a typical institutional building in Canada of 200-400 ekWh/m2/yr.	

3D-Perspective and Illustration

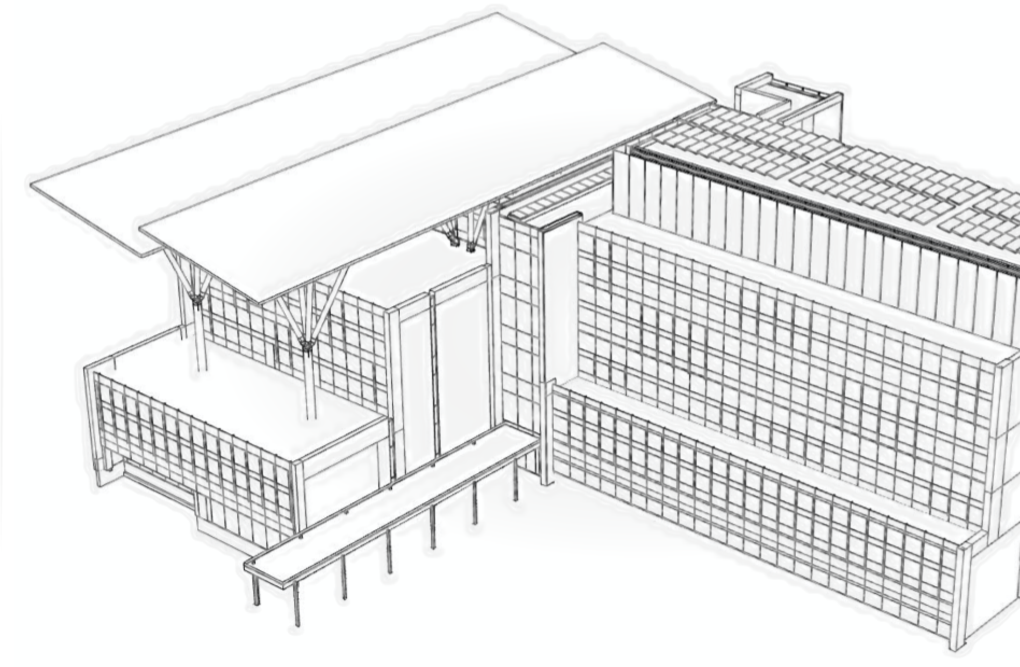
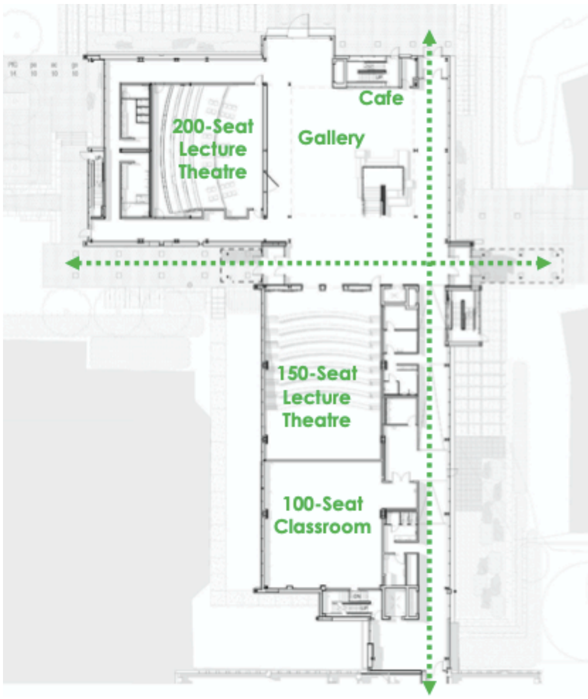


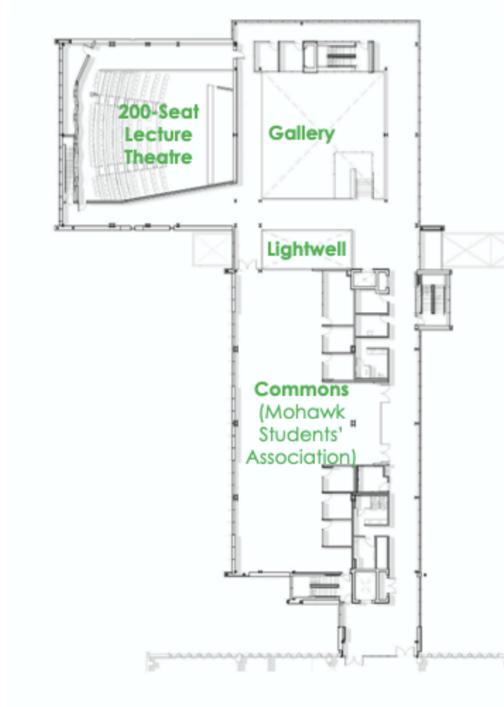
Figure 7: Project 3D-Perspective, 2017, by Pierre G. Bordeaux

Figure 8: Project 3D-Perspective proposal within the site layout, 2017, by Pierre G. Bordeaux

Level 0



Level 1



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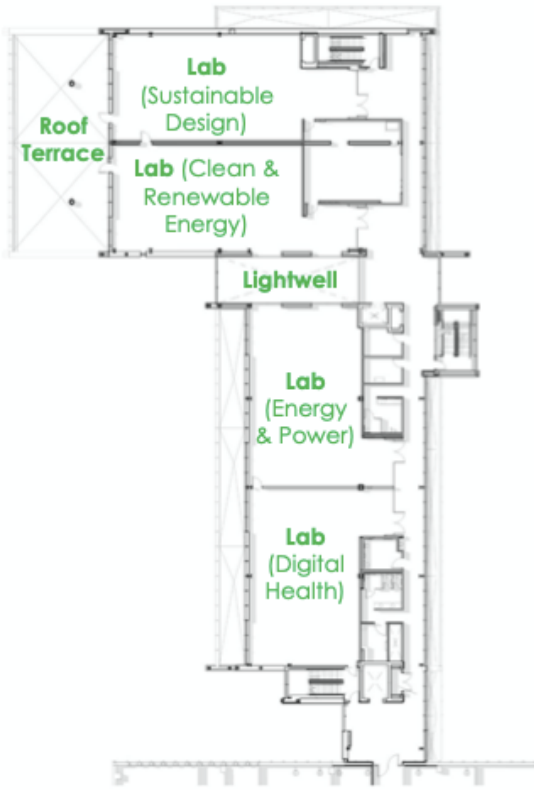

