Water Sustainability at Worcester Polytechnic Institute

An Interactive Qualifying Project Report

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By

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Abstract

The United Nations has set forth a set of sustainable development goals (SDGs) to address some of the most pressing social, environmental, and political challenges of our time. SDG 6 prioritizes clean water conservation and envisions worldwide access to clean water for all. This study focused on the water conservation practices and attitudes among Worcester Polytechnic Institute students, staff, and faculty. The methodology of this project included creating surveys for the WPI community on water conservation, interviewing experts with knowledge on the topic of sustainable water use, and analyzing data on water consumption on campus. These methods helped the research team to understand what practices and methods affect students' behavior regarding water conservation. Moreover, this study will help inform possible activities and methods that could save more water on WPI's campus.

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1.0 Introduction

Freshwater is critical to the health and well-being of humans on earth. The average person drinks 182.5 gallons of water a year. Water is 71 percent of the planet, but 97 percent of the water is saline, leaving humans only 3 percent of freshwater (Manandic, 2022). While water demand is increasing with the increasing population, it is known that the water supply is decreasing. The number of people who need access to clean water will also increase. We cannot imagine our life without fresh water. Humans cannot survive the past three days without water. Despite this critical need, the misuse and low maintenance of water is an issue in high-income economies, which could affect generations after us if people are not more aware.

Universities and colleges require enormous amounts of water to maintain on-campus housing, dining, landscaping, and other amenities. They use 600 million to 1 billion gallons of water annually. Using less water can save universities and colleges a lot of money while also diverting less water from the earth's body of water to help keep the environment healthy. To effectively conserve water on campus, it is essential to renew the buildings and water supplies according to new water standards. Therefore, it is a problematic question of what innovations should be applied to different universities to ensure sustainable water use.

This project aimed to understand the gaps in approaches to water conservation on the WPI campus. To do this, we created surveys for the WPI community on water conservation, interviewed experts with knowledge on the topic of sustainable water use, analyzed data on water consumption on campus, and also recommended what steps could be taken to ensure a decrease in WPI’s water usage. These methods should help understand what practices and methods affect students' behavior regarding water conservation; moreover, they should help with what innovations can be integrated into the WPI campus to ensure sustainable water consumption.

2.0 Literature Review

This section will provide the reader with background information on water consumption issues. It provides important framing and context to establish the importance of research on water conservation issues. First, we explain current issues of water consumption, followed by an introduction to the United Nations Sustainable development goals. Next, the Sustainable Development Goal of clean water and sanitation will be described in depth. Finally, we discuss the role of water conservation in the university setting. We conclude by providing context for the water usage data of WPI academic buildings compared to WPI's water sustainability goals.

2.1 Water Consumption: Current Issues

The demand for water rises as the world's population increases. Clean, accessible water is a necessity for everyday life. According to the Sustainable development goal of Water and Sanitation, if misuse and poor water management continue to happen, then billions of people will not be able to get access to the basic services needed from water, such as hygiene, drinking, and growing food, inevitably leading to sickness and disease. Not only will monitoring water consumption help the environment we live in, but it will also help save money. The United Nations' Sustainable Development Goals 2022 report stated that water use efficiency worldwide rose from $17.4 per cubic meter in 2015 to $19.4 per cubic meter in 2019, a 12 percent efficiency increase.

Water stress is the concept that includes all issues stemming from poor use of water management. Klobucista and Robinson (2017) separate water stress into two categories, physical scarcity and economic scarcity. Physical lack is when ecological conditions cause water loss, and then economic scarcity is caused by inadequate water infrastructure. They shared that even high-income countries like the United States can experience water stress from outdated infrastructure and rapid population growth. This relates to what is happening in Flint, Michigan. This city's water was contaminated because of poor decision-making and a lack of infrastructure. Now “Flint's population has since plummeted to just 100,000 people, a majority of whom are African-American, and about 45 percent of its residents live below the poverty line. Nearly one in six of the city's homes has been abandoned (Denchak, 2018).

2.2 SDG 6: Clean Water and Sanitation

To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations (EPA, 2017, p. 1). Water sustainability is not just important in the United States; it is important globally. SDG stands for Sustainable Development Goals, created by the United Nations to "end poverty, protect the planet and ensure that all people enjoy peace and prosperity." This program helped create the 17 sustainable development goals that Worcester Polytechnic Institute uses today, including Clean Water and Sanitation (UNDP, 2022). Clean water and Sanitation are what we intend to examine on campus. The goal of clean water and Sanitation SDG targets eight areas:

- Safe and affordable drinking water, improved water quality
- Water waste treatment and safe reuse
- Implement integrated water resource management
- Expand water and sanitation support to developing countries
- End open defecation and provide access to sanitation and hygiene
- Increase water use efficiency and ensure freshwater supplies
- Protect and restore water-related ecosystems
- To support local engagement in water and sanitation management

The ultimate global goal is to provide long-term clean and safe water for everyone. The importance of having clean, affordable drinking water has multiple stakeholders – educators, policymakers, professionals, and citizens - taking necessary action to have a sustainable water environment for all. The demand for water rises with population increase, and with over 8 billion people on this planet, essential measures must be taken to ensure freshwater for future generations. Worcester Polytechnic Institute is a school where students are encouraged to innovate and problem-solve. Hence, it is only fitting that these innovations are used to help create a better environment for the world in response to what the future can behold.

Everyone has the right to have clean water, but a rise in population leads to a high demand for water where there is little water. Changes in climate and the environment, as well as pollution, are a factor in it as well. People need to take individual actions to help conserve water. Looking at a university or a campus' use of water where thousands of students attend is a perfect example of taking action. Making people more aware of the situations going on will encourage more people

also to take action. In the Journal of Environmental Management, Singha et al. wrote, “One of the world's most serious concerns is ensuring an adequate water supply." They looked at the conservation habits of 625 international employees and students and found that water conservation is connected to awareness. Hanging up water conservation signs around the school, bringing reusable water bottles to class, and being aware of the amount of water used while showering are all examples of how individuals can help create a sustainable environment.

