SUSTAINABLE BUILDINGS CHALLENGE

February 28 – March 6, 2022

Presented by:

Sustainable Buildings Network (SBN)

Table of Contents

Introduction

The Sustainable Buildings Challenge engages undergraduate and graduate students in designing a technical and policy solution to a problem related to the field of sustainable buildings. This year, the Sustainable Buildings Challenge will focus on the University of Toronto's Whitney Hall, a historical student residence of University College.

Buildings account for 42.8% of all GHG emissions in the GTHA [1] making them the biggest emitting sector. Therefore, it is imperative that building designers improve building efficiency and develop solutions to reduce their carbon footprints to achieve Canada's 2050 net-zero target. Addressing this sector will require transitioning to new green development standards, as well as deeper energy retrofits for existing buildings.

With climate change as an ever-increasing threat, one strategy is to build stronger, more compact communities, thereby reducing transportation demand and energy use. University residences play a role in fostering student communities and reducing student transportation needs. The University of Toronto's St. George campus is well integrated into the urban landscape, allowing for student residents to live near necessities, leisure, and education. In essence, the University of Toronto's St. George (downtown) campus qualifies as part of a "15-minute community.

A 15-minute community is a community or neighbourhood in which you can access all your basic daily needs within a 15-minute walk from your home. These include work, play, leisure, and recreational needs. For example, residents would be able to get to a coffee shop, a park, a library, and a grocery store all within 15-minutes of walking from their homes. These communities necessitate building design that accommodates accommodate the various needs and patterns of its inhabitants. Mixed-use buildings accommodate multiple space uses within the same structure. Typically, this includes commercial uses on the first few floors and residential uses above. Mixed-use buildings are an effective way to improve urban life and reduce greenhouse gas emissions.

In this challenge, you'll be working with a historic student residence building at the University of Toronto St. George campus. Whitney Hall was constructed in 1931, initially as a women-only residence. It now houses students of all genders from all backgrounds. Whitney Hall is the oldest student residence at University College. Whitney Hall was officially recognized as a Heritage building in 1976 by Toronto City Council. This designation is intended to conserve the cultural heritage values, attributes, and character of this property, while mitigating the visual and physical impact. As a result, conservation of the outer façade is imperative, and it is strongly encouraged to conserve as many substantial remaining portions of the building as possible.

Goals

The goal of the Sustainable Buildings Challenge is to engage students in tackling real-life problems faced by urban buildings. Drawing from their day-to-day experiences as building users, participants are expected to apply technical knowledge and skills learned in the classroom, whilst also considering how their design decisions have social and environmental consequences and how these consequences would apply on a broader scale. The challenge aims to foster collaboration among students from various backgrounds and provide an opportunity for participants to develop professional skills in time management and oral/written communication. The problem statement has been left deliberately open-ended to further encourage diverse approaches.

Format

The challenge will be completed in teams of 3 to 4 students from various backgrounds. Participants will be introduced to the technical and policy aspects of the problem package. They will have approximately one week to work on their solutions, poster, and presentation.

For fairness, participants are encouraged to voice any questions or concerns regarding competition rules and format in the beginning. Any subsequent questions or concerns should be submitted via Hopin, where answers will be regularly provided and accessible by every team. There are also question periods scheduled throughout the week when teams can consult with practicing professionals regarding their analysis and solution.

At the end of the week, teams will be participating at a virtual poster symposium hosted on Hopin, showcasing their virtual poster (36in x 24in) which outlines both their technical strategies and policy plans. Each group will prepare a 10-minute presentation for the judges followed by a 5-minute question period.