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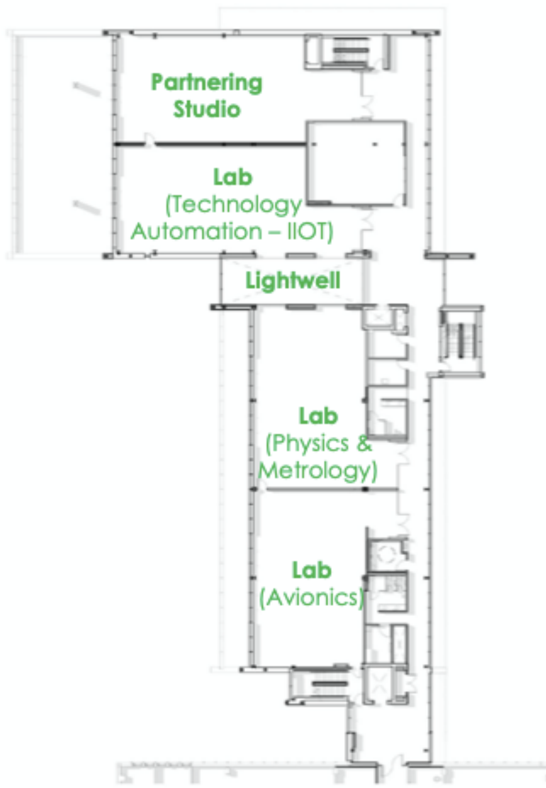


