Vision for a New Data Sciences Centre

FINAL REPORT FOR: UNIVERSITY OF TORONTO CAMPUS AND FACILITIES PLANNING | ENV461/1103 UNIVERSITY OF TORONTO CAMPUS AS A LIVING LAB OF SUSTAINABILITY

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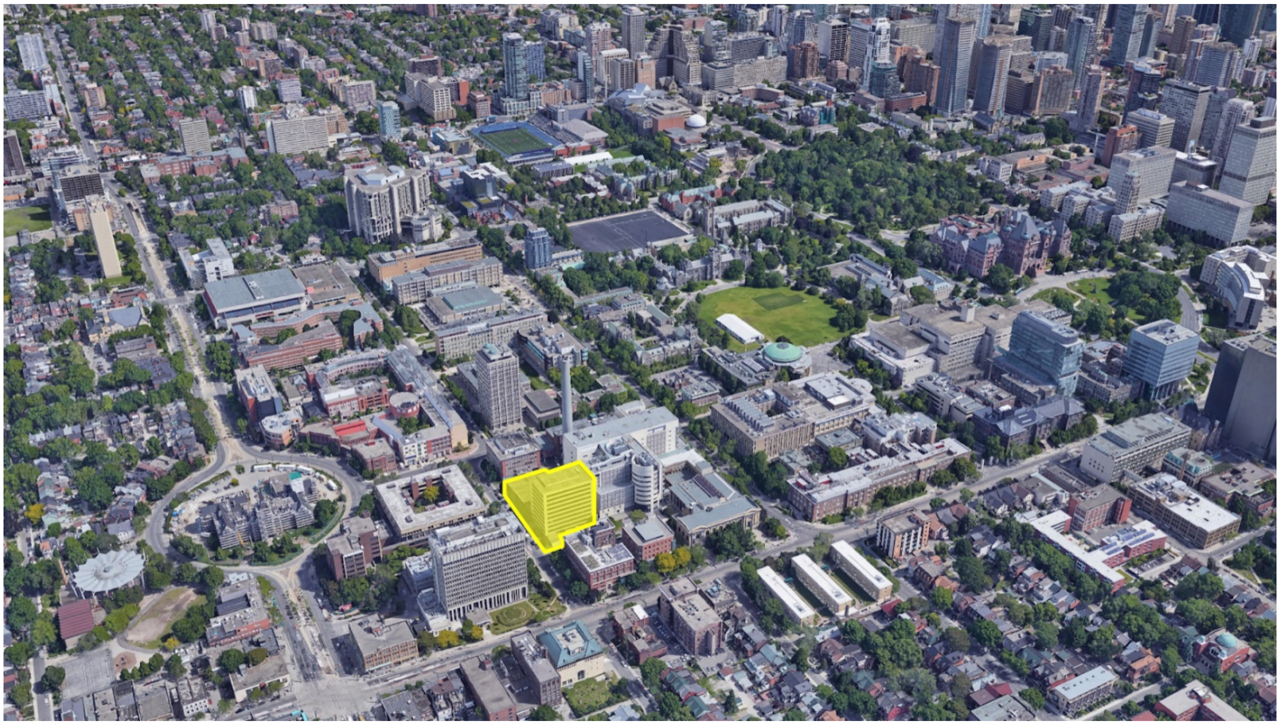


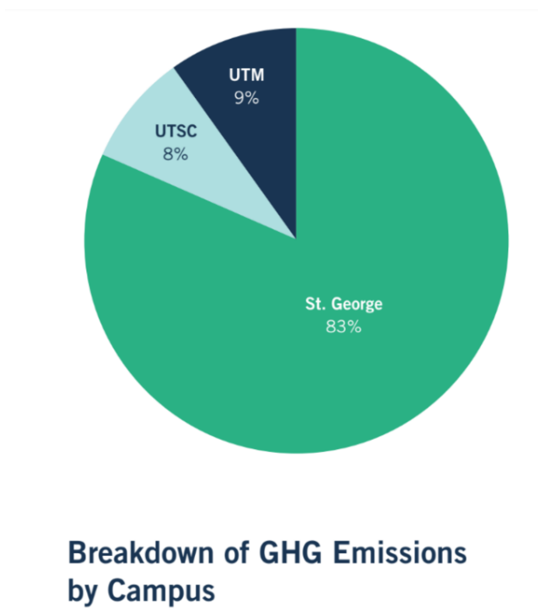
Image: Location for the new Data Sciences Centre

INTRODUCTION

Recently, there has been a movement towards incorporating sustainability in the design and construction of buildings given their historically negative environmental impacts. Since buildings account for 40% of all greenhouse gas emissions (Sustainable Design Collective, 2015), it is clear that implementing sustainable design strategies is crucial for reducing environmental damage. There is a rare building opportunity at the University of Toronto (U of T) for a complete demolition and redevelopment project with potential to assist with the campus' Low-Carbon Action Plan (LCAP) goal of reducing greenhouse gas emissions by 37% from 1990 levels by 2030 (University of Toronto, 2019). This opportunity presents an 18-storey structure known as the Data Sciences Centre (DSC), an initiative being led by the Campus and Facilities Planning (CFP) team. The DSC will house university staff, faculty, and students primarily from the departments of statistics, mathematics, and computer science. Strong physical and programmatic connections to the Bahen Centre are also being considered as a part of this planning process.

The CFP is interested in learning the impacts that a net positive building can have on the campuses LCAP, given that the St. George campus accounts for 83% of the total GHG emissions for U of T (University of Toronto, 2019). The project is currently in a preliminary planning phase, and we have worked with the CFP to produce this project advisory document to help inform the sustainability goals for the new Data Sciences Centre.