2.3 Water use behaviors and Areas for Intervention/innovation in the USA

Generation Z (those born in the late 1990s-early 2010s) are the future of our nation. Educating and empowering that generation is important to share ideas to prevent future global problems. One such problem is the lack of fresh water. The university is one place where the young generation not only cultivates the habits of social living but also can innovate and integrate their ideas to solve these global problems. Most US universities care about efficient water consumption, particularly on campus and in dormitories. There are many benefits for universities to implement efficient water systems, such as decreasing yearly university expenses, conservation of the environment, and technological integration where students can participate to get engineering experience. The energy efficiency companies' standards and recommendations should be applied for consideration. It should help to obtain more valuable technologies with minimizing unfortunate experiences with inefficient technologies.

Governmental regulation and guidance for water conservation are also critical to bring about better water resource management. The government's actions to encourage water efficiency are essential because it provides clear guidelines and operational steps. For instance, students and staff at a university can follow well-organized standards and recommendations to decrease water consumption at systemic and individual levels. Furthermore, the standards and recommendations can help easier implement the innovations and social behavior to the problem because it has the government-level view of the entirety of the issue. The following standards recommended by The Water Resources Commission of Massachusetts (Executive Office of Energy and Environmental Affairs, & Water Resources Commission, 2018, P30) provide clear guidance for university stakeholders:

1. Buildings, facilities, and grounds:

- *Conduct indoor and outdoor audits and account for full water use based on full metering of public buildings, parks, irrigated playing fields, and other facilities.*
- *Analyze existing water-use data to spot trends, patterns, and unexplained increases that could indicate leaks or inefficient water use.*
- *Identify measures where the greatest efficiencies and potential savings can be realized.*
- *Build new buildings with equipment that reduces water use, such as faucet aerators, low-flow showerheads, composting or high-efficiency toilets (HETs) (or "dual-flush" models), and self-closing faucets. Water-saving devices and measures should be well-identified for users of public buildings and facilities.*
- *Focus on replacing/retrofitting water-consuming equipment in buildings (e.g., bathrooms, boilers, chillers).*
- *Practice good, efficient lawn and landscape water-use techniques.*

2. Meter or estimate contractor use of water from fire hydrants for pipe flushing and construction.

3. Strictly apply plumbing codes and incorporate other conservation measures in new and renovated buildings.

As an example, one of the recommendations from the MA government was to conduct water audits of institutions to follow the changes in water consumption through the years. An audit of water systems implies inspecting the water consumption system, which should help reduce inefficient water consumption. An organization like AWWA helps minimize water system losses by auditing water supplies and implementing controls ("Water loss control | American Water Works Association"). Moreover, AWWA has free water audit software to conduct an annual water audit to guide the program for cost-effective water loss control and revenue recovery ("Free Water Audit Software | American Water Works Association," 2020). A detailed audit example of over 400 pages written by AWWA describes the following topics: information about conducting the water audit, the occurrence and impacts of apparent losses (leakage), controlling apparent losses, and optimized revenue capture (Kunkel, 2016). By identifying the imperfections of the water system, the university will be able to understand the mandatory next steps to correct the current situation with water waste.

Another company that can conduct an audit is Energy Star. Energy Star is an American company with a Higher Education Benchmarking Initiative (HEBI); this program provides information about on-campus energy and water performance compared to other institutions. It establishes a "WUI" parameter - the total amount of water (gallons of water per building square foot) used from all water sources per year without consideration of parking or irrigated areas ("Colleges and universities," 2020).

Sustainable innovations are critical for addressing on-campus water usage. Many innovations can be used on campus and have been implemented at many universities. This includes but is not limited to low-flow showerheads, faucets, low-water volume toilets, water-free urinals, dual flush toilets, and more.

2.4 Assessing Sustainability in Higher Education Institutions

In order to understand the impact of water conservation efforts, assessment, and tracking is a critical activity. The Sustainable Tracking and Assessment Rating System (STARS) was created as a voluntary self-reporting system to help institutions keep track of their sustainability progress. Future generations of leaders and researchers attend college to learn the skills and knowledge to assist in what they will be doing in the future. Targeting these institutions is a perfect way to address why it is necessary to participate in sustainable habits within our environment, such as conserving freshwater. Providing students with the opportunity to learn about why sustainability is important will motivate them to take individual action, such as monitoring water use. Starting to teach future generations of our next engineers, doctors, scientists, lawyers, and other careers about sustainable practices will guarantee a more sustainable environment on earth. STARS bases its tracking on its contribution to the SDG goals provided by the United Nations. This source will also provide data on WPI's water use, and it could then be used to compare the data to other schools allowing further research into what other institutions are doing to conserve water. This tool can be used by all higher education institutions.

The STARS technical manual provides helpful information about how they rank institutions based on water use. They provide a visual example of their scoring process and take measurements to determine their scoring. They take measures based on the gross floor area of building space, portable water, recyclable/reusable water, total campus area, vegetated grounds, and the institution's population. Their criteria consist of 3 parts, reduction in potable water use per

person, reduction in potable water use per unit floor area, and reduction in total water withdrawal per unit of vegetated grounds. Their scoring system gave institutions an idea of how they could improve based on where they fall on the scoring line (Mathisen, 2022).

Institutions should give students theoretical and practical knowledge related to a student's major programs; in that case, the students will graduate as professionals in their study area. However, with all the information STARS and the SDG goals provide, institutions should also teach the students about sustainable living in a community that includes good habits of natural resources consumption such as freshwater. This is so that students can continue living in a sustainable environment to pursue their career path when they graduate. In that case, when learning about a sustainability issue such as water consumption, the graduated students will know about the possible future deficit of freshwater, and their behavior toward water consumption will be more careful. Moreover, they will share their habits with other members of the community. As a result, our community will be more knowledgeable about SDG goals. The universities can reduce pressures on local aquifers, streams, rivers, lakes, and aquatic wildlife by reducing campus withdrawals (Technical Manual, 2021).

2.5 Water Usage at Worcester Polytechnic Institute

2.5.1 What WPI already has implemented

Water consumption at WPI for the current year (Comparing dynamics with previous years) WPI pays attention to water consumption on Campus and follows the 2020-2025 Sustainable Plan. WPI has also integrated energy-saving methods such as low-flush toilets and automatic faucets. The results of efforts can be seen through water consumption statistics over the past few years (Caton, 2020). The water consumption dropped in 2020 compared to 2018, from approximately 90 to 73 million gallons accordingly (Worcester Polytechnic Institute, 2020, P 19, 27).