Level 4

Level 5/Penthouse

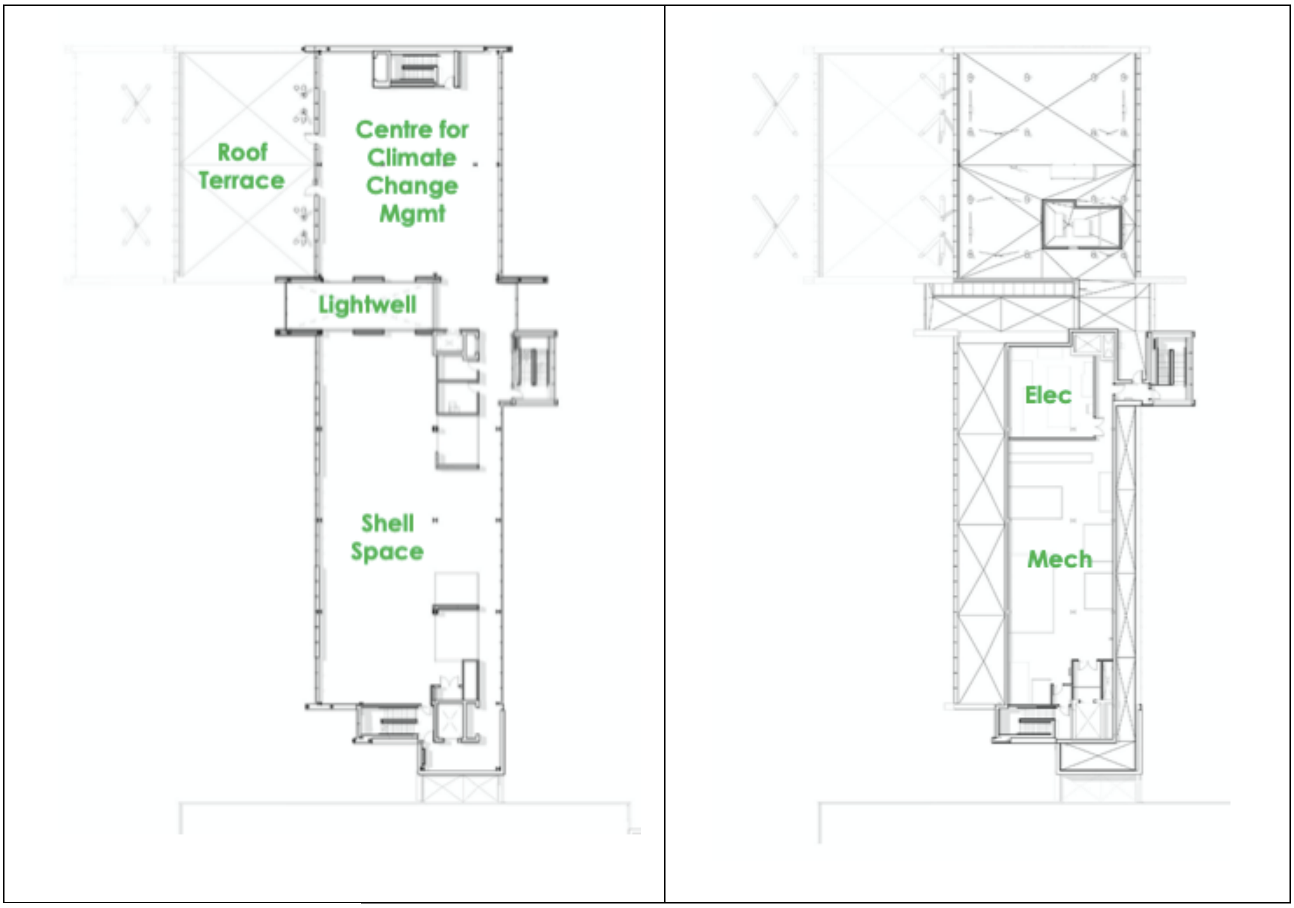


Fig 9: Architectural Floor Plans

Section 4: Corporate Social Responsibility

Who / What / When	Activity / Opportunity	Notes
Walterfedy Quality of life policies	Walterfedy believes in taking the time to celebrate people and achievements through BBQs, sport tournaments, holiday parties, and other regular social activities throughout the year. The Social Club, Sustainability Advisory Committee, Community Initiatives Committee, and the Wellness Committee were all designed to encourage their people to support the environment, the communities they serve, and each other.	
The Joyce Family Foundation Engage in charitable giving and volunteer	The Joyce Family Foundation made history Tuesday morning the 18th of October 2016 at Mohawk College when its trustees announced a $5-million investment in technology and infrastructure. “This morning we celebrate the largest donation ever made to Mohawk in our 50-year history," said Mohawk College president Ron McKerlie to a crowd including students, teachers and industry leaders. The multi-million-dollar pledge by the Joyce family was used to help fund a massive renewal of Mohawk's labs and classrooms —about 30,000 square feet — as well as the construction of a 90,000-square-foot Centre for Partnership and Innovation that will feature state-of-the-art labs for students and faculty to work together with industry partners on applied research projects. "We're not getting manufacturing jobs back. We're getting more technology related jobs and this is geared towards training people for those types of jobs," Joyce said. "Hopefully we attract talent from not just the Hamilton area but from further away to look at Hamilton as a growing, vibrant city that has something to offer." Joyce added. In recognition of the donation, the new building was named The Joyce Centre for Partnership and Innovation which McKerlie said will be a "living lab" and carbon-free building. The Hamilton spectator, Wednesday, October 19, 2016.	
Mohawk College Supporting Pollinators	1- **Mohawk is home to six honey-bee colonies**, three pollinator gardens and bioswales, and a 49-plot community garden, as well as an Indigenous Three Sisters Garden. The grounds maintenance is guided by Mohawk’s Sustainable Landscape Plan which prioritizes the naturalization of grounds. As well, they do have several academic and community-based programs that teach local community about the importance of pollinators and bees.	

Supporting local food access and production	In recognition of these efforts, Mohawk has been designated as a Bee City Campus by Bee City Canada. 2- **The Rooftop Pollinator Garden:** is a space that invites and supports many types of pollinators like butterflies, hummingbirds, beetles and bees. This garden recreates a natural meadow habitat with a mix of grasses and flowing plants that bloom at different types of the year. The garden is open to visitors in the warmer months and is a great place to relax, eat lunch or study! Location: The rooftop off Fennell Campus Library, top floor. 3- **Mohawk Community Garden** Mohawk is home to an on-campus community garden where individuals, college departments and student groups are provided garden space to grow fruits and vegetables for personal consumption. There are 49 plots available at no charge. Tools, soil and a rainwater harvesting system are provided for use of all participants. A portion of the produce from the community garden is donated to local foodbanks and other non-profit partners.	
Waste and Recycling	In 2018, 52% of Mohawk College's waste to landfill was food and organic wastes (Fennell Campus). Addressing food and organic waste on campus is an important part of reducing waste created **on campus**. If you are eating in the C-Wing Cafeteria, there are large roll-off green/compost bins in the seating area. As well, much of our composting is done behind the scenes in the kitchens. They dispose of pre-consumer food such as food preparation scraps.	
Electronic waste and battery collection	Mohawk college adopts a promising procedure to the proper collection, reuse and recycling of electronic materials and equipment which is an important part of environmental stewardship. Anything from televisions, monitors, cell phones and non-cellular phones, desktop computers, keyboard, etc. can be recycled, reused or repurposed. There are dedicated E-Waste cabinets everywhere in two campuses of the college. Mohawk Sustainability has teamed up with Raw Materials Company Inc. (RMC) to bring an on-campus battery recycling program. All students, staff and faculty are encouraged to bring their used batteries to any of the specified locations and the college ensures they are properly recycled.	
Opportunity 1	The happier employees are, the lower turnover is likely to be. For example,	

Improve labor policies and embrace fair trade	**Netflix:** offers their employees 52 weeks of paid parental leave, which applies to both parents. Within that time, employees have the option of going back to work and then resuming their paid leave as it suits them. No matter how they choose to take their leave of absence, they receive their full salary for the entirety of its duration. Netflix also offers unlimited vacation time to their workers, as does LinkedIn. **Spotify:** Offers their employees 24 weeks of paid leave for both moms and dads, which can be divvied up however they choose over the three years following a child's birth. However, you don't need to make grand gestures like these to improve employee morale. Introducing more natural lighting, soft seating, plants, or permitting remote work can also boost team spirits.	
Opportunity 2 Change corporate policies to benefit the environment	Hydrofluorocarbons, a chemical coolant that is commonly used in cold-storage facilities, is one of the most prevalent GHGs in the atmosphere. That's why, in 2015, Target pledged to open new facilities that elected to use ammonia to modulate the temperature instead. Cleaning product company Method does its part to create sustainable products by packaging its dish and hand soap using plastic recovered from the ocean to be "as kind to the planet as they are tough on dirt." It stays true to its mission in other ways too. Method uses wind energy to power its production plants and makes its soap as biodegradable as possible. Here are some ways socially responsible companies can help the environment. ▪ Hold an annual tree-planting event. ▪ Set up recycling bins throughout your facilities ▪ Minimize your amount of paper waste ▪ Permit remote work to reduce the negative impact of commuter traffic ▪ Switch from incandescent light bulbs to energy-saving LED bulbs. ▪ Make socially and environmentally conscious investments	

Section 5: LCA 1: The Supply Chain

Introduction

Defining supply chains as "networks of companies engaged in activities required to bring a product (or service) to market," a 2011 study from the University of Kentucky lays out one of the greatest current challenges in supply chain management:
The design of products, processes and systems in sustainable supply chains (SSCs) must not only seek economic benefits for shareholders and value for customers, but also manage environmental and societal impacts affecting all stakeholders. Realizing this goal mandates considering activities that span the entire life cycle of a product which, in reality, are conducted by many companies in the supply chain (Al Bredenberg, 2012).

Table 1: Grams of C02 produced when generating 1 kWh of electricity by source.

Source	Grams of CO2 produced
Coal	955
Oil	893
Natural Gas	650
Nuclear Energy	60
Hydropower	15
Solar Energy	40

Research- Supply Chain 1

Product: LED light fixtures

With lighting being one of the main energy consumers, MBII's main focus was on the design of illumination systems and the selection of light sources to drive down the overall lighting power density per square foot.

High-efficiency, long-life, low power consumption LED light fixtures complete with 0-10V dimming drivers were specified, paired with dual technology occupancy and daylight sensors in all enclosed spaces and rooms. Daylight dimming sensors that are synced with the overall daylight harvesting strategies were included in all areas with glazing. A wireless web-based lighting control system tied the lighting systems altogether, allowing for time-based, sensor-based (both occupancy and daylight), and local lighting control stations. Additionally, the control system is capable of controlling (ON/OFF and dimming) and adjusting/overriding programming of lighting zones remotely, from any internet connected device via web-based software

All tallied, the overall building interior lighting power density amounts to approximately 0.5W/sq. ft, an impressive reduction of over 40% from the Ashrae Standard 90.1 (2013).