Timeline

Time	Event
Day 1 – February 28, 2022	
20:00 – 22:00 EST	Introduction – Problem Statement
***Day 4 – March 3, 2022**	
20:00 – 21:00 EST	Question Period 1
***Day 6 – March 5, 2022**	
09:00 – 10:00 EST	Question Period 2
Day 7 – March 6, 2022	
13:00 – 16:00 EST	Final Presentations

*Optional Events

Sessions will be recorded

Rules

- Questions should be directed to Hopin, sbnuoft@gmail.com, or the available challenge moderators
- All participants must be current students at the undergraduate, Master's, or PhD level enrolled in a Canadian post-secondary institution
- Each team must submit only one entry
- The completed work must be original and prepared only by the team members
- Input from people external to the project is discouraged but allowed. Any external input should be documented and credited.
- All available internet or physical resources are allowed
- Existing course work, research, or other ongoing or past project of any team member shall not be part of the submitted entry
- Teams and their submissions shall be respectful of all participants over the course of the challenge
- You may use any images, figures, or tables directly from the provided documents with proper citations

Technical Design

For this year's technical competition, you and your team will retrofit the historic Whitney Hall student residence. The main questions to be answered are discussed in this section. Additionally, due to time constraints, your team is asked to specify your scope to a selection of focus areas in order to propose well thought-out, detailed solutions. Focus areas are described in more detail below.

Question

Whitney Hall is located in the heart of Downtown Toronto. It has served as a student dormitory for almost 100 years. Your team is asked to prepare innovative and sustainable improvements to allow this building to keep serving residents into the future.

A complete technical proposal contains some or all the following elements:

- Problem definition and objectives
- Some form of analysis
- Complete technical solution, which may (or may not, as appropriate) include
    - Value proposition
    - Schematic or detailed design
    - Solution budget or financing solution
    - Implementation timeline

This challenge has been left deliberately open-ended. There are some realistic constraints on your proposal:

- No neighbouring land is for sale
- No cost constraint is applied, but costs should be kept reasonable
- The existing structural system should be kept intact
- This is a heritage building, heritage conservation rules and regulations apply

Here are some analysis tools that might be helpful in your project. If you need to brush up on a software, a few short tutorials are linked at the end of this package. Ask the challenge moderators at any time if your team requires access to any resources. These tools are not required, and significant depth could be achieved without the use of any or all these tools.

- Literature review
- Energy model
- Airflow model
- Life cycle analysis
- Costing estimates

Mandatory Objectives

A building, ideally, can be conceptualized as a system composed of many different facets which work together to fulfil its intended function. Aspects such as building envelope, energy systems, and water systems, all factor into the building's design and must work together cohesively. A highly efficient and low-emission building is ideal, but if the space is not practically suitable for its human occupants, then objectively it is a poorly designed building. Thus, it stands to reason that the human factor must be considered at all stages of design.

Below are the objectives that must be considered:

- Occupant well-being, livability, and comfort
- Accessibility and sustainable transportation
- Embodied and operational carbon

More details of the objectives are provided below.

Occupant Well-Being, Livability, and Comfort

Ensuring that the building is conducive to the well-being of its residents, workers, and visitors is key. This includes managing aspects such as air quality. Treating and preventing pathogens (e.g., COVID-19) and other airborne particles like mould, mildew, dust, and other toxins and irritants from spreading will help create a healthier environment for occupants. Additionally, keeping the humidity at a safe level (not too high or low) in all spaces will ensure the comfort of occupants and the durability of building materials. Lastly, avoiding the use of toxic materials known to cause sickness and other health problems is imperative [2].

Managing comfort is a trickier problem to solve, as each individual has their own preferences. As such, building designers have to consider aspects such as lighting (cool- vs. warm-toned, motion activated, daytime running light, night lights etc.), temperature, and humidity. Improving comfort can also result in improvements in productivity.

Ideas for consideration:

- Health and Safety
    - Treating pathogens (COVID-19 relevant) and other airborne particles that could cause sickness or affect well-being
    - Ways to prevent spread of disease through air circulation
    - Humidity
    - Material choice (avoiding unsafe materials that could contribute to poor health e.g., through off-gassing, asbestos)
- Lighting is conducive to productivity
- Temperature and humidity are in comfortable range

Accessibility and Sustainable Transportation

Consideration should also be given to accessibility and ergonomics, to ensure that the building is usable and accessible to everyone [3]. It can also mean incorporating design elements to improve navigability around and within the building.

