The Lawson Centre for Sustainability and the Trinity College community as a Living Lab for Sustainability at the University of Toronto

by Yi Xin Dai, Marah Madokh, Mary Nghi Ngo & Abbigayle Webber

Introduction

The Lawson Centre for Sustainability is an upcoming building project on the Trinity College campus at the University of Toronto - St. George (U of T). It will be a multi-use building with various stakeholders and users, including administration and operational staff, residents, students, faculty, administration and operational staff, and the broader Trinity College and U of T community. The building's proposed design boasts over twenty special features, contributing to its sustainability goals by reducing energy consumption and promoting individual and community well-being.

This report will first examine the various features of *the Lawson Centre for Sustainability*, identifying those that are monitorable for performance and what the collected data can be used to meet energy consumption and well-being goals and promote sustainable behavior. This report will further examine the living labs' ideas and their application to the Lawson Centre and Trinity College by implementing society-level policy ideas and concepts in these smaller communities.

Our research question for this project is: what is the point of monitoring? What features can be monitored, and how can we monitor them? How can we engage the community in using these features?

Methods

Our methods consist primarily of reviewing existing literature. We have researched building management systems, specifically in regards to energy consumption. We looked at case studies on Net-Zero Energy buildings with goals similar to those of *the Lawson Centre for Sustainability* can provide us insights on ways of monitoring feature performance and collecting data. Further research examining published material on sustainability, wellness, and influencing sustainable behavior informed us how collected data could ensure occupant behavior does not hinder but support meeting the building's consumption and sustainability goals. Our group also researched environmental and sustainability policy ideas for implementation at the society level that can apply to the smaller communities of the Lawson Centre and Trinity College.

Furthermore, additional consultation with faculty members and advisors working on this design project helped shape our literature search. Our team met with faculty and staff at the University of Toronto, including professors and advisors with the Daniels School of Architecture, the School of the Environment, and Trinity College.

Monitoring & its Applications

Our entire project is based on monitoring because it is crucial in determining whether a building and its equipment are performing optimally and in ways that meet the building's established goals. We researched monitoring to meet building user goals to ensure occupant comfort and engagement are taken into account and ensure that all community members are supported. The information we gather from monitoring is essential for tracking building performance and function. And it also allows building inhabitants to make adjustments where performance data must be accessible and understandable.

Findings & Recommendations

Our research recommendations are focused on energy consumption monitoring, building user dialogue, and community engagement and education.

1. Energy Consumption Monitoring

Building Management System (BMS)

We recommend *the Lawson center for Sustainability* to use the *BizWatts* building management system, which contains natural design elements and serious gaming to monitor energy consumption.

A BMS is a computer-controlled system installed to control, monitor, and regulate a building's energy demand (Hossian, 2019). BMS aims to control these subsystems' functionality to optimize subsystem usage to allow efficient operations of the building equipment (Joseph, 2018). For example, BizWatts is a management system designed to engage with building occupants directly. It does so by compiling energy data from plug-load monitors, which fed into the BizWatts mobile application.

The BizWatts provides access to building occupants who interact with one another by comparing energy consumption information and discussing conservation strategies through the application. BizWatts system administrators create organizational groups to add inhabitants. Each group’s total energy consumption is measured over different periods to provide meaningful group energy comparisons. Every group can set their own energy-use reduction goal. Occupants can observe their energy consumption data and the data of other groups too. This observation promotes competition between groups through meaningful group versus group comparison, inspiring cooperation among group members to achieve the conservation goal. Using the BizWatts *ranking board*, users can compare their appliance energy breakdown against other members' baseline usage to incentivize conservation and learn how to top the best energy savers in their network to conserve energy. Bizwatts also has a tool that allows individuals and groups to determine appliances used insufficiently, thus, enabling conservation actions to target specific appliance types (Gulbians et al., 2014).

BizWatts engages occupants through their *Eco-Action Center*- a forum for users to post their conservation efforts in the building, which opens a dialogue for other users to comment. It also monitors user interactions with the software interface. This clickstream data observes and interprets “when and which users login to the system, the interface components used the most, and the best energy-conservation strategies used by the top- conservers of the network”(Gulbians et al., 2014). The *Eco-Action Center* also allows occupants to share and report conservation strategies not monitored by the plug-load energy monitors. This feature emboldened mass conservation through occupants' conservation action posts where users can 'like,' 'comment,' and 'check' them. This information is available to all users.

We suggest the information provided from BizWatt's *'Eco-Action Center'* is offered by UofT's research courses like ENV461, ENV491, and other ENV research courses for future research about engaging occupants in sustainable living. On-campus student groups such as "Trinity College Environment Society" can use this data to examine existing buildings' energy consumption patterns. This information will compare new buildings vs. old buildings on campus, especially when looking at that data.