Figure 1: Breakdown of Greenhouse Gas Emissions by Campus (University of Toronto, 2019)

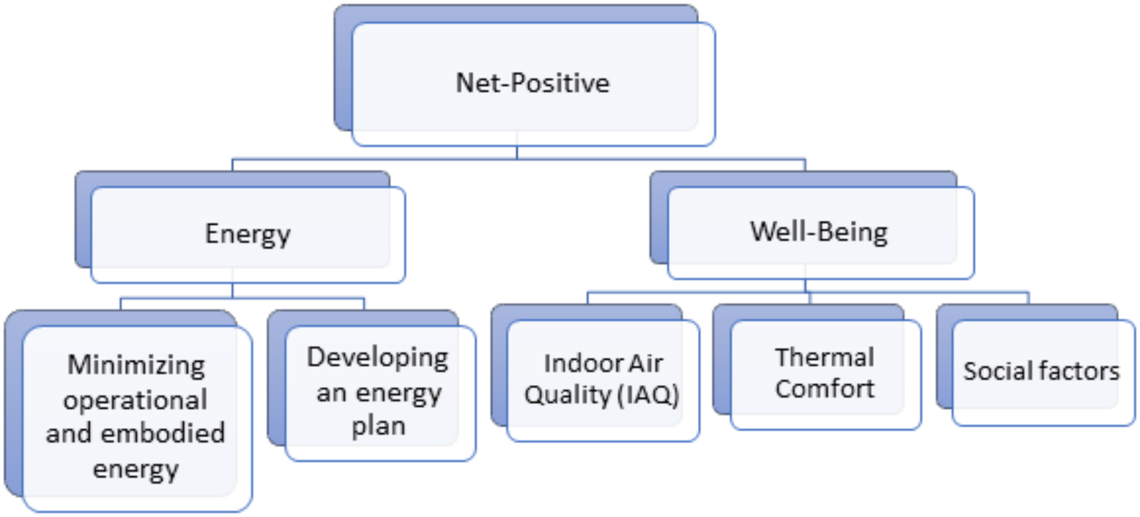


PROJECT OVERVIEW

GOALS AND OBJECTIVES

The main sustainability goal of the CFP is to achieve net-positive, in terms of both energy and wellbeing. We have come up with two objectives to achieve net-positive energy and three objectives to achieve net-positive well-being.

Objectives Overview: Figure 2



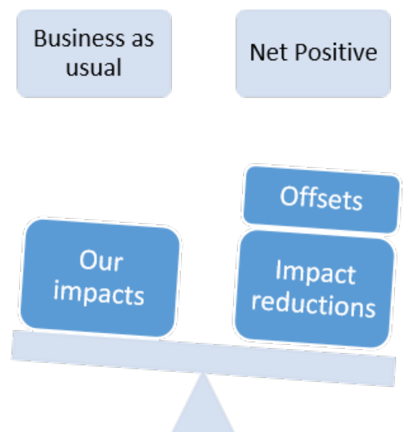
METHODOLOGY AND DATA DESCRIPTION

Our methodology consists of literature reviews on precedent sustainable buildings, academic sources, and simulation models. These methods will allow information-gathering on the most beneficial features that have been used in sustainable building designs to give inspiration for the final DSC design. The data is being collected from various internet sources, including architecture websites, articles, journals, and case studies. The selected sources include information about our specific goals, as well as sustainable buildings of similar size and use as the DSC. We tried to choose from a mix of practical and unique features. All simulations were carried out using Rhinoceros, Grasshopper, and Ladybug to determine the amount of solar gain that each building facade would receive annually.

OUR DEFINITION OF NET-POSITIVE

We defined net-positive in terms of both energy and well-being as “giving back” to the surrounding community. For energy, this will be done by producing more energy than is consumed, therefore supporting the energy needs of other campus buildings. In terms of well-being, what will be given back is mental support to the occupants of the building by boosting productivity, happiness, and physical health.

Our recommendations for the DSC were selected to ensure that net-positive is a possible achievement. By reviewing sustainable buildings that have a net-positive or net-zero energy status we will make considerations for how to significantly improve well-being.



CONNECTION TO THE GREATER COMMUNITY

CONNECTION TO THE GREATER COMMUNITY

With the creation of the DSC on the St. George campus, there is a unique opportunity to provide benefits beyond the confines of this project site as well as the occupants utilizing the space. Through our definition of net-positive, we strive to provide recommendations that extend outside of these visually perceived boundaries to benefit the St. George campus through contributing to the school's carbon action plan goals. Secondly, in regards to energy production, we hope to eventually be able to provide positive power offsets we could then supply to other facilities surrounding the site to further extend the reach of the building's capabilities. In terms of wellbeing, the DSC will provide a new place for students and faculty members to collaborate within the departments who find their new home to be there but also others that are looking to utilize the space. With wellbeing being a focal point for the construction of this building through the implementation of IAQ, thermal comfort, and the social factors discussed in this report, we hope that the utilization of students and faculty outside the three divisions homed here will find benefit.

CONNECTION TO BAHEN CENTRE

An important aspect of the DSC for the CFP is that it is meant to be an extension of the Bahen Centre in terms of programmatic connections and that it is being built directly behind it (Appendix 1). Due to recent devastating events at the Bahen Centre that have brought attention to the mental health of students at U of T, achieving high standards of well-being at the DSC is of great importance. As a result, our recommendations for the DSC have taken both net-positive energy and net-positive well-being into consideration, in hopes that the DSC will provide better support systems for the mental health of all occupants. (See Appendix 1 for image).

PRECEDENT STUDY

After the first meeting with our client, a precedent study was performed on the most well-known and cutting-edge sustainable buildings around the world. A document consisting of over twenty buildings and their top sustainability features was compiled. This precedent study guided our research process by providing a general framework of sustainability to inform our group on the topic of sustainable building design. From there, we refined the precedent study by selecting six buildings once our main objectives were finalized to guide our recommendation process. The buildings were chosen based on our goal of net-positive and our subsequent five objectives, as well as their relevance to the vision of the DSC in terms of size and use. These six sustainable buildings are the Manitoba Hydro Place, 115 North Franklin, The Edge (Amsterdam), National University of Singapore's School of Design and Environment (SDE4), The Bullitt Centre, and Evolv1. A seventh building (CIRS) was added later as it continued to be important in our literature reviews.

Prior to choosing specific recommendations, we created a matrix (appendix A) of the seven precedent buildings and the relevant features from them for each of our five objectives. This gave an overview of the most common, as well as some of the unique features that have been implemented in sustainable building design so far, to help inform our recommendations.