Examples of accessibility related requirements [4]:

- Interior routes within the building should be safe and easy to use by persons with disabilities. Routes should also be clearly identified and laid out logically.
- Entrances should be protected against and accessible throughout all sorts of weather conditions.
- Care should be taking in designing space required to accommodate persons with mobility aids, allowing safe passage within the building
- Lighting systems to accommodate persons with visual disabilities

It is important to remember that a building does not exist in isolation, but rather exists as part of a larger community. Forming connections with the community helps to create opportunities for people to interact, share ideas, and helps to strengthen the community's shared identity. Thus, it is important to consider how the building functions as part of its surrounding community.

Ideas for consideration:

- Ease of use, accessible entrances
- Navigability of building/friendly design
- Signage
- Bike and pedestrian friendly infrastructure
- Encouraging active transport

Embodied and Operational Carbon Emissions

In a building, embodied carbon, usually measured in kilograms of CO_2 equivalent emissions (kg CO_2e), are produced from extraction, manufacturing, and transportation of materials to the construction site, emissions during the construction process, and disposal of the materials. Operational carbon results from building operations during the functional life span of the building. While a major focus of design in recent years has been to reduce operational carbon, embodied carbon also contributes significantly to greenhouse gas emissions [5]. The significant emissions resulting from pre- and post-building operation presents a challenge to reduce total life cycle emissions.

Ideas for consideration:

- Material procurement (raw material extraction, processing, transportation)
- Durability
- Disposal/reuse/recycle options

Sample tasks:

- Task: reduce embodied carbon in material selection (reduce amount of material needed and compare material alternatives)

Focus Areas

For your technical design, select two (2) of the focus areas listed below to address the mandatory objectives:

- Energy management
- Building envelope
- Water use and wastage

More details on the focus areas are provided below.

Energy Management

Energy use in buildings is a very important, if not the most influential, area of focus in the sustainable building industry. Buildings consume huge amounts of energy to sustain our daily activities in the built environment. According to Natural Resources Canada, residential, commercial, and institutional buildings account for about 29% of the total energy use in Canada [6]. This energy consumption translates to about 22% of Canada's total greenhouse gas emissions [7], which exacerbates the ever-increasing threat of climate change.

When we look at energy use in buildings, there are two main forms of energy: electricity, often supplied from the grid (or more recently generated on-site from renewable sources), and energy directly generated on site from burning fuel, such as natural gas. Most of the building energy demand comes from maintaining a comfortable indoor environment for its inhabitants in terms of thermal comfort (heating or cooling) and air quality (ventilation), which accounts for almost 60% of total building energy consumption. Other energy uses include electric lighting, domestic hot water and household appliances or other equipment (refrigerators, stoves, computers, TVs etc.) [8].

To make building energy use sustainable, "*we need to reduce demand, increase supply from non-GHG emitting sources, improve efficiency of appliances as well as plan effective energy management systems etc.* [8]" and there are countless creative ways to achieve these goals. There are many innovative and well-tested energy efficient solutions on the market for building retrofits. However, the best solutions are not always the one that have the most technology installed. A good solution adapts to unique building conditions, and sometimes that may involve passive design instead of a "technology cram". We also have to be careful not to treat buildings as a combination of its parts but as sophisticated and interrelated systems. A successful energy management strategy for buildings accounts for the combined benefits of individual strategies and considers cost and operations efficiency in the building's entire life span [9].

To align with Canada's climate plan and ambitious goals to reduce greenhouse gas emissions, we need to work harder to find and implement environmentally sensitive energy solutions in our buildings to make them more sustainable.

Ideas for consideration:

- Reduce demand/improve efficiencies:
    - Lighting
    - Ventilation

- Space cooling and heating
- Domestic water heating
- Plug load
- Smart controls
- Increase supply/improve efficiencies:
  - Geothermal heat exchangers
  - Solar glass/ PV cells
  - Fuel cells
  - Wind
- Conversion (e.g., gas to electric)
- Storage (e.g., batteries)
- District systems

Sample tasks:

- Task: propose strategies and compare before/after for each
  - Estimate savings or production
  - Propose strategies as part of a portfolio and see how they interact
- Task: propose a combination of strategies, compare before/after and explore interconnectedness of the strategies (e.g., less LTG can mean more HTG)
  - % Improvement in equivalent carbon
  - Peak load reduction