We also recommend incorporating this data into the students' core curriculum to engage students. The Victoria college at the University of Toronto forces all its students to take a mandatory first-year seminar course given by the faculty of Victoria College. All first-year students in the Faculty of Arts and Science (St. George campus), regardless of college membership, are eligible for *Vic One* admission. We recommend that Trinity College offer mandatory first-year seminars for its students that incorporate sustainability and sustainable living on campus. While also making sure that all other UofT students are eligible for admission regardless of their college.

Serious Gaming:

One of *the Lawson Center for Sustainability* goals is to be net-zero and, eventually net positive. Thus, monitoring energy and its consumption will be vital in achieving this goal. When a building is monitored, it can track its performance and adjust inefficiencies accordingly. Additionally, there are other benefits to monitoring, such as reducing the energy costs and quantifying potential energy savings, early detection of malfunctioning equipment, and recognizing when and how the building uses the most energy.

The Lawson Center for Sustainability also acknowledges the benefit of engaging stakeholders in building monitoring. Green buildings typically view occupants as active participants in facilitating comfort and energy efficiency, unlike conventional buildings where occupants are perceived as "passive recipients of indoor conditions, maintained within narrow margins by automated systems" (Brown and Cole, 2008, pp. 7-37). In this approach, green buildings assume that building occupants are aware of a building's systems and can make appropriate decisions when interacting with it (Brown and Cole, 2008). However, in reality, building occupants know very little about the building's environmental benefits and how these benefits influence their comfort and energy patterns (Brown and Cole, 2008). That is, green buildings rarely communicate how the building operates, and when it does, it is incomprehensible (Brown and Cole, 2008). Complex structures with sophisticated equipment typically tend to have overly complex management systems that deter building inhabitants from engaging with and solving building performance issues (Brown and Cole, 2008). Thus, the knowledge gap between green building occupants and the building itself does not come from occupants' unwillingness to learn. In fact, occupants of green buildings are interested in the information a building provides (Brown and Cole, 2008). Instead, the knowledge gap is due to the lack of understandable data. According to Cohen, Ruyssevelt, Standeven et al. (1999, p. 2) as cited in Brown and Cole (2008), the challenge in green buildings is the lack of support with "appropriate and understandable systems with readily-usable control interfaces, which give relevant and immediate feedback on performance" (p. 40).

Therefore, we recommend *the Lawson Center for Sustainability* use serious gaming to engage stakeholders in monitoring building performance and energy consumption. As defined by Ouariachi et al. (2018), serious gaming is gaming that goes beyond entertainment purposes to convey ideas and values while educating the players. Serious gaming simulates real-life contexts to influence a player's thoughts, behaviors, and actions through the medium of interactive gaming (Ouariachi et al., 2018).

The effectiveness of serious gaming to influence individual behaviors and the advancement of 21st-century technology gave birth to a wide range of serious games played. Games like *EnerCities* can be played via an internet connection, whereas games like *Power Agent* and *Power Explorer* use in-situ monitoring equipment to provide their mobile applications data. *EnerCites* was, in general, effective in promoting energy-saving behaviors and a broad sense of what sustainability is (De Vries & Knol, 2014).. Still, there were some inconsistencies in real-life behaviors, as noticed in post-player surveys (De Vries & Knol, 2014). After playing *EnerCites*, some players were more inclined to take shorter showers in the name of energy conservation (De Vries & Knol, 2014). However, other factors such as switching off the lights are not considered by occupants when minding energy-saving behaviors. The game's broad scope was unsatisfactory in promoting real-life environmental actions since the games did not apply to the player's real-life environment (De Vries & Knol, 2014).

In-situ games are more successful in promoting pro-environmental energy efficiency behaviors (Morganti et al., 2017). In-situ serious games rely on a building's existing equipment to generate the data used within the game. Thus, players engage with real-world monitorable and performance data that is relevant to them. Ouariachi et al. (2018) suggest that bridging the gap between the physical and digital realms extends the gaming application into the player's real-life, thereby increasing the chance for real behavioral engagement and change. For example, games like *Power Agent* and *Power Explorer* use in-situ information from a building's HVAC equipment as the data to play the game. In *Power Agent*, the building's metering data is transmitted into the building occupants' mobile application. Each day, the players called "power agents" receives a notifications from *Mr. Q*, "the boss," via their device when electricity consumption is generally high and gives clues to the power agents to complete the mission. Suppose the task for the day is to reduce energy consumption. In this case, *Mr. Q* would suggest adjusting heat levels or unplugging unused appliances.