RECOMMENDATIONS

The following sections provide a detailed description of recommendations for each of our five objectives; each objective consists of 3-4 recommendations based on our academic review and analysis of precedent buildings.

OPERATIONAL AND EMBODIED ENERGY

1. BUILDING WITH CARBON SINKS

In many energy efficient buildings today, the feedstock energy that goes into material manufacturing and construction can equal the operational energy usage for a building's entire lifetime (Lechner, 2015). Accordingly, minimizing this feedstock, or embodied, energy is critical, specifically if an objective of a building project is to obtain net-zero carbon or net-positive energy status. As such, we recommend the use of building materials with as small of an embodied energy footprint as possible. Equally, we recommend the use of building materials with as small of a carbon footprint as possible. New material innovations have allowed for various types of manufactured timber products to possess similar strength/weight ratios and spanning capabilities as many classical building materials (Harvey, 2010). This makes them a viable building material candidate for the DSC, as its energy footprint, when locally sourced (as could be the case), can be around 50% smaller than standard concrete and steel spans, with the potential (albeit, this is rarely the case) for a negative carbon footprint (Lechner, 2015). This is due to the fact that as trees grow, they take in carbon dioxide from the atmosphere. When processed, this carbon is then effectively stored in the building material. Contrasted against the processing of materials like cement and steel, where large amounts of carbon dioxide and other greenhouse gasses are produced from high-temperature heating, timber thus represents an attractive carbon-sink (Harvey, 2010).

2. DESIGNING A TIGHT BUILDING ENVELOPE

While obvious, the best practice for maintaining energy efficiency is to build as tight of a building envelope as possible to limit the amount of heat flow between the exterior and interior (Harvey, 2010; Lechner, 2015). This can be done in a number of ways, primarily by ensuring (a) a high insulation value of the walls, (b) a high insulation value of the windows, and (c) that the material joints of the building are connected so as not to allow for the "bridging" of heat. Specifically, we recommend designing a wall assembly with a thermal resistance value of over 10 m2·K/W, and a window glazing unit with a thermal resistance value of over 5 m2·K/W. Using highly heat-flow-resistant materials can accomplish the former in wall assemblies. In windows, we recommend using at least triple or quadruple paned windows, with heavy gasses like Argon between panes to further resist heat travel. We recommend using low-emissivity coatings on windows. We recommend using large window units, minimizing the perimeter to surface area ratio, as the perimeter is where heat leakage occurs most. We also recommend better frames and spacers within window units to improve energy efficiency (Harvey, 2010).

3. GENERAL BUILDING FORM CONSIDERATIONS

Because windows have generally lower insulating values than walls (see above), it is important that the window-to-wall ratio remain below 50%. We recommend minimizing the surface area-to-volume ratio, to minimize heat loss per unit of indoor space - this means, practically, making the building shaped as cubic as possible. It has also been shown that using external shading, as opposed to internal shading, is four times as energy-efficient, and we accordingly recommend its implementation (Harvey, 2010).

4. SPECIFIC TECHNICAL RECOMMENDATIONS

In the above recommendations, these are generally dictated by architects and planning teams, and can reduce operational and embodied energy by roughly 80% (Lechner, 2015). The remaining potential for energy reduction relies on more technical recommendations, and a more technical expertise. These recommendations follow: energy can be reduced in the circulation of air and water by making pipes or ducts bigger, and by minimizing the length of transportation and the number of turns in the delivery pathway. Energy can be saved in the HVAC (heating, ventilation, air conditioning) system by separating the ventilation and heating/cooling function. This allows for the distribution of heat through water circulation (either in pipes underneath the flooring or in the ceiling), making its distribution much more efficient. In addition, this allows for demand-controlled ventilation, through the floors, at a distance much closer to our respiratory systems. Energy can be reduced through distributing hot water, by better insulating pipes, and by using a point-of-use heating system (thereby eliminating the need for a tank - which loses heat over time). Energy reduction can be achieved through energy capture; for example, we can better capture the waste heat from hot water or hot air to be reused via a heat exchanger (Harvey, 2010; Lechner, 2015).

CONCLUSION

Energy efficient measures can be considered either active (such as a moving shading system or a demand-controlled ventilation system) or passive (such as the usage of an insulating material or the strategic placement of windows). It can be noted that net-zero energy can be almost exclusively achieved by designing with passive strategies (i.e. those that don't require energy or come with a large operating cost, but instead require a more integrated and thoughtful design approach) At the core, we recommend bringing all design stakeholders to the conversation early, working as an integrated unit rather than via a linear chain.

ENERGY PLAN

1. BUILDING INTEGRATED SOLAR

Initial massing information from the FSC restricts the role of rooftop solar capacity due to the limited rooftop space and Highrise nature of the building. So, in order to maximize power generation, the use of building-integrated photovoltaics (BIPV) is suggested. "(BIPV) are solar power generating products or systems that are seamlessly integrated into the building envelope and part of building components such as façades, roofs or windows." (Natural Resources Canada, 2018). Beyond being able to convert solar energy to electricity, BIPVs are able to serve a dual purpose acting as an important component to the building envelope in the form of thermal insulation along with others. The use of BIPVs would greatly assist in making the building net positive if the excess power generated in the summer is feed into the grid. Our precedent building the Edge, has its roof covered in solar and has solar panels and windows going down the southern wall of the building. Additionally, the Powerhouse building has a solar array mounted on its slanted façade, with this building having the façade designed specifically to maximize solar capture, something that should be considered on the DSC.