The list of electrical energy saving initiatives goes on, including a digital web-based energy metering system for real-time monitoring of energy spend via the lobby's interactive screens, and premium efficiency power transformers. PoE (Power over Ethernet) lighting was designed for the Physics & Metrology Lab and 24VDC lighting was designed for the Clean & Renewable Energy Lab and Collaboratory/Commons spaces to test and showcase these emerging technologies.

1- **System Boundaries:**

From Cradle-to-Cradle approach diagram:

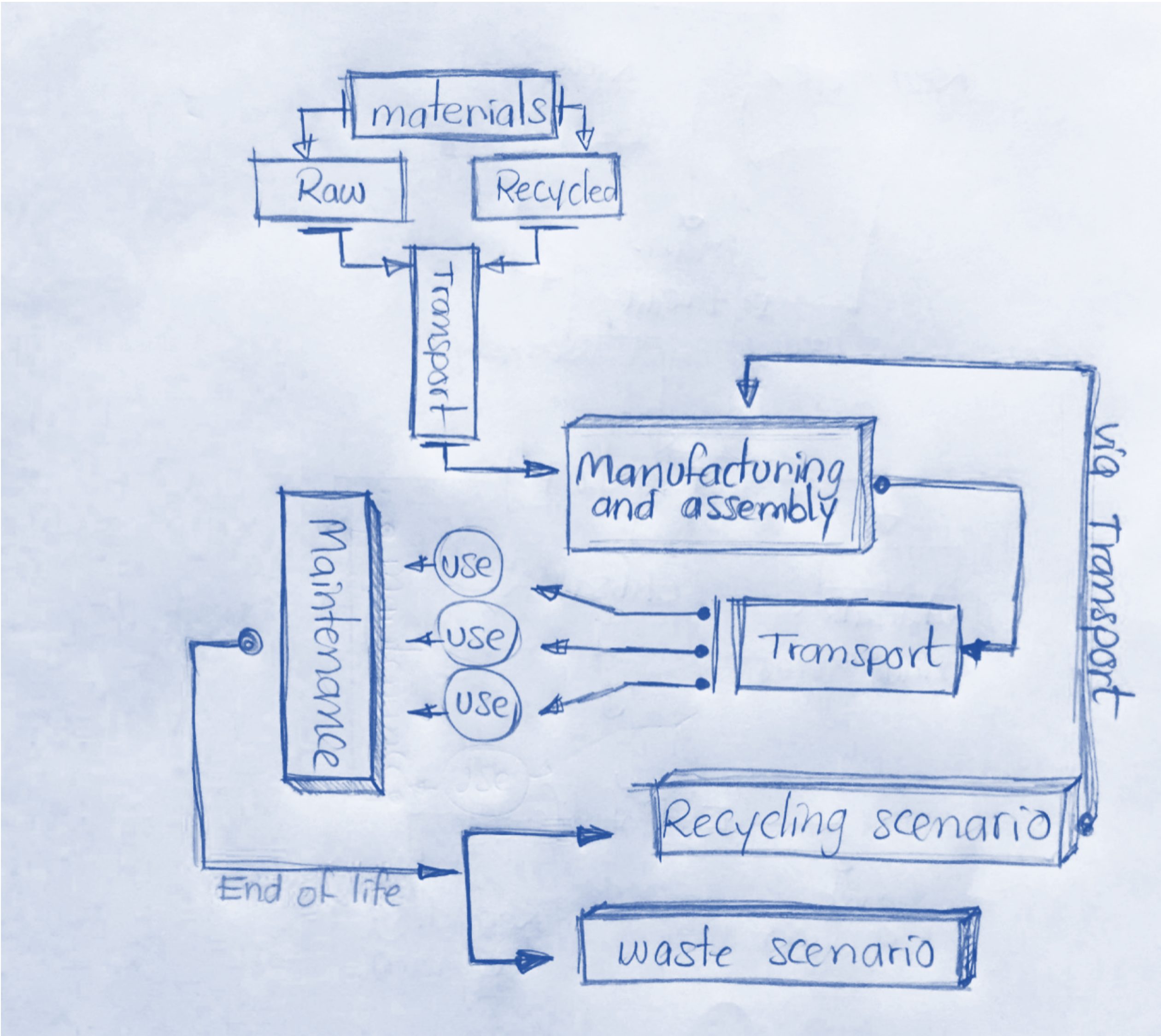


Diagram 02: Cradle to Cradle cycle by Pierre G. Bordeaux

2- **Source of Raw materials:**

Most of the LED light raw materials are originated for India. This counts as a disadvantage as transport cost are high. But going down the diagram, there are few leading manufacturing and assembly facilities in the USA and Canada within a close proximity to Hamilton, where the project is located. The compoents of the LED light are as in the diagram 3

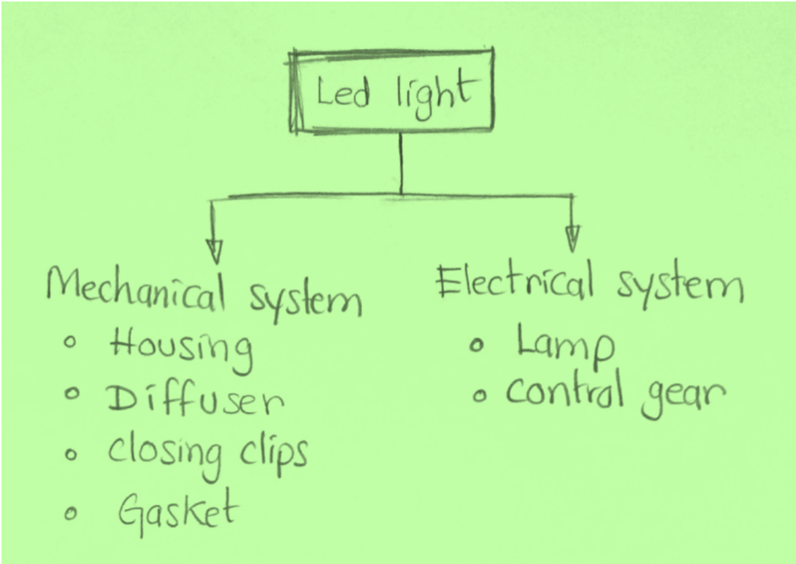


Diagram 3: LED light components, by Pierre G. Bordeaux

3- End of life scenario

are showed in diagram 4. Most of the waste goes to land-fills. This is a disadvantage too. But measuring the pros over the lifetime of the LED light overweighs the cons

End of life datasets.