Morganti et al. (2017) concluded that *Power Agent* was unsuccessful in changing long-term behaviors, and energy consumption returned to baseline conditions when the trial game study ended. However, *Power Explorer*, the advancement of *Power Agent*, maintained a long-term reduction (10 weeks) in energy consumption by 14% after the study trail (Gremaud, 2013). *Power Explorer* uses wifi-equipped electricity sensors placed on various appliances throughout a residence, which automatically report instant feedback of the said appliance's consumption levels to the mobile phone application. The goal of *Power Explorer* is to keep a "monster" healthy and safe by consuming low levels of energy in individual and competitive minigames (Gremaud, 2013). For example, in a competitive minigame, two players' monsters are stuck on an iceberg. To win, each player must try to knock the other monster off the iceberg. To knock off the opponent's monster, each player must earn objects by switching on and off appliances within the home; the more energy intensive the appliance, the greater the object's chance to win. *Power Explorer*'s goal is to not only reduce energy usage but to create an awareness of energy consumption (Gremaud, 2013). According to Gremaud (2013), *Power Explorer*'s success is due to two main reasons. First, the game's causal nature requires little effort, prioritizing occupant comfort (Gremaud, 2013). Secondly, the gameplay provided instant feedback, which increased player activity and energy consumption awareness (Gremaud, 2013). Serious gaming can be a useful tool to promote energy efficiency because it can communicate sustainable behaviors with a reward and penalty system (Morganti et al., 2017). This promotes long-term behavioral changes by establishing short and long-term goals while enabling the players to view short-term results (Morganti et al., (2017). It also encourages collective discussion of pro-environmental behaviors through competitions and feedback scores; and maintains active engagement while having fun (Morganti et al., 2017).

The Lawson Center for Sustainability should not use serious gaming as a tool to reduce the responsibility of the *Lawson Center for Sustainability* and Trinity College to decrease energy consumption. Instead, *the Lawson Center for Sustainability* should view serious gaming as a tool that can change individual behaviors of building occupants and seek to engage building occupants in the *Lawson Center for Sustainability* monitoring and performance processes in a fun and interactive way.

Energy consumption monitoring -- water sculpture:

We used the *Oberlin College* case study as an example to provide another recommendation for monitoring the building energy consumption while engaging stakeholders in the use of monitorable equipment that does not necessarily rely on data. For example, *Oberlin College's Adam Joseph Lewis Center (AJLC)* for Environmental Studies uses a solar-powered water sculpture to implicitly engage building occupants in the building energy generation and consumption.

The AJLC building philosophy was "How could a building be more like a tree?" (Oberlin College and Conservation, 2020). This meant that the building was meant to be integrated into the landscape and continually adapt, change, and improve its performance over time (Oberlin College and Conservation, 2020).

The AJLC has been consistently monitored since the building's opening as a part of this core philosophy to increase its sustainable performance (Peterson, 2011). One idea that emerged from the Environmental Studies and Studio Art Programs week-long seminar at the Lewis Center that brought together artists to consider ways to foster environmental stewardship in the built environment was a water sculpture in the building's common atrium (Peterson, 2011). This sculpture now doubles as both an art piece and a way to monitor energy availability (Schaefer, 2009). This art piece is powered by solar panels, which acts as an indicator of how much energy is available to the AJLC building (Schaefer, 2009). For example, when light is low, water flow trickles over the sculpture, and you get a modulation in sound. Likewise, on bright and sunny days, the flow of water is more solemn, it sounds different. On cloudy days, the flow lessens and at night turns off. The water sculpture can monitor the amount of daylight, energy availability, and it allows building occupants to be aware of the building equipment performance.

The water sculpture supports building occupants with an appropriate and understandable system that gives relevant and immediate feedback on the building's energy performance and availability. Likewise, the water sculpture's implicit nature as a monitoring device permits even those with the least amount of knowledge or interest in monitoring features to participate and engage with the building. Moreover, natural elements, like waterfalls and trees, incorporated into the building's architecture, positively affect human functioning, and reduces stress (Joye, 2007).

Furthermore, the sustainability-focused AJLC acted as a teaching building to students and visitors of the building and operated as an exemplar for the "Oberlin Project,"; a joint project between the college, the city, and private institutions to revitalize Oberlin's downtown holistically and sustainably ("The Oberlin Project," n.d.).

2. Building-User Dialogue

Occupant comfort plays a critical role in building sustainability. We examined that ventilation plays a vital role in the maintenance of thermal comfort. Occupants typically perceive lower temperatures in well-ventilated rooms (i.e., ventilated rooms feel cooler) (Camuffo, 2019). Natural ventilation via the opening and closing of windows can reduce energy consumption, leveraging wind, and buoyancy temperature gradients' natural forces to ventilate a room. If a room is ventilated naturally by an open window, there is no need for ventilation by the HVAC (heating, ventilation, air conditioning) system or the energy it consumes (Krarti, 2018). Our research investigated ways to reduce HVAC energy consumption and maintain occupant comfort through natural ventilation methods.