2. GEOTHERMAL EXCHANGE

Also suggested is the use of an onsite geothermal potential to help reduce the energy demands from heating and cooling. Geothermal HVAC systems work by extracting thermal energy from below the surface. This energy is then supplied for either heating and cooling within a building irrespective of the climate and the temperature underneath the surface remains relatively constant ("Ontario Geothermal Association", 2019). In the case of Ontario, the Earth's temperature ranges from 6-11 degrees Celsius throughout the year at the top 200 meters of the crust ("Ontario Geothermal Association", 2019). Underground aquifers are usually constructed to store warm water for the winter and cold-water for the summer. The benefits of using geothermal is that the technology is extremely scalable and can work on projects ranging from single houses to entire neighbourhoods. Given that DSC is a complete rebuild on land this presents the perfect opportunity to build geothermal capacity on site as it will be easier to perform all the necessary drilling and construction. For the DSC it is recommended that a closed-loop vertical system is used given the limited horizontal space of the site. Almost all the precedent buildings we examined used sort geothermal exchange systems. Manitoba Hydro Place used a solar chimney to harness the sun's heat energy in conjunction with geothermal to further decrease energy needed for heating ("Manitoba Hydro Place", 2019).

3. GOING BEYOND THE SITE

Finally, to help achieve net-positive status possible solutions based beyond the site should be considered. It was not until solar was installed on the rooftops of neighboring university buildings that the Edge was able to boast that it produces more energy than it consumes (Randall, 2019). This same concept could be applied on the DSC with the installation of solar in the surrounding buildings with the electricity flowing back to the DSC before being efficiently being distributed around the campus. Minimal retrofits will have to be done on the other buildings but they will still be able to reap the benefits. Geothermal project could be done larger than what the building would need and allow for neighbouring building to have some of the benefits. Much as what is being done with inner circle road project the DSC could become a geothermal node for the encompassing area. Conclusion

CONCLUSION

Both BIPV examples were able to achieve their respective net positive statues by offsetting electricity drawn from the grid in the winter months with the surplus they supplied to the local grid during the summer months. DSC should take a similar approach as the current technologies do not exist for total energy independence during winter. Some options initially considered are not given as recommendations, however these technologies should be watched and may prove useful in the future.

- Academic research suggests an analysis should be done before deciding on battery storage, which is dependant on the energy production and applicability of feed-in tariffs (Dumont et al, 2016). New battery chemistries and other improvements make this a better option in the future.

- Wind energy is currently considered impractical due to limited past successes and issues (Wilson, 2009) and will need further research as the technology continues to improve.

- More research needed on the role thermal energy from IT infrastructure can contribute. As of now most projects using this have been trials at large data centers used by big technology companies. More information would be needed on the capacity and type of computer hardware that would be installed at the DSC.

- Power and heat generation using renewable natural gas made from food waste was used in one of our initial precedent study buildings. Size considerations mean this would likely be impractical at the DSC.

INDOOR AIR QUALITY

1. INDOOR WATERFALL

Humidity is an important factor to consider while trying to achieve good IAQ, as it can have negative health effects on building occupants when outwith the optimal range. The literature states that humans are most comfortable when the relative humidity is between 20%-60% (General Filters Inc, 2019). If the indoor humidity is over 60% mold can start to form which causes a variety of irritations, and if the humidity is lower than 30% it can increase virus survival and transmission as a result of dry air (Wolkoff, 2018). The recommendation to improve humidity within the DSC is a feature inspired by MHP, that implemented an indoor waterfall in the atrium. The waterfall regulates air humidity in summer by using cooler water to absorb additional moisture in the air, thus lowering humidity (Manitoba Hydro, 2011). In winter months it uses warmer water to add moisture to the air (Manitoba Hydro, 2011). The MHP has received a lot of positive feedback about the quality of indoor air within the building (Canada Green Building Council. 2014), which has led to a decrease in absenteeism of employees in comparison to other hydro facilities. The hope for the DSC would be that the occupants consisting of faculty, students, and staff, would report the same positive feedback and well-being from being in the building.

2. LOW-VOC CONSTRUCTION MATERIALS

Since the DSC will be a redevelopment project, it provides the opportunity to limit indoor pollutants in comparison to older buildings that are challenging to modify. A common indoor pollutant is volatile organic chemicals (VOCs) which are found in building-associated materials. According to the Environmental Protection Agency (EPA), VOCs include chemicals that can have short and long term health effects such as headaches, dizziness, fatigue. Further, It is suspected that some VOCs can cause cancer in humans. Due to the negative effects of VOCs on human health and thus, well-being, it is recommended that the DSC consider using low or zero-VOC products during the construction process. Through survey reviews it has become evident that it will be important to consider using low-VOC products, such as paint, primers, finishes, stains, flooring, timber products, adhesives, and insulation, to have high IAQ in the DSC. Yanpeng et al. (2018) performed field studies and questionnaire surveys on the IAQ of library rooms in the University of Science and Technology Beijing, and found that VOCs were found to be the most common indoor pollutant causing discomfort for the occupants. We found from our precedent study that the MHP used indoor materials which met low-VOC standards in order to provide a safe and healthy working environment. Based on positive occupant reports on IAQ in the MHP building mentioned in the previous section, it is likely that this was an important factor.

3. LIVING WALL

Living walls are vertical structures made of multiple green plants and come in various sizes. They have been shown to contribute to air purification by a process called phytoremediation. Through this process, living plants are able to clean the surrounding air by absorbing contaminants into their roots (Gunawardena & Steemers, 2019). Thus, they are able to remove VOCs from the air (Perez-Urrestarazu et al, 2016), which we have identified as a main indoor pollutant. Some specific plant suggestions that could be used for a living wall in the DSC are species with small roots such as succulents or tropical and fern species, since they require little water and have similar care requirements (Page, 2013). The living wall would contribute to our goal of net-positive energy since plants absorb GHG's and store them in their tissues as they grow, acting as carbon sponges which would decrease the DSC's carbon footprint (Green Over Grey: Living Walls and Design, 2009). Further, one of our precedents, Evolv1, which has achieved the status of a net-positive workplace, successfully implemented a 3-story living wall in the atrium to improve indoor air quality (Accelerator Centre, 2018). It is a 40 ft. living wall that used over 4,000 tropical plants, and took only a week and a half to install (The Cora Group, 2018). The implementation of a living wall in the DSC could be a contributing factor to achieving net-positive status as it was a key feature in the success of Evolv1.