2.5.2 Water recommendations from past IQPs

Worcester Polytechnic Institute has an Interactive Qualifying Project that gives experience in solving the problem that lies at the intersection of science and society. From the information that was found, there were only two IQPs since 2014 that focused on WPI's water sustainability. In 2014, undergraduate researchers Stephen Couitt, Christopher Preucil, and Alexander Wong, with the help of faculty at WPI, discovered there was a problem with WPI's meter system. They

focused on improving water sustainability through behavioral and technological changes. They identified the issues in efficient water consumption on campus and recommended more efficient water meter use, upgrading fixtures such as shower heads, faucets, toilets, etc., to become eco-friendlier to save water (Couitt, 2014). In 2020 Lenihan, E., Curiel, A., Zhong, S., & Pierre, J. all worked to recommend more signage, obtaining removable, easy-to-install, and accurate meters to be used for cooling towers and all mechanical systems, and to keep record of all water using appliances and their flow rates. They also worked to create a 5-year to guide WPI to becoming more sustainable on campus. What these two IQPs had in common was that they both suggested some technological changes. Through individuals living on campus doing their part, we can all work together to conserve water.

3.0 Methodology

The goal of this project was to compare water usage data for WPI to student behaviors to find trend trends to assess how student behaviors affect water usage. Interviews were conducted, and when considered together with the data analysis, action steps could be recommended that would help WPI become more water sustainable. This was done by determining the current rates and trends of water consumption on the WPI campus, relating it to student/staff behavior regarding efficient water consumption through surveys, and suggesting improvements for WPI's campus with the help of surveys and interviews. This section provides the methodology to achieve this project's goal. The project pursues the following three main research questions:

1. What implementations should be integrated based on WPI's recent experience in water consumption?
2. What practices and behaviors affect water usage on WPI's campus?
3. What is the importance of water conservation efforts in higher education?

3.1 Objectives

In order to strengthen the validity of the results, a mixed methods approach was used to gather quantitative and qualitative data. This enabled the researcher's recommendations to be more credible by gathering robust data from different sources. This method was needed because neither quantitative nor qualitative methods would not be enough to convince the reader that the concluded recommendations are important if used alone. Comparing the Worcester Polytechnic Institute community's water conservation habits with numerical data from WPI's facilities reports on water consumption allowed the researcher to see where areas of improvement are needed, based on the quantitative research, and why, based on the qualitative research. These findings allowed credible recommendations to be created and strengthened the validity of what was concluded. To answer our research questions, we addressed the following objectives:

1. Analyze Water Consumption in WPI's academic buildings and residence halls

2. Understand the Challenges and Opportunities around Water Consumption at WPI

3. Complete an integrated analysis to understand the relationship between Objectives 1 and 2 and develop recommendations

These objectives are described in the following sections.

3.1.1 Objective 1: Analysis of WPI's buildings' water consumption

Our team analyzed WPI's water consumption in academic buildings for the past three years to understand the most consumable buildings. Next, we made graphs based on the 2019-2022 fiscal year water consumption records to represent the collected data. We have chosen to analyze water volume units instead of bills because the cost of water volume can vary with time as water volume consumption, and it can lead to inaccurate data reading.

The yearly water consumption for the past three years was analyzed. It helped to understand the trends of water usage in academic buildings and residential buildings. The graph was Years Vs.—consumed water volume. Next, we found the Full Time Equivalent (SCE) data separated by buildings. This data showed how many students attended on campus in different years or at one period of time in different buildings. Then, we combined Consumed water volume and SCE data; it helped to understand the relation between the number of students on campus and consuming water through the years and buildings' water usage efficiency. Next, we compared the water consumption on campus for the past three years in different months. This graph shows the trends related to months. As a result, we defined the most consumable month for WPI's campus. Then, based on the collected data from surveys where we defined what buildings are used by different students' years (First, second, third, fourth, and graduated), we found a correlation with most water-consumable buildings and defined students' behavior by their year at the university.

3.1.2 Objective 2: Understand the challenges and opportunities around water conservation at WPI.

Another objective was to understand the current state of water conservation related to higher education practices, policies, and attitudes. We gathered qualitative data from subject matter experts to answer this question. The experts we interviewed are campus sustainability directors from colleges and universities in Massachusetts. The experts were interviewed through the

prepared questions to help to understand better the university's water consumption issues throughout Massachusetts from the Sustainable Development Goal 6 side.

To understand the challenges/opportunities even more profoundly, our team prepared surveys for students/staff to analyze their awareness and behavior toward water conservation at WPI. The survey questions were related to campus technologies and student/staff behavior. In addition, students were surveyed about their personal water use and knowledge. This information allowed us to assess how much WPI's community knows about water conservation and their water conservation habits. This was known to be personal information, so we ensured that the appropriate measures were taken to ensure the rights and welfare of the survey participants by following the guidelines introduced.

3.1.3 Objective 3: Combined Data analysis.

The next step was analyzing all collected data (Objective 1, 2). Then, we combined the collected data from surveys/interviews and water consumption statistics to understand which social/technical innovations can be implemented. The analysis of the data was subjected to limitations. Some of the buildings have more rounded data than others. We used the average water consumption throughout the year, leading to inaccurate results. Also, the information sits at different departments at WPI; it means that the data is independent of one another due to the other metrics systems. Many students were not interested in participating in the surveys, so it took much work to say how the collected data was correct compared to real life. Water consumption data can differ from standard campus operations due to the COVID shutdown in 2020-2021. Also, many of the most consumable buildings did not have many classes, so the SCE parameter was not applicable to them, and there was no way to define the building's attendance more accurately.

3.2 Project deliverables

It was necessary to understand the challenges and opportunities around water conservation at WPI and analyze the water consumption of academic buildings for the past three years to minimize water consumption on WPI's campus. Recommendations were written on ways WPI can reduce water consumption based on current experience and Experts' advice. The recommendations were created to encourage the WPI community to start implementing these recommendations.