The Packard Foundation HQ case study:

The Packard Foundation headquarters is a Zero Net Energy (ZNE) building with a special implementation of the user-engagement strategy for natural ventilation via operable windows and HVAC monitoring. The facility employs a BMS that controls where certain features automatically, while the occupants control other features. The natural ventilation strategy combines both automatic monitoring by the building and user/occupant control. All desktops in the Packard Building have an application that updates users on outdoor conditions, as monitored by the building's BMS, and provides them with recommendations for opening/closing the windows. The proposals appear as displaying air quality information from the BMS's HVAC component—the natural ventilation status icon— either an upward green arrow or a downward red arrow. The green arrow means it recommends that users open their windows, while the red arrow suggests that the windows are closed. A desktop text alert additionally accompanies them.

The Bullitt Centre in Seattle, Washington, has also implemented a natural ventilation strategy. Unlike *the Packard Foundation*, however, this building's system uses carbon dioxide sensors and outdoor temperature sensors and either opens or closes windows automatically based on its evaluation of ventilation conditions and cooling needs (Peña, 2015). This natural ventilation and the cooling method does not leave any choice for the building occupants when it comes to their thermal comfort. However, occupants should be able to have control over their thermal comfort because thermal comfort is subjective (Camuffo, 2019). It varies based on the person, and the building management system cannot adequately account for every occupant's subjective evaluation of thermal comfort. Therefore, building users should be responsible for controlling factors contributing to thermal comfort (i.e., natural ventilation through operable windows) for evaluation.

The Packard Building's system leaves control in the occupants' hand, allowing them to manage their comfort while issuing reminders to consider the building's net-zero goals (Dean, 2014). If the occupants prefer not to open/close the windows, they do not have to. The notifications remind them that the option is available to them, and they can act on the BMS recommendations according to their thermal comfort needs. The building's HVAC system will adjust itself accordingly. Regardless of the BMS selected by the Lawson Centre design team, incorporating natural ventilation and an operable window system similar to *the Packard Foundation*'s can be helpful. It exemplifies the balance between occupant desires for comfort the building/operators desires for reduced energy consumption. Since *the Packard Foundation*'s BMS was custom designed for the building, the Lawson Centre would have to engineer a system based on this one. We suggest the inclusion of outdoor temperature sensors and HVAC capabilities of cooling and heating based on room ventilation. Recommended alterations to better tailor the system to the Lawson Centre include using smartphone notifications via building Wi-Fi or Bluetooth, similar to the Canadian COVID-19 exposure app (Government of Canada, 2020). Not all inhabitants of *the Lawson Centre for Sustainability* will have access to a desktop. Most notably, students attending class in a lecture hall, residence students, and professors teaching a course out of the building do not have consistent access to a desktop computer due to their high mobility. Desktop notifications can be a supplemental notification system for those working in the administrative offices and do not check their smartphones.

Further studies of *the Packard Foundation* headquarters building found their ventilation and operable windows system successful (Dean, 2014). Addressing occupant needs (i.e., for comfort) is shown not necessarily to interfere with sustainability and reduce energy consumption. If anything, occupant comfort is necessary for sustainability-promotion and energy consumption reduction.

Smart Bins for Food Waste:

Winnow Vision Smart Bin is a product developed to measure and monitor food waste in the kitchen and dining area. Winnow vision comes with a scale under the waste bin to measure food waste’s weight thrown into the container. The scale connects to a touchscreen tablet that allows the users to identify the type of food thrown away, which is fully customizable according to the kitchen menu (Winnow, n.d.). The software will then analyze the entered data and generate a report for the operators that highlights volume, value, and environmental impacts to support cutting down food waste (Winnow, n.d.). The presence waste monitoring system increases user awareness by showing the users how much food and the value of the food they are throwing on the tablet and stimulates behavior changes to reduce food waste (CEC, 2019). The reports generated by the software help the kitchen plan the meals to minimize food waste and manage their expenses.

Soma et al. suggested that combining activities such as a food waste competition and gamification with passive information campaigns can further engage the users in increasing their pro-environmental behaviors (2020). The community kitchen operators can create online-quiz games regarding food waste questions and generate a QR Code that links to the URL of the quiz website page to provide easy access to the game on mobile devices. There are existing online-quiz games and QR generators that are found online via search engines. Participants are encouraged to play the games by providing rewards through the points collected. If the online-quiz game questions are answered correctly by participants, they can exchange their points for cash or a free meal. Researchers can use the quiz game score as data in related research fields to study user behavior under the participants' acknowledgment. The game can also inform the users of their food waste knowledge and encourage them to pay more attention to food waste spontaneously. Soma et al. found that participants who participated in a combination of online quiz games and information campaigns have decreased their weekly food waste from 1.5kg to 0.8kg (2020). Participants in the study also reported in an after-campaign survey that the game improved their knowledge of reducing their food waste and started to keep track of their consumption behaviors (Soma et al., 2020).