Building Envelope

The building envelope is the interface that separates the interior of a building from the exterior environment, and it comprises of many elements such as below- and above-grade walls, roofs, windows, doors, and floors. It is one of the most important components of a building design because of its foundational role in the maintenance and protection of a building. Serving as the boundary between the indoor and outdoor environments, building envelopes provide almost everything we expect from being in a building, including shelter, security, control of indoor environments such as light, moisture, thermal and air quality, fire resistance, acoustics, aesthetics, and more. Within the building envelope, there are many opportunities to optimize and balance cost, environmental, societal, and human benefits. Therefore, it is a key area to improve sustainability of the building.

An ideal envelope design maximizes these three goals: safety, aesthetics, and sustainability. In reality, there are limited resources; we should aim to optimize design, so it satisfies safety requirements and apply aesthetics and sustainability principles as much as possible. A sustainable building envelope design or retrofit can be assessed by how well it "*optimizes site potential, uses and conserves energy, protects and conserves water, uses material of low carbon footprint and enhances indoor environmental quality* [10]."

Ideas for consideration:

- Structural function and moisture management (e.g., against wind storms, flood)
- Reduce space heating and cooling demands
- Comfort (thermal and solar glare)
- Aesthetics/other functions (e.g., retractable roofs)

Sample tasks:

- Task: propose retrofit/replacement options and compare before/after
- Task: propose a flood proof design + other function

Sample analyses:

- Thermal insulation and thermal comfort analysis
- High reflectance and green roof design
- Energy simulation tools and life-cycle analysis

Water Use and Wastage

Water is one of the most important natural resources that humans cannot live without. Neighboring the Great Lakes, Ontario enjoys an abundance of clean, potable water supply. Canada is also one of the biggest per capita users of freshwater in the world [11]. However, even with that abundant water supply, we are not exempt from the water related risks and challenges caused by urban growth, industry expansion and the evolving situation of global climate change. Over the years, more extreme weather events have been observed in North America with floods and storms occurring at higher frequencies and magnitudes. The continuing expansion of urban spaces is also putting increasing pressure on water supply and treatment capacities. As a result, our cities are more vulnerable to water related damages and events such as flooding, shortage of supply, water contamination, sewage backup etc. Therefore, we must articulate strategies to better manage our precious water resources and build resilience against these damaging events to prevent further environmental and economic problems.

Buildings play a huge role in this movement to sustainable water management as they are hubs that serve concentrated groups of inhabitants and therefore consume large amounts of water and produce lots of sewage daily. An average person requires 50 litres of water per day [12] to fulfill sanitation, food preparation and bathing needs, and the water demand of a building is often determined by its occupancy. In addition, water is required for building operations (e.g., hydronic heating systems). Because of this high demand, there are many opportunities to improve water management in buildings. Sustainable building designs shall make every effort to reduce water consumption and improve efficiency of use. This involves smart utilization of innovative technologies and practices to fit unique building conditions and demands.

Ideas for consideration:

- Reduce demand
  - Kitchen and bathroom fixtures
  - Landscaping, (e.g., low-water plant species)
- Increase supply
  - Rainwater collection
  - Greywater
- Reuse options

Sample tasks:

- Task: propose water saving options

- Task: propose strategies to increase resilience against shortage or contamination (e.g., from flooding)
    - E.g., Local filtration system

Resources

- Embodied Carbon in Construction Primer for Ontario (from Toronto Atmospheric Fund): http://taf.ca/wp-content/uploads/2018/04/Embodied-Carbon-in-Construction.PRIMER-FINAL.pdf
- ASHRAE Standard 62.1, 62.2 *Ventilation for Acceptable Indoor Air Quality*
- ASHRAE Standard 90.1 *Energy Standard for Buildings Except Low-Rise Residential Buildings*
- ASHRAE Standard 100 *Energy Efficiency in Existing Buildings*
- ASHRAE Standard General Link
- ASHRAE Handbook - Fundamentals
- ASHRAE Indoor Air Quality Guide
- ISO 13790 *Energy performance of buildings - Calculation of energy use for space heating and cooling*
- LEED v4.1, Fitwel, WELL, BREEAM, or other guidelines from certification programs
- Toronto Green Standard (TGS)
- Zero Emissions Building Framework
- Ontario Building Code
- Toronto Building Permit Regulations
- Energy Star Certification
- Net Zero Building Standards
- National Building Code of Canada
- National Energy Code of Buildings (NECB 2017)
- SB-10 Energy Efficiency Requirements