3.3 Ethical Considerations

Since this project uses research data provided by human subjects, we went through WPI's IRB Institutional Review Board. We believe the questions we are asking were considered personal information, and we wanted to ensure we are taking the necessary precautions by complying with the ethical guidelines and regulatory requirements that come with the involvement of human subjects. We conducted interviews and created surveys with the intent of collecting data from them. WPI policy states that these types of data collection need to be approved by the IRB before being conducted. This way, we are minimizing the risk of breaking any ethical guidelines, and the WPI community can feel comfortable with answering our questions, knowing that a higher authority approved them.

4.0 Results and Discussions

The results of this project provided insight into the awareness of the WPI community regarding water sustainability and water use. The results in this section include analyses of water use data on campus, survey results, and also interviews with experts. The interviews also helped to consider the water sustainability issues from different sides because most of the experts have many years of experience and high proficiency. In addition, surveys helped to understand the behaviors that affected water usage on WPI's campus. In this section, we described the survey results. We highlighted important aspects to correlate student behavior to water conservation issues and statistics of water usage on the WPI campus as well as residential buildings to understand the importance of water conservation efforts in higher education. Finally, when all of these data were combined, they helped to give solid recommendations about possible implementations that can help conserve clean water on WPI's campus.

4.1 Water usage statistics at WPI

This section summarizes WPI's water usage data, as represented in a calendar year format. The period time for each year starts from July to the June of the following year, which represents the fiscal year for WPI. For example, the data for 2019-2020 means that the water usage data started in July 2019 and ended in June 2020. Water usage is represented in 100 cubic feet of water; it means that the Y component on the plots should be multiplied by 100, and it is the volume in cubic feet.

4.1.1 Total water usage Academic Buildings vs. Residential Buildings

First, consider the overall water usage trends for the past three fiscal years. **Figure 1** shows that WPI's academic buildings have greater yearly water use than residential buildings for 3 of the past 4 years.

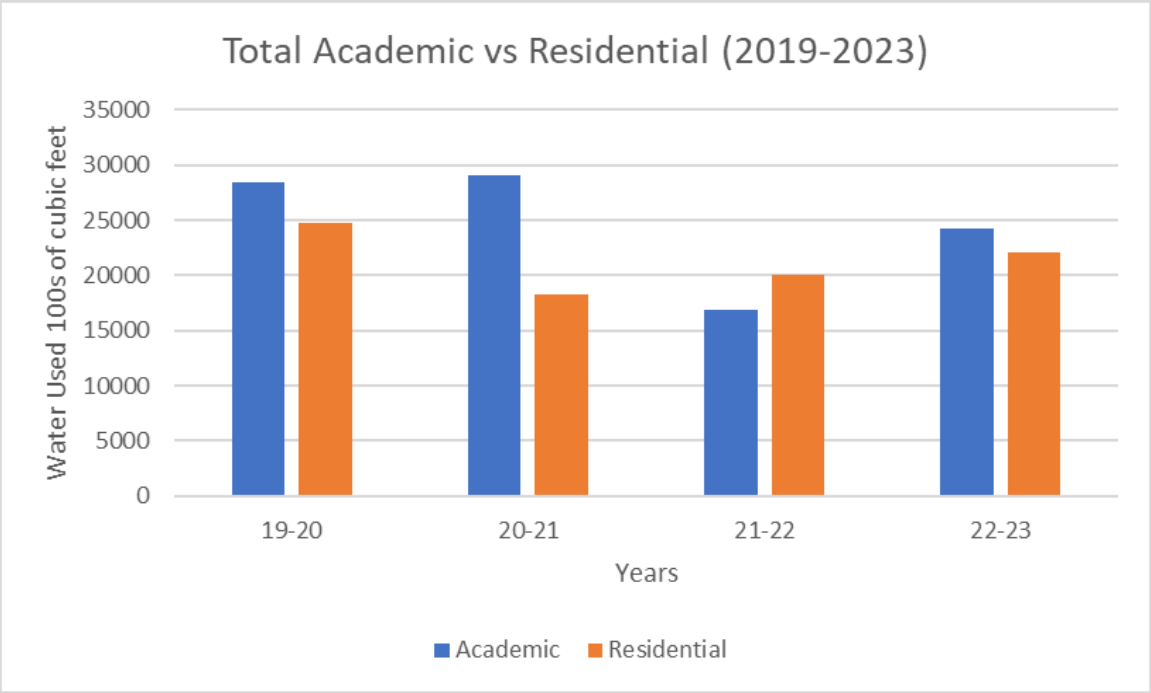

Figure 1: Total water consumption Academic vs. Residential over the billing years (2019 - 2023).

Figure 2 shows that, even though there is a lower water usage in residential buildings for the 2022 fiscal year, the residential buildings have higher average water consumption in the academic year when classes are in session, except in September when the campus starts operating after the summer break. Similar statistics results are observed for the 19, 20, and 21 fiscal years.