CONCLUSIONS

In order to achieve our definition of net-positive well-being, excellent IAQ should be provided to the occupants of the DSC in order to boost productivity, happiness, and physical health. The three recommendations listed above have been successful at contributing to sustainability in other Canadian buildings- both the MHP in Winnipeg, MB, and Evolv1 in Waterloo, ON. These locations have a very similar climate to Toronto and thus are applicable to the site-specificities of the DSC.

LIMITATIONS

Since it is not possible to quantitatively measure well-being in humans, it is difficult to determine cause-and-effect relationships between specific building features and the well-being of building occupants. Therefore, there was a shortage of literature on the direct effects of indoor air quality on well-being. Instead, the literature discussed the "perceived" IAQ of building occupants based on surveys and questionnaires which we reviewed to inform our recommendations. Also, since it was not possible to conduct pre or post-occupancy surveys for the DSC, there was no way to determine whether these recommendations will meet the well-being needs of the future occupants.

THERMAL COMFORT

1. EFFICIENT BUILDING EXTERIOR

The material used in the construction of a sustainable building is often overlooked. One of the most efficient ways to ensure thermal comfort is to use the right materials for insulation purposes. The insulation shell of a building can determine how efficient energy consumption can be. One of the basic principles of thermal comfort in sustainable buildings trying to achieve a net-zero or net-positive status is being able to naturally maintain thermal comfort without energy consumption (Omer, 2008). As highlighted in the report of the Bullitt Centre, one of the biggest priorities for sustainable buildings is ensuring that heat stays within the building interior during the winter months (Pena, 2014). Designing a high-performance building entails designing a strong exterior, which can trap maximum heat and keep the cold out: this can be done through finding the right balance between glass to insulated wall area. The exterior of the building consisted of a rain screen system, composed of a metal panel, air space, and mineral wool, which ensures minimal heat escape (Pena, 2014). By using thermal breaks in the exterior envelop, and an airtight closure are essential in reducing the heat load (Pena, 2014). Additionally, the Bullitt Centre uses Schuco system for the installation of glass windows, that has the most efficient functioning in terms of water penetration resistance, air tightness, and thermal performance (Pena, 2014). Additionally, For the summer months, to avoid overheating and maintain ambient temperature, automated louvre blinds block direct solar radiation (Pena 2014).

2. NATURAL VENTILATION SYSTEM

Natural Ventilation systems is one of the most common mechanisms that are used in sustainable buildings as a method to maintain thermal comfort while optimizing on energy efficiency (Omer, 2006). Mechanical ventilation and passive cooling systems improve the overall efficiency of the building, and a natural ventilation system is important for the maintenance of a high air quality index (Omer, 2006). A classic example of natural ventilation systems used in sustainable buildings is automatic operable windows, that is present in University of Singapore's SDE4 as well as the Bullitt Centre (Coleman, 2016) (Pena, 2014). Taking the example of the Bullitt Centre, the building has weather sensors installed in the building that keep track of the building inside and outside. In the summer months, the motorized actuators open the windows for cooling, acting as a passive cooling system (Pena, 2014). This not only serves to indoor air quality, but also keeps optimal thermal comfort. This system is very energy efficient: with it, the building saves 750 hours' worth of annual cooling (Pena, 2014).

3. USING AI FOR INDIVIDUAL THERMAL COMFORT

The use of Artificial Intelligence has been an overall recommendation within this report that encompasses every domain of our sustainable recommendations. The Edge, which is known to be one of the most sustainable buildings to ever be built, is a building that functions on a data-driven machine learning software, that tracks the internal functioning of the building and its occupants (Jalia et al., 2018). There are sensors installed throughout the building that track occupant's thermal preferences, among other things. Occupants use an app called Mapiq to install their comfort preferences. Users can modify their micro-environments to reach their optimal thermal comfort standards (Jalia et al., 2018). By being in control of your micro-environments and personalizing thermal comfort, the building achieves optimal comfort through an energy-efficient model. There is often an emphasis on achieving true thermal comfort because of the lack of individualism in deciding what constitutes thermal comfort (Coleman, 2016). But through this technology, users can now choose standards that best suit their needs.

LIMITATIONS

Some of the key limitations to achieving thermal comfort is that thermal comfort is often very subjective. All-though there are standardized mechanisms for optimal thermal comfort, sustainable buildings rely on the adaptive model of achieving thermal comfort, which implies occupants manually improving their thermal comfort standards (Taleghani, 2013). Another limitation to the machine learning thermal comfort model is that it is considered to be a privacy hazard, as not all occupants what other individuals to know their daily schedule and where they're going to be present.

SOCIAL FACTORS

1. THE USE OF STAIRS ENCOURAGING COLLABORATION THROUGH INTERACTION AND VISUAL CONNECTIVITY.

This concept of wellbeing encompasses both mental and physical health which is tackled by this recommendation. In all six of the precedent studies, either a central staircase open to an atrium or several staircases in larger buildings were used as a measure to encourage the movement of people around the building on foot, promote a healthy lifestyle with physical activity in their daily routine, and lastly minimize energy consumption through the constant use of elevators.

In a larger building like that of ‘Site C’, the use of staircases and corridors throughout the building to connect different faculties and departments rather than employing a single central staircase is recommended. The flow of people throughout the building provides the ability to interact and stay visually connected to colleagues providing opportunity for informal data transfer and collaboration (Griffiths, 2019). This is executed in a similar capacity specifically in the University of Singapore’s “SDE4”, a living lab for the exploration of people-centric approaches to the integration of sustainable development (Jenie, 2019). Another example of the social benefit to collaboration that comes with the implementation of these staircases to connect floors is the Evolv1 located in Waterloo. This building is a perfect example of how the implementation of these simple elements can provide the means for collaboration in spaces that do not normally provide the opportunity for informal interaction situations preventing collaboration to spontaneously occur (Williams, 2019). In an article we analyzed on the basis for creating a collaborative space stated that the creation of a collaborative environment requires the nurturing of connections and an increase in the daily movement of people through open spaces (White, 2017). This provides an opportunity to both encourage collaboration and provide the basis for a healthier daily routine to the inhabitants of ‘Site C’.