A few useful tools and their documentation:

- Microsoft Excel - Documentation
- eQuest, EnergyPlus
- CONTAM
- Literature review tools: Web of Science, ScienceDirect, SCOPUS
- Microsoft Project - Documentation

Public Policy Section

In a world that is becoming more and more politically and technologically advanced. The role of engineers in informing policy decisions and direction are increasing drastically. It is important for engineers to understand the laws and regulations that affect their work and working environment. The technical expertise of engineers allows them to make informed comments and criticism on the economic, environmental, health, and safety implications of various public policies [13]. Therefore, the next section will focus on crafting effective policy to complement and spotlight your technical solutions.

Question

You are a multidisciplinary committee put together from provincial government employees tasked with designing a new policy related to sustainable buildings. You have been handed a report (your work from day one) and told to turn that into a broadly applicable policy.

Your policy should integrate with your technical work from day one. A good piece of public policy should have the following elements:

1. Problem Definition
2. Goals to achieve
3. Methods with which to achieve those goals

This description of public policy is based off "Understanding and Applying Basic Public Policy Concepts" by Melissa Mackay (University of Guelph) and Louise Shaxton (Delta Partnership). This document is available at this link. A further introduction to public policy can also be found in the tutorial section of this document.

These elements might look familiar, as they share a lot of structure with the typical technical report. Just like a technical report, there are many tools available to achieve your goals. In public policy these include:

- Information-based tools e.g. marketing or instruction, other forms of communication
- Monetary-based tools e.g. taxes or spending
- Regulation e.g. codes or prohibitions
- Direct Actions e.g. government construction and maintenance

When developing your policy, you may want to include the following elements

- Goals of the policy
- Affected parties and stakeholders
- Path to implementation: who do you have to convince to get this policy in place?
- Methods with which to achieve the goals
- Timeline/plan for implementation
- Paths to compliance for affected parties (if applicable)
- Consequences (both positive and negative)

Again, if you need any help, please approach the challenge moderators!

Resources

Features of Public Policy

As the role of engineers in informing policy decisions and direction increases, it is becoming important for engineers to understand policy and policy making. The technical expertise of engineers provide advice on various public policies [13]. Therefore, strong policy will complement your technical efforts by making them easier to implement.

Unlike research problems, policy problems are designed to be addressed and solved. For that reason, policy problems need to be structured with defined parameters narrowing the focus on issues. There are three key factors required for a policy statement:

1. A problem must be identified and recognized
2. A problem should have an expected solution
3. A problem is defined by specific policy goals

In public policy, the government can choose between doing nothing, acting indirectly, or acting indirectly. Acting indirectly can involve providing information, making an expenditure, or implementing regulation. The government can act directly through a state agency, state corporation or through a third-party partnership or contract. The questions below will help you identify the components of your policies.

- What is the policy and what resulting behaviour, condition or service is expected?
- What behaviour, service of condition is expected to result?
- What will the government do?

References

[1] The Atmospheric Fund, "Carbon Emissions Inventory in the GTHA," 2018. [Online]. Available: https://taf.ca/gtha-carbon-emissions/. [Accessed 29 August 2021].

[2] State of California, "CHEMICALS KNOWN TO THE STATE TO CAUSE CANCER OR REPRODUCTIVE TOXICITY," 19 March 2021. [Online]. Available: https://oehha.ca.gov/media/downloads/proposition-65//p65chemicalslistsinglelisttable2021p.pdf. [Accessed 07 August 2021].

[3] Government of Ontario, "INTEGRATED ACCESSIBILITY STANDARDS," Government of Ontario, 01 July 2016. [Online]. Available: https://www.ontario.ca/laws/regulation/110191#BK92. [Accessed 07 August 2021].