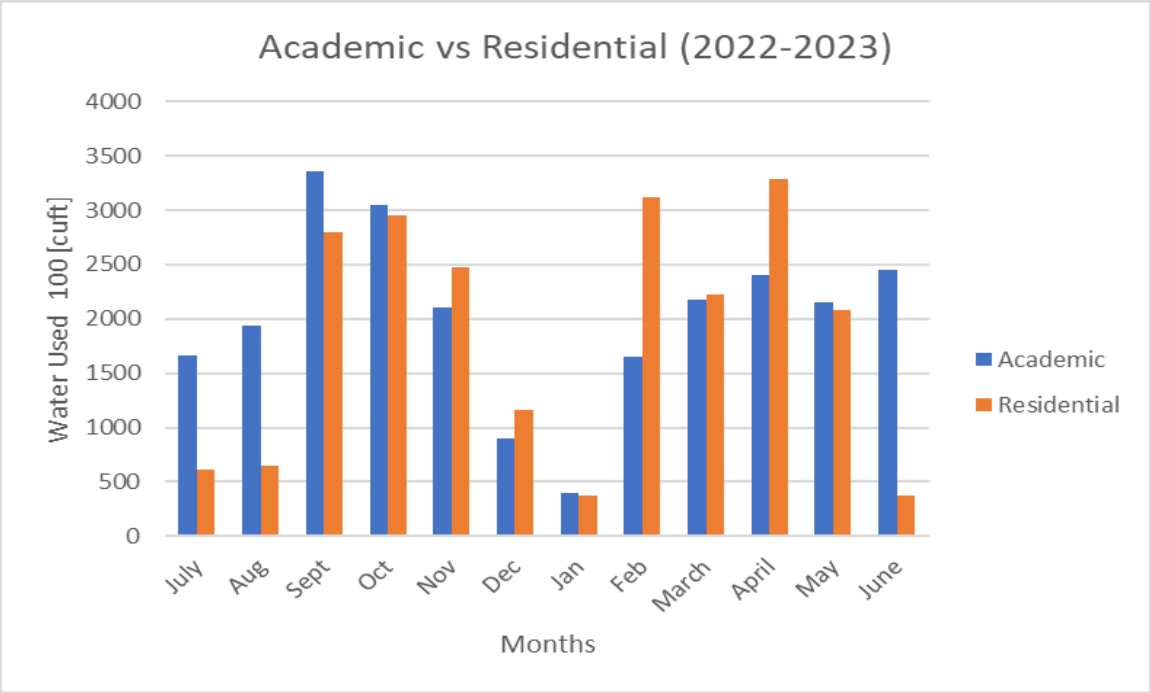

Figure 2: Academic vs. Residential water usage in the 2022 fiscal year.

4.1.2 Data of Academic Buildings

4.1.2.1 Water Usage in Academic Buildings by Months

We can see the correlation between higher water usage and academic periods in **Figure 3**. WPI buildings use much more water during studying periods, especially at the beginning of the A term in September, when the institute starts working after the summer break.

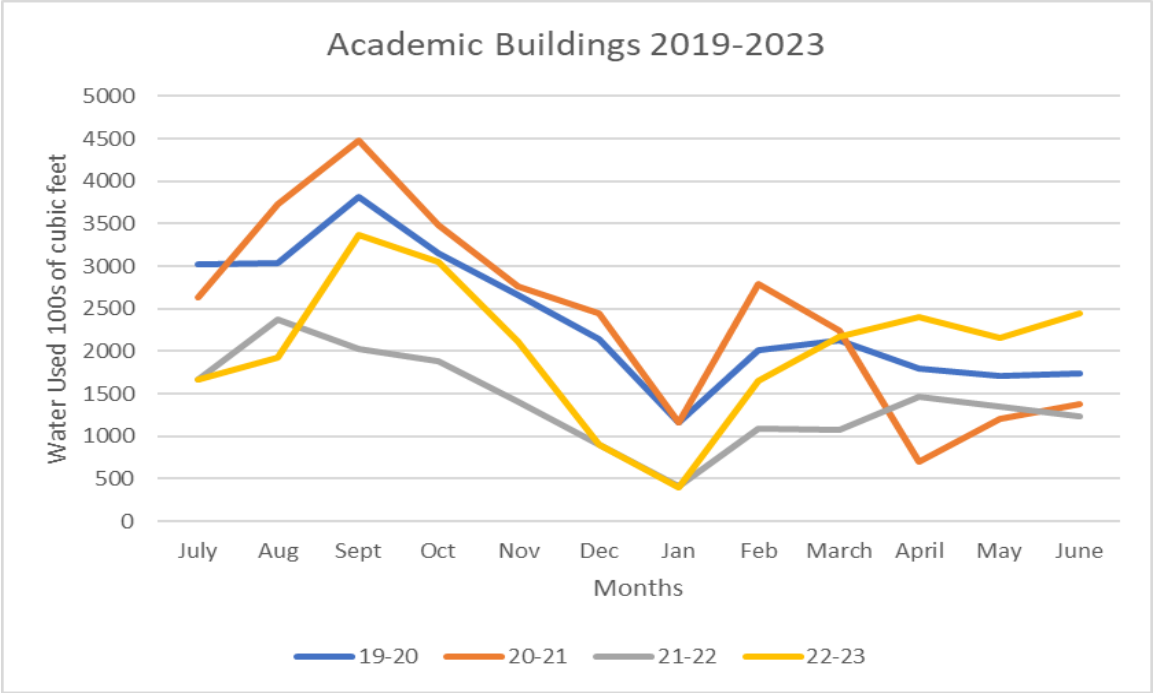

Figure 3: Monthly water usage at academic buildings.

4.1.2.2 Student Course Enrollment (SCE) Parameter of Academic Buildings

Figure 4 shows attendance in different academic buildings by SCE based on the last academic year for different academic buildings. This attendance is based on class enrollments and does not include staff or students working in the labs. This data cannot be applicable to all of the buildings because some of the buildings have a large amount of water usage due to buildings' specialties with a few classes. For example, the recreation center is one of the buildings with the highest water use, but it does not have many classes compared to other academic buildings. The building's attendance diagram shows that Salisbury Labs has the highest number of classes. In second place are Fuller Labs and Higgins Labs. In third and fourth place are Unity Hall and Atwater Kent, accordingly.