2. OUTDOOR TERRACE SPACES THAT PROVIDE INFORMAL MEETING PLACES ALONG WITH PLACES TO RELAX.

The use of outdoor spaces within the confines of a large building like that of Site C provides a connection to the outside world when consumed in the stressful activities of going to class or producing research work for your department or faculty. While reviewing literature on the design of the work environment and its correlation with occupant wellbeing, majority of the time places to relax are the one thing missing (Heerwagen et al., 1995). The use of outdoor terrace spaces on higher floors as well as ground floor outdoor 'rooms' that can be carved into the building offer the opportunity for outdoor relaxation space as well as informal meeting spaces. With the task of energy production on our agenda to create a net-positive building, the rooftop space of Site C could be used for different purposes however the implementation of rooftop terraces was also common in the precedence studies. The provision of a space that changes the usual dynamic of the workplace to give a space of natural daylight and fresh air without having to go to the ground floor allows for a renewal of positive mental space.

3. IMPLEMENTATION OF THE NO FIXED WORK SPACE CONCEPT FACILITATED THROUGH THE USE OF TECHNOLOGY

A priority for the desired outcome of the Data Science Centre is to encourage collaboration throughout the building between all faculties and departments. Through an article by White referenced above it is noted that the flow of people spurring interaction teamed with visual connectivity is essential to facilitating this collaboration. This recommendation involves the implementation of no fixed work desks, with a variety of different working spaces that serve different purposes. The schedules of the occupants is then uploaded to an app service which will assign you to certain spaces depending on the activities you have scheduled for the day. This app technology also keeps the user's temperature and lighting preferences to ensure individual comfort (Randall, 2015). This recommended philosophy and technology implementation allows for multiple boxes to be checked off in achieving our goal of being net-positive. It will assist with operational energy optimization with the ability to learn flow patterns of the occupants and effectively turn of certain parts or rooms if they are not being used (Randall, 2015). The application used for this service in The Edge however was created and supplied by the main inhabitant of the building, Deloitte Netherlands. An alternative that offers similar services regarding the energy optimization and comfort preference settings is the Bridge service offered by Sensible Building Science. With the ability for the data to be stored over time and be provided through the Bridge's API to third-party services to make personalized applications opens the door up for addition of a scheduling function similar to that of Deloitte's (Storey, 2019).

4. CREATION OF SPACE TO SERVE THE COMMUNITY WHILE EXHIBITING THE FEATURES AT THE FOREFRONT OF SUSTAINABILITY

Creating a space that is not-positive in well-being requires the creation of multipurpose space that increases the flow of people in the building. In a building of this size, the use of large galleries or event spaces that can be used for a variety of things beyond the buildings main function as the home of data science faculties and departments. Beyond solely event type space, the inclusion of the community in spaces that encourage collaboration and promote physical and mental health benefits feed in perfectly to the definition of net-positive that has been identified for the project. The inclusion of students and staff outside of the faculties housed at Site C is seen in buildings across our precedent buildings being a common feature. To ensure productivity and security throughout the building though it is recommended to have separation between the spaces that are for public use to those that are for students and staff members. By using the main floor area and second floor allows for the separation between productive behavior on the upper floors and that of casual conversation teamed with relaxation on the public access floors. Further, bringing people into the building for events or simply a resting spot after a stressful day not only shows off the incredible features that have been implemented into the creation of this building at the forefront of sustainability but also allows for the ability to be in a space with top priority to their wellbeing both mental and physical.

CONCLUSIONS

Overall, successful encouragement of collaboration comes as a result of nurturing connections and increasing visual connectivity. Teaming this up with the facilitation of movement around the building promotes both physical and mental wellbeing of the occupants.

LIMITATIONS

Limitations associated with achieving this goal of increased collaboration is the scale of the project. Being a large building extending 18 storeys vertically, the use of grand staircases would have to be replaced with multiple sets of stairs connecting certain parts of the building. Secondly, the challenge of which option would be most beneficial through any analysis other than a post occupancy review presents a challenge when accessing which objective delivers the most benefit.

CONNECTION TO "DATA SCIENCE" THROUGH THE USE OF AI TECHNOLOGY

As a final recommendation, spanning across the pillars of energy minimization, energy production, health, productivity, and well-being, we suggest the implementation of a data sensing system, in order to fuel a data-driven machine learning software, enabling the building to talk to its inhabitants, to the grid, and to itself.

In practical terms, in terms of operational energy usage, the above platform would allow users to plan their daily schedules online, such that the software could organize the building's space to meet the user demands. Software like this means that not as many individual desks are needed, and has been shown by the Edge and Deloitte to save around 30% in floor space and, accordingly, in energy usage. Beyond this, sensors allow for an understanding by the building where people are, and when, such that heating and cooling functions of the building could be optimized (Jalia et al., 2018).

In terms of energy production, the building would be able to talk to the grid, knowing when to provide power to the grid, and when to draw power from the grid - in, ideally, a positive ratio, as to maintain a net positive energy status.

In terms of indoor air quality and thermal comfort, sensors could provide feedback on local humidity, enabling the control of an indoor waterfall (above recommendation), to maintain continued control over indoor humidity. Further, the implemented smart building technology could control the watering and care requirements of the living wall (above recommendation). This would make it easier to have multiple living walls throughout the building, since there would be no extra burden of having to pay staff to perform these tasks.

In terms of productivity, the software would allow for each occupant to have their own virtual assistant at all times, optimizing their scheduling and enhancing their wayfinding throughout the space.

LIMITATIONS AND FUTURE CONSIDERATIONS

LIMITATIONS

One of the major limitations we faced collectively was the difficulty in defining the term "net-positive". We found that throughout our academic literature review and precedent building analysis, there were different conceptions of the term "net-positive"; there wasn't one standard definition at a universal level. Furthermore, we have found that very few buildings have achieved a net-positive status, as it is a difficult status to achieve. Lastly, there were obstacles in coordinating between the needs of our client and the professor's ideas about what should be included in our recommendations and analysis, as well as on what should be given more importance.