[4] City of Toronto, "City of Toronto ACCESSIBILITY DESIGN GUIDELINES," April 2004. [Online]. Available: https://www.toronto.ca/wp-content/uploads/2017/08/8fcf-accessibility_design_guidelines.pdf. [Accessed 07 August 2021].

[5] World Green Building Council, "New report: the building and construction sector can reach net zero carbon emissions by 2050," World Green Building Council, 23 September 2019. [Online]. Available: https://www.worldgbc.org/news-media/WorldGBC-embodied-carbon-report-published. [Accessed 23 February 2022].

[6] Natural Resources Canada, "Total End-Use Sector - Energy Use Analysis," Government of Canada, [Online]. Available: https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=AN&sector=aaa&juris=ca&rn=1&page=0. [Accessed 23 February 2022].

[7] Government of Canada, "Total End-Use Sector – GHG Emissions," Government of Canada, [Online]. Available: https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=AN&sector=aaa&juris=00&rn=1&page=0. [Accessed 23 February 2022].

[8] Velux Group, "Energy use in buildings," [Online]. Available: https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/energy/energy-use-in-buildings. [Accessed 07 August 2021].

[9] United States of America Department of Energy, "AN ASSESSMENT OF ENERGY TECHNOLOGIES AND RESEARCH OPPORTUNITIES," September 2015. [Online]. Available: https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter5.pdf. [Accessed 07 August 2021].

[10] R. Bolin, "Sustainability Of The Building Envelope," Whole Building Design Guide, 08 November 2016. [Online]. Available: https://www.wbdg.org/resources/sustainability-building-envelope. [Accessed 07 August 2021].

[11] Government of Canada, "Residential water use," Government of Canada, 10 April 2017. [Online]. Available: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/residential-water-use.html. [Accessed 07 August 2021].

[12] Program on Water Governance, "FACTSHEET: WATER USE & CONSUMPTION IN CANADA," [Online]. Available: http://watergovernance.sites.olt.ubc.ca/files/2010/04/FS_Water_Use.pdf. [Accessed 07 August 2021].

[13] F. I. Denny and R. L. Robinson, "The Engineer's Role in Public Policy," in *American Society for Engineering Education Annual Conference & Exposition*, Nashville, 2003.

[14] NASA, "The Effects of Climate Change," 17 February 2021. [Online]. Available: https://climate.nasa.gov/effects/. [Accessed 28 February 2021].

[15] City of Toronto, "Toronto at a Glance," 2018. [Online]. Available: https://www.toronto.ca/city-government/data-research-maps/toronto-at-a-glance/. [Accessed 28 February 2021].

[16] City of Toronto, "About Toronto," 2021. [Online]. Available: https://www.toronto.ca/community-people/moving-to-toronto/about-toronto/#:~:text=Toronto%20is%20Canada's%20largest%20city,multicultural%20cities%20in%20the%20world.. [Accessed 28 February 2021].

[17] City of Toronto, "Strong Economy," [Online]. Available: https://www.toronto.ca/business-economy/invest-in-toronto/strong-economy/. [Accessed 28 February 2021].

[18] United Nations, "Cities and Pollution," [Online]. Available: https://www.un.org/en/climatechange/climate-solutions/cities-pollution#:~:text=Cities%20are%20major%20contributors%20to,cent%20of%20greenhouse%20gas%20emissions.. [Accessed 28 February 2021].

[19] Ontario Ministry of Finance, "Ontario Population Projections Update, 2019–2046," Queen's Printer for Ontario, 2020, 2020. [Online]. Available: https://www.fin.gov.on.ca/en/economy/demographics/projections/#:~:text=The%20Greater%20Toronto%20Area%20(%20GTA,over%209.5%20million%20by%202046.. [Accessed 28 February 2021].

[20] CBC News, "Welcome to the 15-minute neighbourhood: Intensification key to city's official plan," CBC News, 22 August 2019. [Online]. Available: https://www.cbc.ca/news/canada/ottawa/ottawa-first-glimpse-official-plan-1.5256386. [Accessed 28 February 2021].