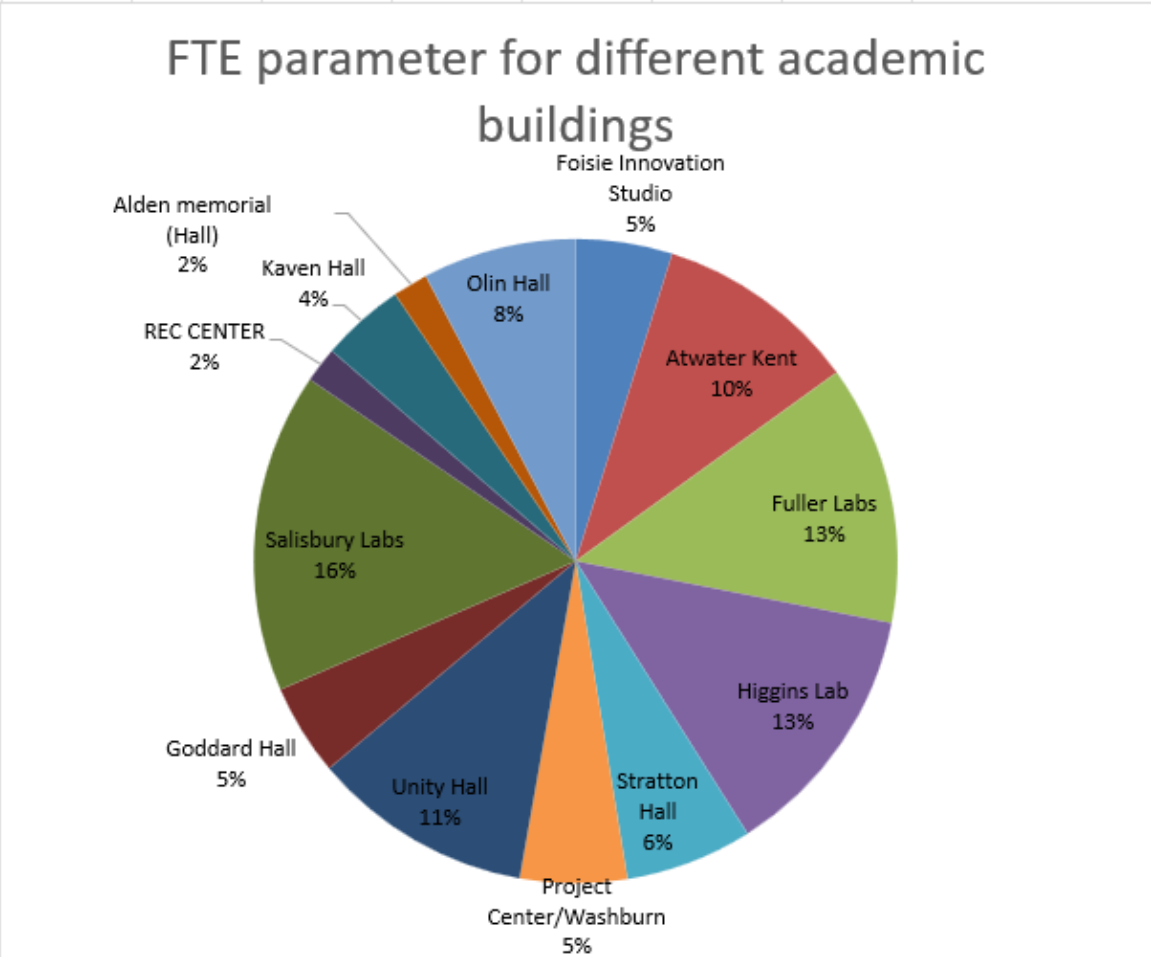

Figure 4: Academic Buildings SCE parameter.

4.1.2.3 Total Water Usage in Academic Buildings

We tried to identify the buildings on campus with the highest water consumption. Still, some buildings stand out a lot, having the highest water usage, so the following buildings will be grouped in a separate diagram because attendance cannot be applied for the buildings with the SCE parameter in **Figure 5**: recreation center, campus center, Gordon library, innovation studio, and unity hall. Behavioral changes are an important aspect of water conservation. As we can see, the Recreation Center, Campus Center, and Innovation Studio have the most significant water consumption compared to the other buildings in **Figure 6**. Still, the Unity Hall is included as a reference building for both diagrams. We found that Olin Hall, Higgins Lab, and Goddard Hall are the buildings with the highest water consumption, likely because of the number of classes. At the same time, Unity Hall has a solid average position from the water usage side.

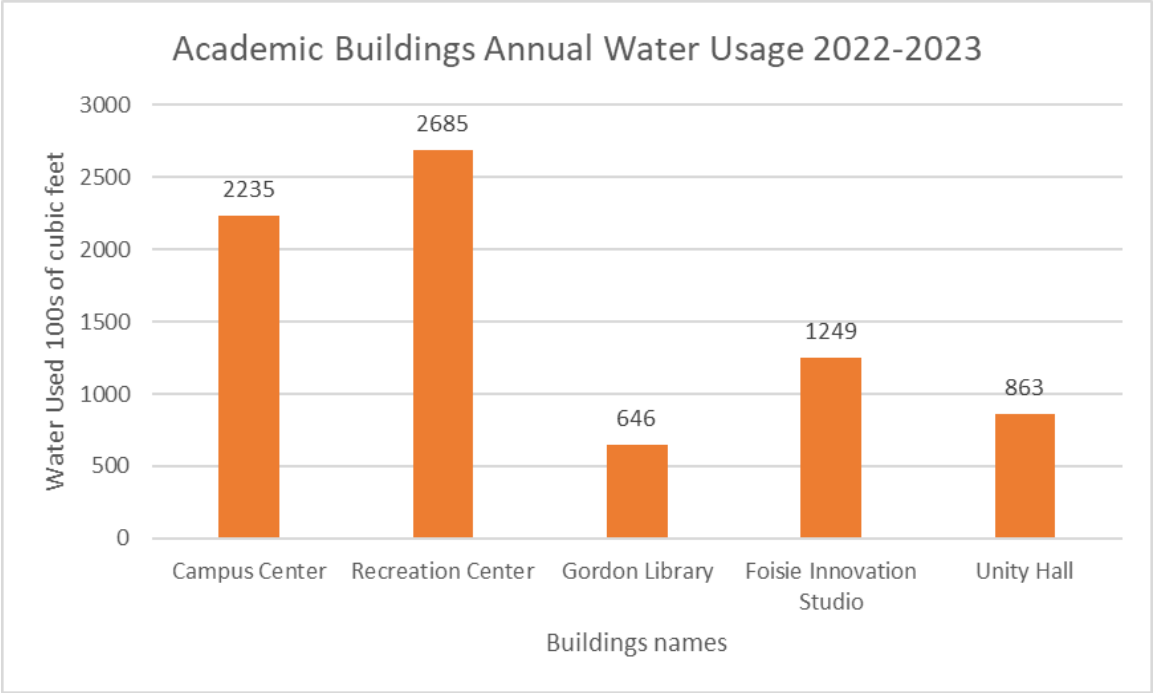

Figure 5: Academic Buildings top part.