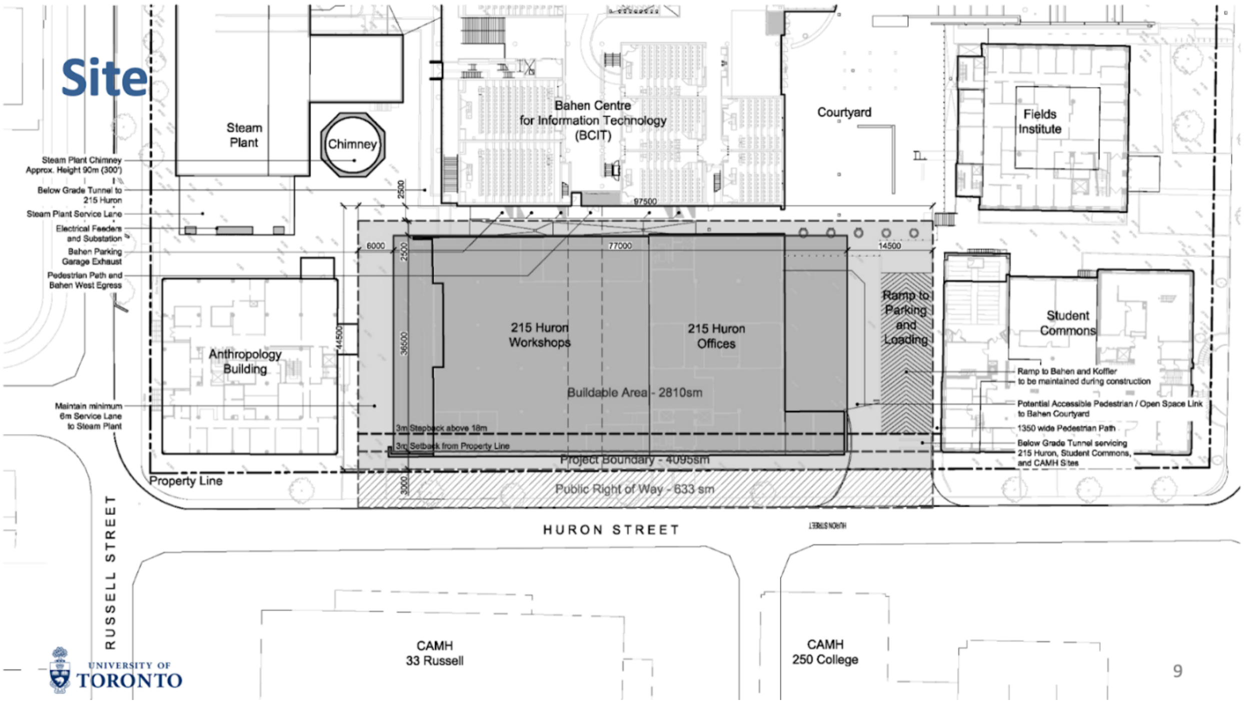
FUTURE CONSIDERATIONS

The research conducted for our client has taught us a lot about the complexities that come with sustainable architecture, and the ambiguity behind net-positivity. Moving forward, we would like to see a more standardized meaning of what net-positivity means to the U of T community so that sustainability and net-positive targets are easier to achieve.

Furthermore, with regards to the installation of AI technology at the Data Sciences Centre which formed the focal point of our recommendations: there needs to be further research into the issue of privacy with regards to the technology. While machine learning software is the most convenient and effective tool in energy efficiency and well-being, tracking the movement of inhabitants calls for a review of stringent privacy policy review, to make sure the technology doesn't cross personal boundaries. Therefore, we would recommend future groups to research further into the issue of privacy with regards to the AI technology being implemented at the Edge Building.