Material	Incineration	Landfilling
Stainless Steel	-	Treatment of scrap steel, inert material landfill (GLO)
Aluminum	-	Treatment of waste aluminum, sanitary landfill (GLO)
SMC PC PMMA SAN PA GF10	Treatment of waste plastic, mixture, municipal incineration (GLO)	Treatment of waste plastic, mixture, sanitary landfill (GLO)
PU	Treatment of waste polyurethane, municipal incineration (GLO)	Treatment of waste polyurethane, sanitary landfill (GLO)

Table 2: End of life waste

End of life Scenario 1.

Part	Material	End of Life Scenario		
		Recycling (%)	Incineration (%)	Land Fill (%)
Housing	PC	0	5	95
	SMC	0	5	95
	Aluminum	91	0	9
Diffuser	PC	0	5	95
	PMMA	0	5	95
	SAN	0	5	95
Clips	PA6 GF10	0	5	95
	Stainless steel	94	0	6
Gasket	PU flexible foam	0	5	95

Table 3: End of life Scenario

4- CO2 emission reduction:

LED light unit pulp produced 0.01818 tons of CO2 compared to 0.15148 tons for traditional lighting fixtures this means a savings of 88% of CO2 emission.

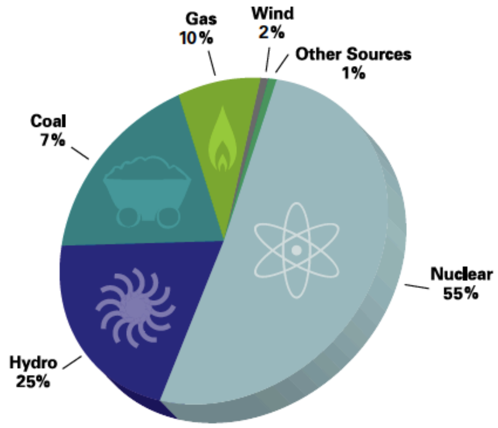
Research- Supply Chain 2

Product: SOLAR PHOTOVOLTAIC (PV) ENERGY SYSTEMS

The Joyce Centre for Partnership and Innovation's (JCPI) solar photovoltaic system (including JCPI, A-Wing, J-Wing & H-Wing rooftop systems) consists of 1,980 solar panels, capable of generating roughly 721,000 kilowatt-hours (kWh) of clean, renewable electricity on an annual basis. The system is capable of generating up to 500 kilowatts (kW) of AC power.

The Fennell Campus P4 parking lot carport solar photovoltaic system consists of 1,316 solar panels, capable of generating roughly 505,000 kilowatt-hours (kWh) of clean, renewable electricity on an annual basis. The system is capable of generating up to 300 kilowatts (kW) of AC power. The rooftop of the David Braley Athletic and Recreation Centre (DBARC) at our Fennell Campus is solar photovoltaic ready, allowing our campus solar photovoltaic system to be expanded without additional structural upgrades at that facility.

Ontario gets its electricity from a mix of energy sources. About half of our electricity comes from nuclear power. The remainder comes from a mix of hydroelectric, coal, natural gas and wind.



Minding Table 1, we for 1 KW of electricity produced in Ontario, the average of CO_2 could be calculated as;

55% x 60 gms + 25% x 15 gms + 7% x 955 + 10% x 650 = 165.8 gms of CO_2
As the Solar Photovoltaic Energy Systems produced 40 gms of CO_2
The savings per KWh = 165.8 – 40 = 125.8 gms

721,000 KWh produced by the PV system annually x 125.8 gms CO_2 = 90.7 tons of saved CO_2 annually would have been released if the PV system was not utilised.

To put it into perspective, this savings of 90.7 tons is equivalent to reducing gasoline consumption by 10,500 gallons per year. If the average of gasoline consumption in Canada is 500 gallons, the saving could be expressed in other words as stopping of (10,500/500) = 21 cars from running. If every Canadian motorist avoided idling their vehicle for just five minutes a day, 365 days of the year, more than 1.6 million tonnes of carbon dioxide, along with other toxic substances, would be spared from entering the atmosphere. So, we could imagine how much the benefit of completely stopping 21 cars 24 hours a day 365 a year.

1- Cost and pay backs:

The Ontario Power Authority facilitates the FIT program which offers a 20 year contract for electricity from renewable sources. Prices for solar power sent back to the electricity grid ranges from 44.3 to 80.2 cents per kilowatt hour (kWh) plus community adder of 0.4 cents per kWh

2- Maintenance:

Because many PV panels have no moving parts, there is no wear and tear and thus virtually no maintenance required once the system is up and running. You may occasionally need to clear leaves, snow, dust or other debris.

Research- Supply Chain 3
Product: SOLAR THERMAL WATER ENERGY SYSTEMS

Installing a solar thermal energy system is one of the most reliable and cost-effective renewable solutions to reducing electric or gas bill. When properly installed, a system can provide up to 60% of annual water heating, enabling year-round savings.

Sunlight is converted into heat through solar panels (collectors) mounted on the roof. Water, or a water/antifreeze solution, carries heat from the panel(s) and pumps it through a heat exchanger to a tank for storage and subsequent use. The solar panel is mounted facing south. As the sunlight passes through the glazing, it strikes an absorbing material. This material converts the sunlight into heat while the glazing prevents the heat from escaping.

Heat energy is then transferred through a heat exchanger and into the water storage tank. Solar-heated water is then stored in an insulated tank until needed. Hot water is drawn off the tank when tap water is used, and cold make-up water enters at the bottom of the tank (Terratek Energy, 2020).

The Joyce Centre for Partnership and Innovation's (JCPI) rooftop houses 5 flat-plate solar collectors that use collected energy to preheat domestic hot water for showers and sinks throughout the building, reducing the amount of non-renewable energy required.

Research- Supply Chain 4

Product: GROUND SOURCE ENERGY EARTH SYSTEM (EES)

In Canada, where air temperatures can go below –30°C, and where winter ground temperatures are generally in the range of –2°C to 4°C, earth-energy systems have a coefficient of performance (COP) of between 2.5 and 3.8.

A ground water EES installation in southern Canada will have a heating seasonal performance factor (HSPF) of between 10.7 and 12.8, compared with an HSPF of 3.4 for electrical-resistance heating. Similarly, a closed-loop EES in southern Canada will have an HSPF of between 9.2 and 11.0, with the higher value achieved by the most efficient closed-loop heat pump available.