Feedback Surveys:

Post occupancy survey is a useful tool for the operators to recognize short-term and long-term problems in the building's design, well-being features, and energy-saving features (Vischer, 2001). We recommend sending out post-occupancy surveys by email at the end of each semester to have up-to-date feedback from the occupants. The survey should include a range of questions regarding occupant comfort and energy consumption reduction for *the Lawson Center for Sustainability* to measure its performance and achievements from different perspectives. The survey could include questions on the convenience of using the natural ventilation system and building infrastructures, such as the BMS. The survey can assess the building's wellness features by evaluating the benefits of the rooftop garden and the helpful partnership programs offered by *the Lawson Center for Sustainability*. We also suggest to include questions on the dining experience and food waste for the operators to make any necessary alterations that comply with user expectation and allow the users to reflect on their food waste practices.

3. Community Engagement & Education

A response during a discussion period at a conference, *Taking It to the Curbside: Engaging Communities to Create Sustainable Change for Health*, described sustainability as “[not] necessarily an intervention that we need to maintain, it can also be a way of thinking…” (Hacker et al., 2013). Users, occupants, and community members of the Lawson Centre for Sustainability should adopt sustainability in a way, as mentioned earlier, as a way of thinking. They should care about and engage in behaviors promoting sustainability beyond the confines of this building’s walls, meaningfully engaging with sustainability beyond opening windows, responding to surveys, etc..

Multi-stakeholder engagement spaces:

Creating multi-stakeholder engagement spaces at the Lawson Centre for Sustainability would provide opportunities for its occupants, users, and community members to engage with the topic of sustainability meaningfully. In general, they open up individuals to the plurality of specific issues, exposing them to other opinions on the matter. In these spaces, participants can partake in mutual learning and co-produce new knowledge on a topic through conversation and discussion (Frantzeskaki & Rok, 2018). Integrating multi-stakeholder engagement spaces in the Lawson Centre where all community members (students, staff, faculty, etc.) can discuss and share ideas on the environment and sustainability will allow for meaningful engagement—through mutual learning and knowledge production—with these topics.

Focus groups are an essential tool for policy analysis. Focus groups are examples of a space where various stakeholders can express their ideas on a specific topic. The critical identification of focus groups allows interaction between participants while following a discussion outline enforced by a moderator. Focus groups are finding increasing usage in research regarding the public view of policies. This focus group usage allows participants to partake in the policy-making process and affect large scale change (Kahan, 2001).

As such, we recommend that the Lawson Centre for Sustainability apply the concept of multi-stakeholder engagement spaces via the implementation of policy focus groups in partnership with the provincial government. The benefits are symbiotic. The local government has an opportunity to examine the various values and interests of the student demographic through guided focus group discussions regarding provincial environmental and sustainability policy. The guided discussion with fellow students will provide a controlled environment for students to expose themselves to other viewpoints on the matter, as is the case with Multi-Stakeholder Engagement Spaces. Students in these focus groups are allowed an opportunity for mutual learning and co-producing knowledge through participation in the sustainability and environmental policy-making process.

Student participation in these focus groups can be encouraged in two ways where students can receive co-curricular credit for their involvement. Or they will be given extra credit in environmental studies or sustainability courses (e.g., Trinity One Environment & Sustainability) for their participation.

Community Initiatives & Partnerships:

The Lawson Centre for Sustainability community should be able to take over the sustainability process. Getting to this point, where an organization can respond to needs—in this case, sustainability needs—as they arise, is known as capacity building (Hacker et al., 2013). A study on *Integrated Coastal Zone Management* (ICZM)—the proposed use of harmonization, participation, and strategic planning for sustainable development—in Coastal Scotland found that capacity building is crucial to the successful implementation of sustainability initiatives (Barker, 2005). *The Lawson Centre for Sustainability* has design features in place to reduce energy consumption. Still, this community requires capacity building that will allow members to promote sustainability even when there are no features and systems (i.e., smartphone notifications, renewable energy sources) intervening.