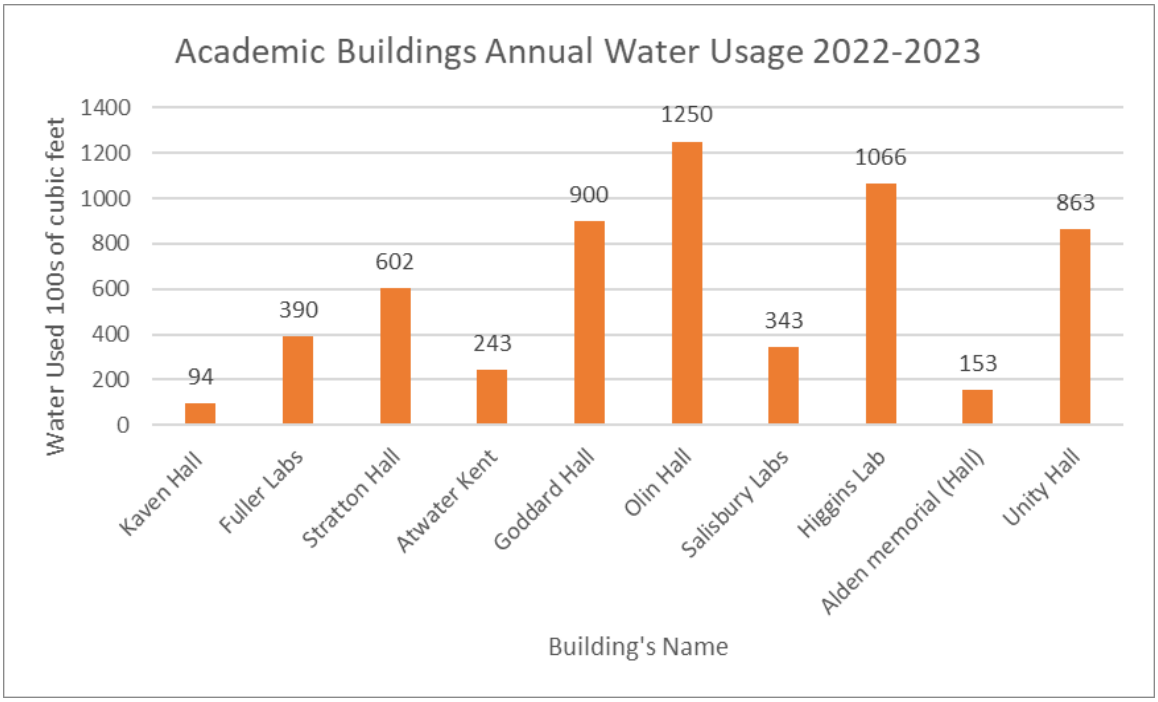

Figure 6: The rest of the Academic Buildings-relate.

4.1.2.4 Scaled Total Water Usage in Academic Buildings

Next, it is important not only to look at water usage separately but also to consider water usage for many buildings in relation to students' registration in classes. A pie chart with students' attendance (as indicated by student registrations in courses) and selected academic buildings' water usage were combined in **Figure 7.** So, the water used is in percentage equivalent to the number of students using the specific building. For example, if one building has higher water usage than another, it means that this building is more inefficient while it can have overall low water usage. One of the buildings with the highest consumption is Goddard Hall, Olin Hall, and Alden Memorial Hall.

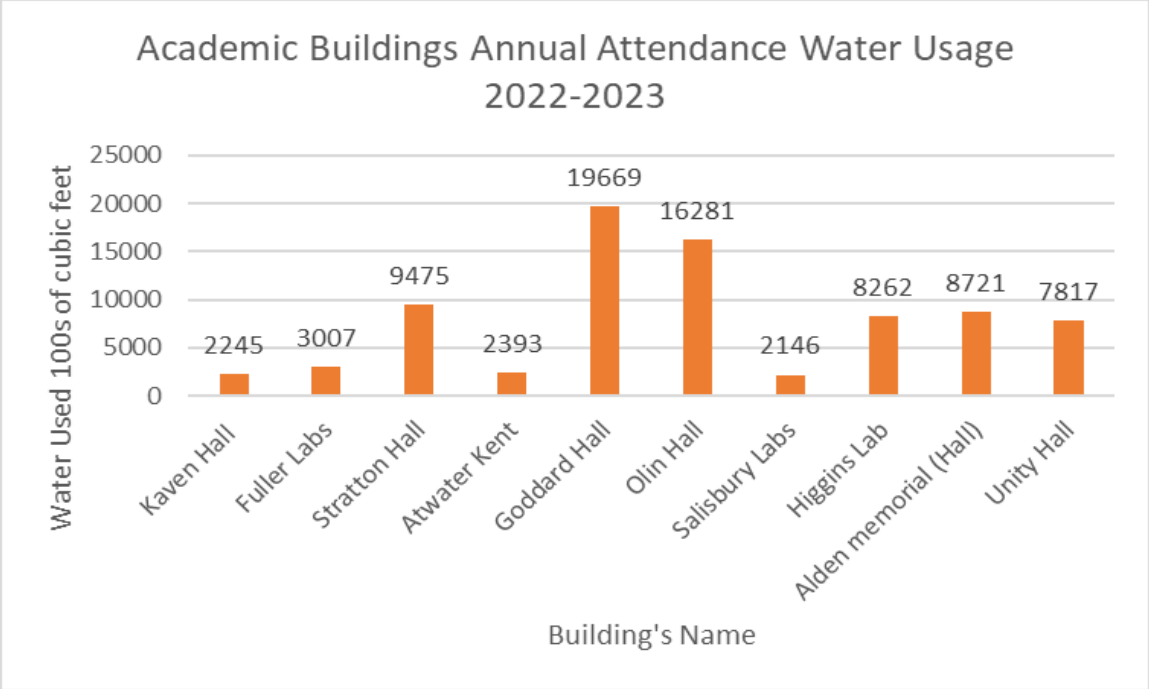

Figure 7: Water usage at academic buildings related to SCE.

4.1.3 Data of Residential Buildings

4.1.3.1 SCE Parameter of Academic Buildings

We were able to obtain overall occupancy data for the residential halls and can use this to assess water use. Based on the occupancy data of residential buildings in **Figure 9**, we found that the Founders dormitory is the residential building with the highest number of occupants.