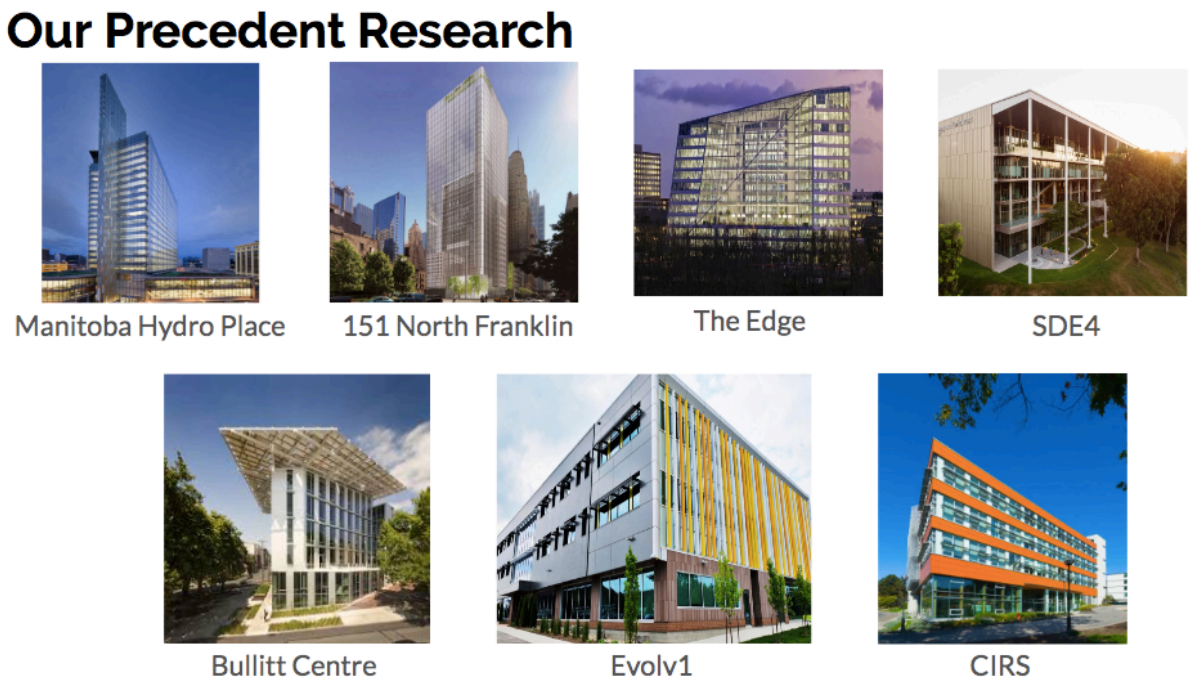
APPENDIX

APPENDIX 2



Site
Steam Plant
Chimney
Bahen Centre for Information Technology (BCIT)
Courtyard
Fields Institute
Steam Plant Chimney Approx. Height 90m (300')
Below Grade Tunnel to 215 Huron
Steam Plant Service Lane
Electrical Feeders and Substation
Bahen Parking Garage Exhaust
Pedestrian Path and Bahen West Egress
Anthropology Building
Maintain minimum 6m Service Lane to Steam Plant
2500
97500
6000
2500
77000
14500
36500
44500
3000
215 Huron Workshops
215 Huron Offices
Buildable Area - 2810sm
3m Stepback above 18m
3m Setback from Property Line
Project Boundary - 4095sm
Public Right of Way - 633 sm
Property Line
Ramp to Parking and Loading
Student Commons
Ramp to Bahen and Koffler to be maintained during construction
Potential Accessible Pedestrian / Open Space Link to Bahen Courtyard
1350 wide Pedestrian Path
Below Grade Tunnel servicing 215 Huron, Student Commons, and CAMH Sites
HURON STREET
RUSSELL STREET
CAMH 33 Russell
CAMH 250 College
UNIVERSITY OF TORONTO
9

PRECEDENCE BUILDINGS



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PRECEDENCE MATRIX

	Manitoba Hydro Place	151 North Franklin	Bullitt Centre	The Edge	SDE4	Evolv1	CIRS	"Site C" recommendations
Operational energy optimization	Standard passive and active measures for energy efficiency South-facing garden warms air in winter Solar chimney minimizing heat loss and collects excess heat Natural ventilation to save energy Heat pump to warm incoming cold air/ hot air Dimmable and adaptive lighting	Open concept promoting efficiency Coloumn free lease plans Coloum-less corners Demand-based HVAC system	High performance envelope (glass, walls) Successful heat recovery Round source heat pumps Demand controlled ventilation and cooling Radiant slab cooling Operational windows Triple glazed curtainwall system Automated external louvered blinds	AI technology with 28,000 data sensors Ethernet powered LED lights Dimmable and adaptive lighting Atrium providing natural ventilation	Hybrid cooling system Natural ventilation Natural lighting Environment plays large role in energy consumption optimization	Triple glazing envelope Solar wall for preheated ventilation	Timber construction Natural light Controllable windows and lights	Building with carbon sinks Tight building envelope General building form considerations

Energy Production	377 ft tall solar chimney Geo thermal HVAC system connected to an underground aquifer Natural ventilation One-meter wide double exterior wall with computer-controlled vents	Rooftop Solar	Rooftop solar	Rooftop solar Façade solar Offsite solar feeding into building Aquifer thermal energy storage	Rooftop solar	Rooftop solar Solar wall Geothermal well	Solar panels Solar collectors Harvests waste heat from Earth and Ocean Sciences building Geothermal	Integrated solar Geothermal exchange and aquifer Going beyond the site

Indoor Comfort	Indoor waterfall Solar chimney for passive ventilation Under-floor displacement air delivery for individual environmental control Operable windows Low VOC materials	Low VOC materials in flooring Set back distances allowing for high levels of light and air Minimal neighboring obstructions Tenant controlled HVAC	Natural ventilation Low VOC materials	User preferences	Open concept utilizing natural ventilation	Living wall	Exposed timber to reduce paint chemicals Natural ventilation	Indoor waterfall Low-VOC construction materials Living wall
Social Features	Atrium Staircase Large corridors Rooftop terraces and atria Gallery for community events Public courtyard Natural light	Rooftop sky garden “Third space” options in plaza Major general staircase Food kiosks Outdoor terrace for public use	Irresistible staircase Natural daylight User controlled windows Designated relaxation space Collaboration rooms	Large atrium Restaurant and café Conference and exhibition facilities AI technology No fixed workspaces Variety of different work space types	Flexible teaching spaces Open concept for enhanced interaction Staircases and corridors Outdoor spaces for informal learning	Atrium Grand staircase Café Collaboration spaces	Atrium Staircase Café Variety of spaces for different function Open study spaces	Staircases Outdoor terrace spaces Flexible work seating Community spaces

General Details	Location: Winnipeg, Manitoba Building Height: 377 ft (115 m) Building Size: 695,250 sq ft Use: Headquarters for Manitoba Hydro Construction complete: Dec. 22, 2008 Cost: $278 million Certifications: LEED Platinum	Location: Chicago, IL Building Height: 35-storey Building Size: 880,000 sq. feet Use: Office & commercial space Construction complete: 2018 Cost: $184 million Certifications: WELL Gold Certification, LEED Gold	Location: Seattle, Washington Building Height: 65 meters Building Size: 42, 823 sq. feet Use: Commercial office building Construction complete: 2013 Cost: $32.5 million (including land and soft costs) Certifications: Net-positive, Living Building Certification	Location: Amsterdam, Netherlands Building Height: 16-storey Building Size: 40000 m² Use: Office space Construction complete: September 2015 Cost: Undisclosed Certifications: Highest BREEAM score in the world, net-zero	Location: Singapore Building Height: 6 storeys Building Size: 8517.22 m² Use: School of Design and the Environment Construction complete: January 2019 Cost: Withheld Certifications: Net-zero, WELL Gold Certification	Location: Waterloo, Ontario Building Height: 3-storey Building Size: 110,000 sq ft Use: Office space Construction complete: 2018 Cost: 21.5 million Certifications: Net-positive, LEED Platinum	Location: University of British Colombia Building Height: 4-storey Building Size: 61,085 ft2 Use: Living Lab Construction complete: 2011 Cost: 35 million Certifications: Net-zero, LEED Platinum	Location: Toronto, Ontario Building Height: 18-Storeys Building Size: 35000-40000 m2 Use: Data Science Center Construction complete: TBA Cost: Undetermined Certifications: TBD