At the abovementioned conference, further discussion revealed partnerships and community commitment as two critical elements of capacity building (Hacker et al., 2013). The recommendations for the accomplishment of these elements are as follows:

The *NexSens* green roof monitoring system consists of sensors for monitoring water level, water quality, weather, and soil moisture through different sensors. It has a live web datacenter that allows users to access real-time data remotely (NextSens, 2020). Measuring and monitoring features like temperature and soil moisture can contribute to better management, as well as provide a space for the users to research sustainable agriculture (e.g., organic gardening, composting, and water conservation) (Ferris et al., 2001). These measures are critical to garden maintenance as soil moisture is associated with soil earthworm population, which, alongside temperature, must be within a specific range for plant survival. *Ryerson University'*s Urban Farm monitors the earthworms' presence because they improve soil fertility, structure, and nutrients (Santos, 2018). However, they are manually collecting the data. With NexSens, *the Lawson Center for Sustainability* soil and earthworm population analysis can streamline. This system reduces instances of farm management errors, such as over-watering. Further, the temperature sensor and the soil moisture sensor could be useful tools for users responsible for managing the garden to protect the crops under extreme weather. This monitoring system can streamline the management and care of green spaces, including *the Lawson Centre for Sustainability*'s rooftop garden, allowing for its continued use for capacity building.

The healthy maintenance of the garden can yield crops used for a variety of purposes. These crops can be fresh ingredients in the community kitchen, as part of community cooking lessons and workshops, including group cooking lessons, can be hosted—through community partnerships with local educators. Programs can include but are not limited to collaboration with the First Nations House on Indigenous culture, information campaigns in reducing food waste, workshops on sustainable agriculture, and cooking workshops. The fresh produce can donate to community kitchen partners in Toronto to support those struggling with food insecurity in the surrounding community.

The rooftop garden itself can further function as an education and research site (Ferris et al., 2001). We had a conversation with Simone Davis from Trinity College to discuss how the Lawson Centre community members can get involved with the rooftop garden through volunteer opportunities. The students can monitor the garden, monitoring its production volume, crop distribution, and budget. These opportunities can connect the majority population of the Lawson Centre community (i.e., students) with the garden, involving them in and building their commitment to its maintenance (S. Davis, personal communication, December 4, 2020). In addition to volunteer positions, a rooftop garden presents various workshop opportunities. It can partner with related courses in U of T (e.g., NEW111: Food, Ethics & Sustainability) for students and other community members to participate in, such as propagation, transplanting, harvesting, and sustainable agriculture (Ferris et al., 2001). These workshops can be organized with community educators, forming partnerships to educate and involve students in achieving shared sustainability goals.

Interdisciplinary Sustainability Education:

Biomorphic architecture is the intersection of environmental psychology and design and applied research on natural design elements' impacts on motivation for environmental action. These findings indicate a space for architecture and psychology in sustainability education. Our study finds that incorporating natural features such as trees, waterfalls, shrubs, and other natural contents as design elements installed inside *the Lawson Centre for Sustainability* can positively affect human functioning and cognitive functioning as it can reduce stress. This results from human evolution in a natural environment, which explains why incorporating vegetative elements in buildings cause aesthetic reactions to its occupants. For example, trees guarded humans against the sun and provided humans with prospects on nearby landscapes and shelters from potential predators (Joye, 2007). Nature-based architecture infers that the building's design enters into a dialogue with innate human affiliations. Such buildings can only prevail by a transdisciplinary research approach that involves architects' and psychologists' knowledge alongside environmentalists.

Our research found that stand-alone sustainability courses are the best method of integrating sustainability into education to promote sustainability as a way of thinking (Ashraf & Alanezi, 2020). Our group recommends introducing a mandatory course on sustainability that incorporates knowledge from the physical and social sciences, architecture, and psychology. It can be a new course offered by Trinity or an alteration of an existing curriculum. We recommend that Trinity collaborates with other faculties such as Daniels Faculty of architecture, the school of the environment, and the psychology department of the faculty of Arts and Science to create this interdisciplinary course.

Equity & Sustainability:

Equity is an often-overlooked and inadequately understood dimension of sustainability. Svara et al. (2015) note that American cities' case demonstrates the social exclusion and inequality are not compatible with sustainability as they undermine community viability. Governments with social equity initiatives in place, like affordable housing and job creation, still view social equity as distinct from Sustainability and leave out addressing social equity's fundamental issues out of their sustainability plans. Therefore, the establishment of viable communities should pursue sustainability with consideration of the role of social equity (Svara et al., 2015). Our recommendations apply these societal-level concepts of sustainability and equity to the small community of *the Lawson Centre for Sustainability* and Trinity College.

We propose that *the Lawson Centre for Sustainability* have measures to promote equity to be a sustainable community. Local government efforts for equity promotion include the advancement of equal opportunity and access to health, employment, and education (Svara et al., 2015). While *the Lawson Centre for Sustainability* and the Trinity College community cannot directly influence health access, it can contribute to employment and education accessibility. *The Lawson Centre for Sustainability* can serve as a living lab for the community impacts of equity. The Lawson Centre seeks to be a learning opportunity in Sustainability for its users; all individuals should access that opportunity regardless of marginalization. As such, we propose that Trinity College provide additional financial aid for marginalized students, meager income and BIPOC (Black, Indigenous and People of Colour) students to access student housing at *the Lawson Centre for Sustainability* and the Trinity College community.