JCPI has a ground source heat pump system, which provides heating and cooling to the building year-round. This system consists of 28 geothermal wells, which extend 185 metres below the ground surface. This system allows us to store heat in the ground when it is not required by the building and draw that heat back when it is required by the building.

On average, an EES will yield savings that are about 40 percent more than would be provided by an air-source heat pump. This is due to the fact that underground temperatures are higher in winter than air temperatures. As a result, an EES can provide more heat over the course of the winter than an air-source heat pump.

Operating Costs

The operating costs of an earth-energy system are usually considerably lower than those of other heating systems, because of the savings in fuel. Qualified heat pump installers should be able to give you information on how much electricity a particular earth-energy system would use.

However, the relative savings will depend on whether you are currently using electricity, oil or natural gas, and on the relative costs of different energy sources in your area. By running a heat pump, you will use less gas or oil, but more electricity. If you live in an area where electricity is expensive, your operating costs may be higher. The payback on an investment in an earth-energy system may be anywhere up to a decade or more. Later in this booklet, operating cost estimates are provided for EESs (Natural Resources Canada, 2017).

Life Expectancy and Warranties

EESs have a life expectancy of about 20 to 25 years. This is higher than for air-source heat pumps because the compressor has less thermal and mechanical stress and is protected from the environment.

Most ground-source heat pump units are covered by a one-year warranty on parts and labour, and some manufacturers offer extended warranty programs. However, warranties vary between manufacturers, so be sure to check the fine print.

Section 6: Sustainable Planning & Procurement

Research- Relevant Policies/ Regulations

Ontario's Previous and Proposed Low-Carbon and Greenhouse Gas Reduction and Targets

Prepared by the Office of the Auditor General of Ontario

Year	Source of Target	Target Year	Target Emission Reductions	Target Emissions (Mt)	Target Status
2007	Go Green: Ontario's Action Plan on Climate Change	2014	6% lower than in 1990[1]	169	Achieved
		2020	15% lower than in 1990[1]	153	Repealed in 2018
		2050	80% lower than in 1990[1]	36	Repealed in 2018
2016	*Climate Change Mitigation and Low-carbon Economy Act, 2016*	2030	37% lower than in 1990[1]	113	Repealed in 2018
2018	Preserving and Protecting our Environment for Future Generations: A Made-in-Ontario Environment Plan	2030	30% lower than in 2005[2]	143	Current target

1. Ontario's 1990 emissions were 180 Mt.
2. Ontario's 2005 emissions were 204 Mt.

Examples of Current Ontario Programs and Initiatives that Affect Greenhouse Gas Emissions

Prepared by the Office of the Auditor General of Ontario

Sector of Emissions	Program or Legislation
Transportation	• Ethanol in gasoline – O. Reg. 535/05 under the *Environmental Protection Act* requires 5% of all gasoline to be comprised of ethanol biofuel • Greener diesel – O. Reg. 97/14 under the *Environmental Protection Act* requires 4% of diesel to be biofuel • 2041 Regional Transportation Plan – increase availability and use of public transit throughout the Greater Toronto and Hamilton Area • Speed-limiting systems for commercial motor vehicles – reduced truck speed results in reduced greenhouse gas emissions • Land use planning and approval of municipalities' official plans
Industry	• Emissions reporting – O. Reg. 390/18 under the *Environmental Protection Act* requires large emitters to report and verify their emissions data • Natural gas conservation programs (encourages reducing natural gas use)
Buildings	• Ontario Building Code – specifies levels of insulation and energy efficiency in buildings • Natural gas utility conservation programs (encourage reducing natural gas use) • Broader Public Sector energy reporting and conservation – O. Reg. 507/18 under the *Electricity Act* requires public agencies to have energy conservation and demand management plans
Waste	• Food and organic waste diversion (to minimize methane-producing organic waste in landfills) • Landfill gas – O. Reg. 232/98 under the *Environmental Protection Act* requires the collection, burning or use of methane gas at landfilling sites
Electricity	• Time-of-use energy pricing to reduce electricity use during peak times • Energy-efficiency standards for appliances and equipment (under *Electricity Act* regulations) • Electricity conservation programs through the Independent Electricity System Operator (under *Electricity Act* directives)

Ontario’s Actions to Reduce Carbon and Greenhouse Gas Emissions

Prepared by the Office of the Auditor General of Ontario

Year	Event
2005	Ontario begins decommissioning five coal-fired generating stations to improve air quality.
2007	Ontario releases “Go Green: Ontario’s Action Plan on Climate Change,” establishing emission-reduction targets for 2014, 2020 and 2050. Enacts regulation that prohibits the use of coal to generate electricity after December 2014.
2008	Ontario joins the Western Climate Initiative, a group of US states and Canadian provinces collaborating on reducing emissions.
2009	Ontario passes the *Green Energy and Green Economy Act* to expand low-carbon energy generation (solar and wind power) and amends the *Environmental Protection Act* to enable the creation of an Ontario cap and trade system.
2014	Ontario closes the Thunder Bay Generating Station. This completes the phase-out of coal-fired electricity generation in Ontario. The closure of the five stations* is the single largest greenhouse gas reduction action in North America.
2015	Ontario announces it will create a cap and trade system to price carbon emissions, and sets a 2030 emission-reduction target of 37% below 1990 levels (to 113 Mt). Ministry releases Ontario’s Climate Change Strategy.
2016	Ontario passes the *Climate Change Mitigation and Low-carbon Economy Act*. The Act establishes a legal framework for emissions reductions and reductions targets for 2020, 2030 and 2050. A cap and trade program is established by regulation under the Act. A five-year Climate Change Action Plan is released, with plans to reduce emissions across all sectors.
2017	Cap and trade program launched. In its 18-month duration, the program raises $2.9 billion, earmarked for programs to reduce emissions. The revenues were used mainly for energy efficiency retrofits for homes, businesses, hospitals and educational institutions, as well as electric vehicles, cycling infrastructure and transit.
2018	Ontario passes the *Cap and Trade Cancellation Act*, which repeals the *Climate Change Mitigation and Low-carbon Economy Act*. This cancels the cap and trade program and programs dependent on its revenues. Ontario also withdraws from the Western Climate Initiative. The Ministry of the Environment, Conservation and Parks releases an Environment Plan, outlining a proposed new path to meet a new 2030 greenhouse gas emissions target of 30% below 2005 levels by 2030 (143 Mt).