Conclusion

Given the above recommendations for energy consumption and its applications, facilitating building-user dialogue, and promoting community engagement and education, the Lawson Centre for Sustainability may become a living lab for sustainability at the University of Toronto campus.

References

Ashraf, M. W., & Alanezi, F. (2020, April 5). *Incorporation of Sustainability Concepts into the Engineering Core Program by Adopting a Micro Curriculum Approach: A Case Study in Saudi Arabia* (Report No. 12). https://doi.org/10.3390/su12072901

Aviva A. Musicus et al. “Implementation of a Rooftop Farm Integrated With a Teaching Kitchen and Preventive Food Pantry in a Hospital Setting”, *American Journal of Public Health* 109, no. 8 (August 1, 2019): pp. 1119-1121. https://doi.org/10.2105/AJPH.2019.305116

Barker A. (2005). Capacity building for sustainability: towards community development in coastal Scotland. *Journal of Environmental Management*, 75(1), 11-19. https://doi.org/10.1016/j.jenvman.2004.11.002

Boomsma, C., Hafner, R., Pahl, S., Jones, R., Fuertes, A. (2018). Should We Play Games Where Energy Is Concerned? Perceptions Of Serious Gaming As A Technology To Motivate Energy Behaviour Change Among Social Housing Residents? *Sustainability 10*(1729). doi:10.3390/su10061729

Brown, Z. B., and Cole, R. J., (2008). Engaging Occupants in GREEN Building Performance Addressing the Knowledge Gap. *ACEEE Summer Study on Energy Efficiency in Buildings.* https://www.aceee.org/files/proceedings/2008/data/papers/7_113.pdf

Camuffo, D., (2019). Chapter 2 - Temperature: A Key Variable in Conservation and Thermal Comfort. *Microclimate for Cultural Heritage (3rd edition)*, 15-42. https://doi.org/10.1016/B978-0-444-64106-9.00002-X

Commission for Environmental Cooperation. (2019). *Why and How to Measure Food Loss and Waste: A Practical Guide.* Montreal, Canada: Commission for Environmental Cooperation. http://www3.cec.org/islandora/en/item/11814-why-and-how-measure-food-loss-and-waste-practical-guide-en.pdf

Dean, E. (2014). Case Study No. 1: Packard Foundation Office Building. *Zero Net Energy Case Study Buildings*, 1, 1–23. https://www.pge.com/pge_global/common/pdfs/save-energy-money/savings-programs/zero-net-energy-program/ZNE-Case-Study-Buildings-Vol1.pdf

De Vires, P. W., Knol, E. (2011). Serious Gaming as a Means to Change Adolescents’ Attitudes Towards Saving Energy; Preliminary Results from the EnerCities Case https://www.researchgate.net/publication/228295645_Serious_Gaming_as_a_Means_to_Change_Adolescents'_Attitudes_Towards_Saving_Energy_Preliminary_Results_from_the_EnerCities_Case

Ferris, J., Norman, C., & Sempik, J. (2001). People, Land and Sustainability: Community Gardens and the Social Dimension of Sustainable Development. *Social Policy & Administration*, 35(5), 559–568. https://doi.org/10.1111/1467-9515.t01-1-00253

Frantzeskaki, N., Rok, A. (2018). Co-producing urban sustainability transitions knowledge with community, policy and science. *Environmental Innovation and Societal Transition*, 29, 47-51. https://doi.org/10.1016/j.eist.2018.08.001

Government of Canada (2020). Download COVID Alert today. *Canada.ca.* https://www.canada.ca/en/public-health/services/diseases/coronavirus-disease-covid-19/covid-alert.html

NextSens. (2020, August 20). *Green Roof Monitoring*. https://www.nexsens.com/case_studies/green_roof_monitoring.htm?fbclid=IwAR1U_9Tvy6CsUOY14mQfHaN0NLYBocM8OEDO9fy9RI_MqCos1eiiTD_uzRk

Gremaud, P. (2013). Pervasive, Persuasive Gaming for Energy Conservation. Pervasive and Artificial Intelligence Seminar report. Department of Informatics. https://diuf.unifr.ch/main/pai/sites/diuf.unifr.ch.main.pai/files/PAI_Seminar_2013_Gremaud.pdf

Gulbinas, R., Jain, R.K., & Taylor, J.E. (n.d.). Applied Energy. In *BizWatts: A modular socio-technical energy management system for empowering commercial building occupants to conserve energy*. https://doi.org/10.1016/j.apenergy.2014.07.034 (Reprinted from "BizWatts: A modular socio-technical energy management system for empowering commercial building occupants to conserve energy," 2014, *Elsevier*, *136*, 1076-1084)

Hacker, K., Tendulkar, S.A., Rideout, C., Bhuiya, N., Trinh-Shevrin, C., Savage, C.P., Grullon, M., Strelnick, H., Leung, C., & DiGirolamo, A. (2013). Community Capacity Building and Sustainability: Outcomes of Community-Based Participatory Research. *Progress in Community Health Partnerships: Research, Education and Action*, 6(3), 349-360. https://doi.org/10.1353/cpr.2012.0048

Hossain, M, F. (2019). “Best Management Practice” In *Sustainable Design and Build.* Elsevier Inc. *419-43*. https://doi.org/10.1016/B978-0-12-816722-9.00007-0

Joesph, J. (2018). “Facility Design and Process Utilities” In *Development, Design, and Implementation of Manufacturing Processes.* Elsevier. 933-986. https://doi.org/10.1016/B978-0-08-100623-8.00045-1

Joye, Y. (2007). *Architectural Lessons From Environmental Psychology: The Case of Biophilic Architecture* (Research Report No. 4). American Psychological Association. https://doi.org/10.1037/1089-2680.11.4.305

Kahan, J.P. (2001). Focus Groups as a Tool for Policy Analysis. *Analyses of Social Issues and Public Policy*, 1(1), 129-146. https://doi.org/10.1111/1530-2415.00007

Krarti, M., (2018). Chapter 6 - Integrated Design and Retrofit of Buildings. *Optimal Design and Retrofit of Energy Efficient Buildings, Communities, and Urban Centers*, 313-384. https://doi.org/10.1016/B978-0-12-849869-9.00006-5

Masseroni, D., Facchi, A., Depoli, E. V., Renga, F. M., & Gandolfi, C. (2016). Irrig-OH: An Open-Hardware Device for Soil Water Potential Monitoring and Irrigation Management. *Irrigation and Drainage*, *65*(5), 750–761. https://doi.org/10.1002/ird.1989

Morganti, L., Pallavicini, F., Cadel, E., Candelieri, A., Archetti, F., Mantovani, F. (2017). Gaming For Earth: Serious Games And Gamification To Engage Consumers In Pro-Environmental Behaviours For Energy Efficiency. *Energy Research and Social Science 29*, 95-102. http://dx.doi.org/10.1016/j.erss.2017.05.001

Oberlin College and Conservatory. (2020). *Design Philosophy.* https://www.oberlin.edu/ajlc/design-philosophy

The Oberlin Project. (n.d.). https://oberlinproject.org/

Ouariachi, T., Olvera-Lobo, M, D., Gutierrez-Perez, J. (2018). Serious Games and Sustainability. *Encyclopedia of Sustainability and Higher Education.* https://doi.org/10.1007/978-3-319-63951-2

Peña, R.B. (2014). *Living Proof: The Bullitt Center.* University of Washington Center for Integrated Design. http://www.bullittcenter.org/wp-content/uploads/2015/08/living-proof-bullitt-center-case-study.pdf

Peterson, J. (2011) Early Adopter. *High Performing Buildings.* https://www.hpbmagazine.org/content/uploads/2020/04/11W-Oberlin-College-Adam-Joseph-Lewis-Center-Oberlin-OH.pdf

Santos, C. V. (2018, January 1). *Earthworm Populations In Agricultural Green Roofs And Their Influence On Soil Nitrogen, Greater Toronto Area* (thesis). *Ryerson University Digital Repository*. Retrieved from https://digital.library.ryerson.ca/islandora/object/RULA%3A7563

Schaefer, K. (2009). Environmental Group Features Colleges Going Green. *Voice of America.* https://www.voanews.com/archive/environmental-group-features-colleges-going-green

Soma, T., Li, B., & Maclaren, V. (2020). Food Waste Reduction: A Test of Three Consumer Awareness Interventions. *Sustainability*, *12*(3), 907. https://doi.org/https://doi.org/10.3390/su12030907

Svara, J., Watt, T., & Takai, K. (2015). Advancing Social Equity as an Integral Dimension of Sustainability in Local Communities. *Cityscape: A Journal of Policy Development and Research*, 17(2), 139-166. https://www.jstor.org/stable/26326943

Vischer, Jacqueline. (2001). Post-Occupancy Evaluation: A Multifaceted Tool for Building Improvement. *Learning from our buildings: a state-of-the-practice summary of post-occupancy evaluation.* 23–34.

Winnow. (n.d.). *Waste Monitor*. https://www.winnowsolutions.com/en/product.

Williams, K. J., Lee, K. E., Sargent, L. A., Johnson, K. E., Rayner, J. S., Farrell, C. U., . . . Williams, N. U. (2019). Appraising the psychological benefits of green roofs for city residents and workers. *Urban Forestry & Urban Greening*, *44*(126399). https://doi.org/10.1016/j.ufug.2019.126399