* Ontario’s five coal-fired electricity generating stations included Nanticoke, Atikokan, Lambton, Lakeview and Thunder Bay. They were closed between 2005 and 2014. The Hearn Generating Station, also coal-fired, was closed in 1983.

Research- Potential certification schemes (eg BREEAM, LEED)

Critical Reflection

Section 7: LCA 2: Carbon Analysis

Research- Policy and Regulation

Major Carbon impacts from the Case Study are

1- Air Pollution

PM 2.5 was found by a 2017 report by the Organisation for Economic Co-operation and Development to be “the most serious pollutant globally from a human health perspective.” Hamilton is considered one of the most areas in Ontario that is identified as communities with particular air pollution challenges as it has pollution levels that have exceeded the Canadian Standards for annual PM2.5. The Joyce Centre for Partnership and Innovation has considered this concern in the design.

2- Level of Insulation and Building Envelop

High-Performance Envelope

The Joyce Centre’s building envelope is designed to be as air-tight as possible so that heating and cooling systems work a minimal amount of the time – if at all. The roof was also designed to increase thermal performance, with green (planted) areas and surfaces that reflect heat from the sun.

3- Energy Efficiency

Natural Light

Let the light in! The Joyce Centre uses natural light to reduce energy needed for lighting. Large, insulated windows allow sunlight to illuminate classrooms, labs and hallways. A specially designed central light well allows natural light to flow through five floors. Sensor-controlled LED lighting detects sunlight and will dim, or turn off, when there’s plenty of sunshine available.

Solar Arrays

The Joyce Centre is designed to take advantage of an important source of free energy: sunlight! There are a total of 1,980 solar panels installed as part of this project, projected to generate 730,000 kWh of energy annually. That’s enough to power 67 homes for a year! The Centre also uses no natural gas onsite – the all-electric set up allows for the easiest route to low carbon for most buildings.

Geothermal System

The Joyce Centre generates its own renewable energy using a geothermal system. Energy is generated and stored in 28 geothermal wells drilled to a depth of 605 feet. A geothermal system takes advantage of our unique climate by storing heat extracted from the building during cooling season into the ground and by drawing that heat from the ground during heating season for use in the building.

Critical Reflection

The Ministry's Climate Change Policy Branch (Branch) led the development of a climate change plan. In July 2018, Ministry staff began considering options, including the plan's vision, targets, principles, actions, structure, and process. The Branch proposed six pillars under which key actions in the climate change plan would focus, including:

- Building Resilience
- Making Polluters Pay
- Leveraging the Private Sector • Leading by Example
- Using Energy Wisely, and
- Being Transparent.

The Plan outlines the province's proposed approach for achieving progress in four main environmental areas:

- protecting Ontario's air, lakes and rivers
- reducing litter and waste, and keeping land and soil clean;
- conserving land and greenspace; and
- addressing climate change.

According to the Ministry, the Plan's climate change chapter fulfils the commitment under the Cap and Trade Cancellation Act, 2018 to prepare a climate change plan.

Section 8: Emerging Tools and Manufacture

Example used in the Case Study – and impact

Solar arrays at the Joyce Centre for Partnership and Innovation building was built in a fixed way to face the average sun direction. Being fixed wastes some potential solar energy that could have been used if the system can rotate, incline, and twist freely to face the sun.

Proposed for in the Case Study – potential impact: Dynamic Solar Facades:

The field of dynamic facades as sustainable building elements is in its infancy. However, the field is growing rapidly due to the requirement for better environmental performance of buildings, and the recent rise of computational tools and electronics for control.

Dynamic facades have the potential to add to the architectural expression of a building by visualizing the changeable aspects of the environment (Meagher, 2015). PV-embedded textile shading system which consists of individually movable stripes could be utilised instead of the fixed system that is installed at the Joyce Centre of Partnership and Innovation. The dynamic system will allow for maximization of the solar irradiation as the textile stripe scan could be raised and twisted using DC motors. The benefits go beyond irradiation to include the maximisation of other functions such as shading and the utilisation of wind to serve the ventilation purposes by directing the panels at the time of shade.

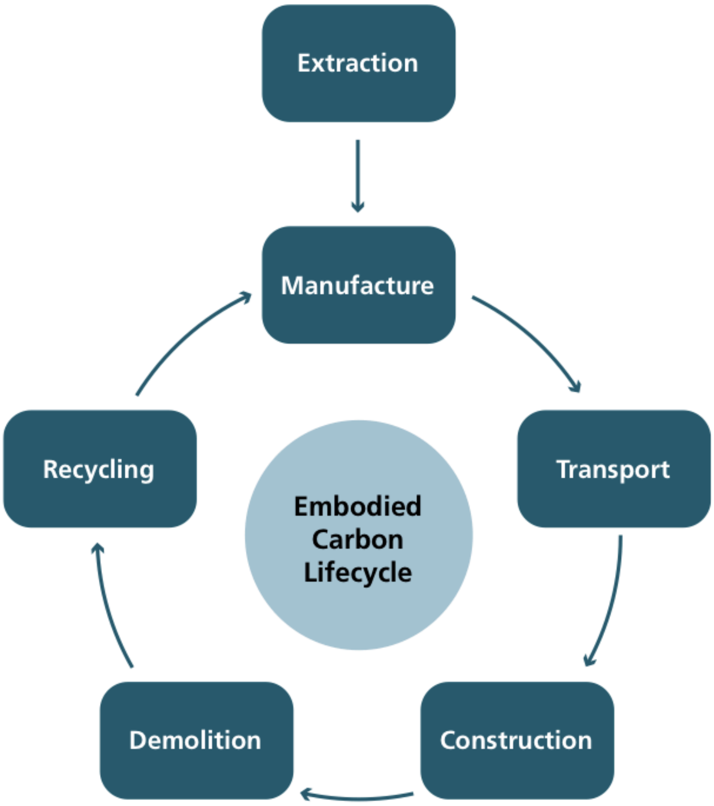
Section 9: Low-Carbon Design

Description

The Joyce Centre for Partnership and Innovation demonstrates the cost and programme performance of comparable structural designs. The same models developed for each structural option have been used to calculate their embodied carbon impacts by applying the carbon rates from the simple design tool to the quantities for each material.

Structural grid at 7.5m x 9m was established, based on an optimum grid for a typical Educational institution building not dictated by site constraints. Four frame types were considered:

1. Steel composite beams and composite slab
2. Steel frame and precast concrete slabs
3. Reinforced concrete flat slab
4. In-situ concrete frame with post-tensioned slab



For all options the foundations were designed as unreinforced mass concrete pads. The core construction is steelwork cross-braced framing with a medium density blockwork infill for the steel options and concrete shear walls for the concrete options.

For both steel options, the 30-minute fire resistance is provided by intumescent coating to beams and bracing members and boarding to columns. For the concrete options, the internal columns are plastered and painted for aesthetic purposes.

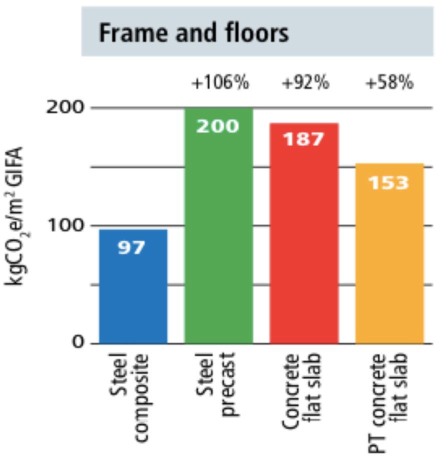
The embodied carbon impacts for each option have been considered on a cradle to cradle basis. Only the structural aspects of each option have been assessed, using the data set from the SCI's simple design tool.

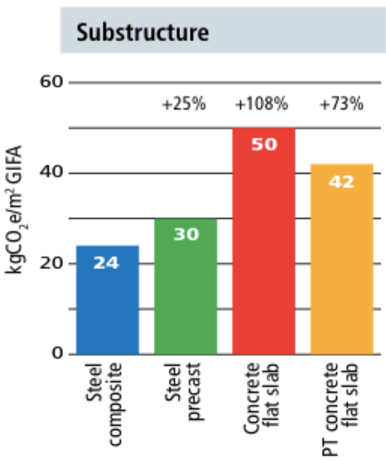
For frame and floors, the embodied carbon impact of the steel composite option is significantly lower than all the other options at 97kgCO2e/m , with the post-tensioned flat slab 58% higher at 153kgCO2e/m , the concrete flat slab 92% higher at 187kgCO2e/m2 and the steel precast 106% higher at 200kgCO2e/m.

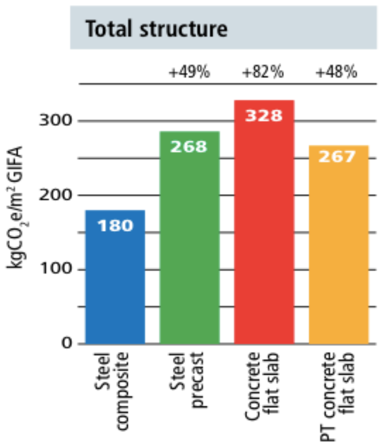
The lighter superstructure for the steel options results in smaller foundations than those of the concrete options. Consequently, the impacts from the substructure are different for each option. The foundations for the steel composite option have an embodied carbon impact of 24kgCO2e/m . This compares with 30kgCO2e/m2 for the steel precast option, 42kgCO2e/m2 for the post-tensioned flat slab concrete option and 50kgCO2e/m2 for the concrete flat slab option.

For the total structure, which includes frame and upper floors, foundations and roof construction, it can be seen that the steel composite has the lowest embodied carbon impact at 180kgCO2e/m. Interestingly, steel precast and post-tensioned flat slab have similar total impacts at 268kgCO2e/m and 267kgCO2e/m , respectively, with concrete flat slab at 328kgCO2e/m .

It can therefore be seen that the steel composite option has significantly lower embodied carbon impacts than any of the other options. Whilst the steel precast and post-tensioned flat slab concrete options have similar embodied carbon impacts, the steel precast has significantly lower cost and a quicker construction programme.







Section 10: Professional Responsibility

Research- Professional Codes

The Zero Carbon Building – Design (ZCB-Design) Standard is a made-in-Canada framework for designing and retrofitting buildings to achieve zero carbon. Zero carbon buildings represent the industry's best opportunity for cost-effective emissions reductions that spur innovation in design, building materials and technology, creating jobs and business opportunities.

The second iteration of the Standard introduces greater rigour while increasing flexibility, to support the goal of transforming all buildings to be zero carbon. The updates to the ZCB-Design Standard are designed to facilitate this change by incorporating the findings from ZCB Standard certified projects and by responding to evolving knowledge that is shaping operational solutions. Special consideration was given to the following four topic areas.

EMBODIED CARBON IN CONSTRUCTION MATERIALS

While the energy efficiency of buildings has improved and reduced the emissions associated with building operations, the relative embodied carbon associated with building materials has increased.4 Emphasis now needs to be directed at reducing the carbon associated with the life-cycle embodied carbon of materials. Of particular importance are the emissions from the production of construction materials, which the industry calls upfront carbon. These emissions become a factor even before a building begins operation (Environment and Climate Change Canada, 2020).

ENERGY GRIDS AND BUILDINGS

Building design must now consider the interplay of drawing power from the grid and sending power back, to ensure the exchanges provide measurable carbon reductions. For example, building design should aim to reduce and shift peak electricity demand to minimize consumption at times when fossil fuels are being used to meet grid power generation needs (Environment and Climate Change Canada, 2020).

ONSITE RENEWABLES

Onsite renewables offer a cost-effective path to reduce carbon emissions from buildings located in areas with high-carbon electricity grids. They can also be effective in low-carbon grids provided they displace fossil fuel fired power generation typically used to meet peak demand (Environment and Climate Change Canada, 2020).

NEAR-TERM CLIMATE FORCERS

Refrigerants and methane are near-term climate forcers – GHGs that last a short time in the atmosphere but trap a large amount of heat. As a result, these near-term climate forcers accelerate the impact of climate change. Increasingly, refrigerants are used in heat pumps to enhance efficiency and drive down carbon emissions. This necessitates a better understanding of refrigerant options and best-management practices to minimize potential refrigerant leaks. In addition, the impact of unintended methane releases resulting from extraction, processing and distribution is significant and is now recognized in the IPCC Guidelines for National Greenhouse Gas Inventories (Environment and Climate Change Canada, 2020).

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