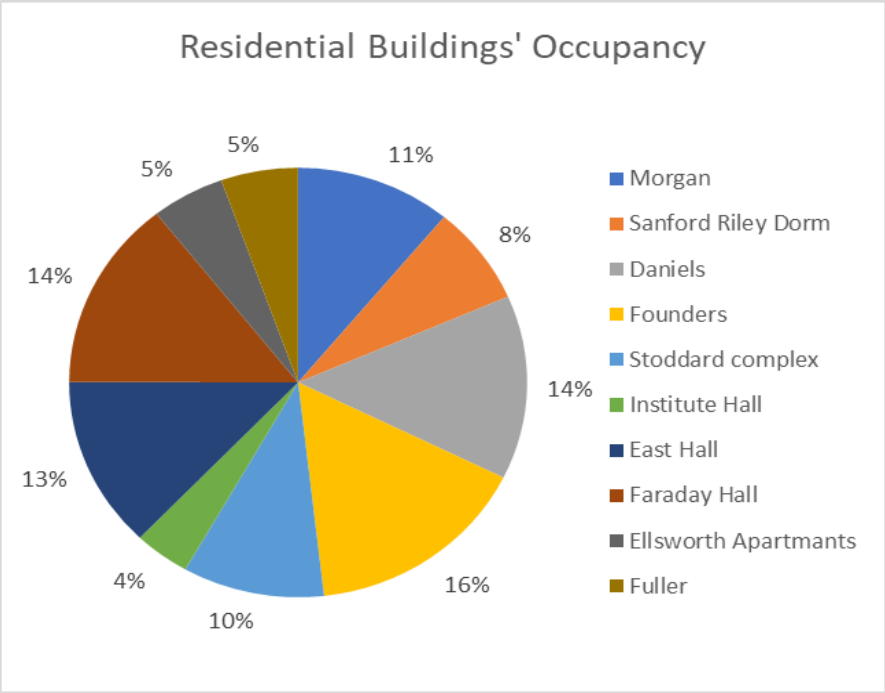

Figure 8: Residential buildings occupancy.

4.1.3.2 Total Water Usage in Academic Buildings

Also, our team considered the water usage for residential buildings. The overall water consumption trends for all residential buildings look the same, so we show data only for the 19-20 years in **Figure 8**. Morgan Hall has the highest water usage, in second place is Founders Hall, and Daniels Hall is in third place. Morgan Hall accumulates all students' years every day because this building has a cafeteria.

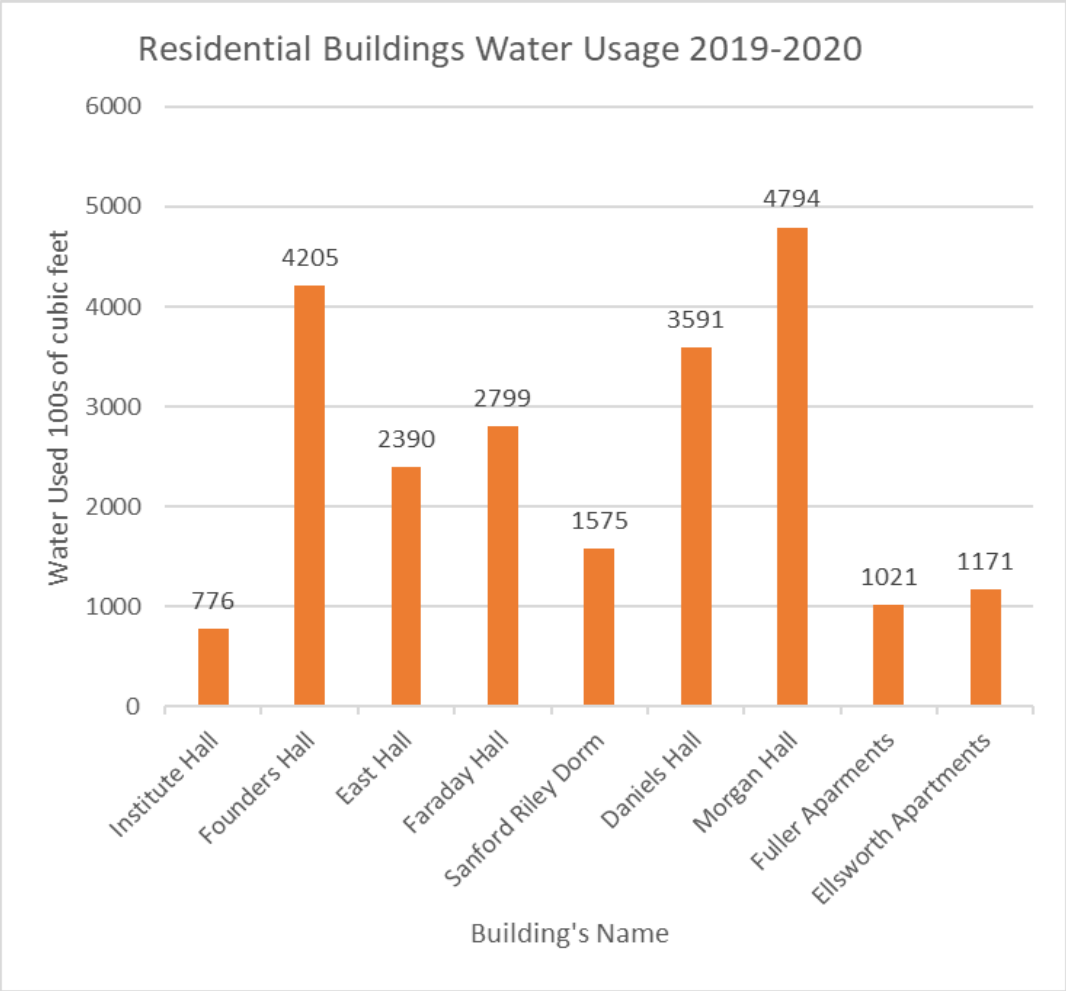

Figure 9: Residential Buildings Water Usage 2019-2020.

4.1.3.3 Scaled Total Water Usage in Residential Buildings

Also, it is important to compare the water usage for residential buildings to understand which of them needs more attention. For example, as we can see from **Figure 10,** Founders Hall is more efficient than Morgan Hall because Founders Hall has less unified water used than Morgan, but Founders has higher occupancy simultaneously.

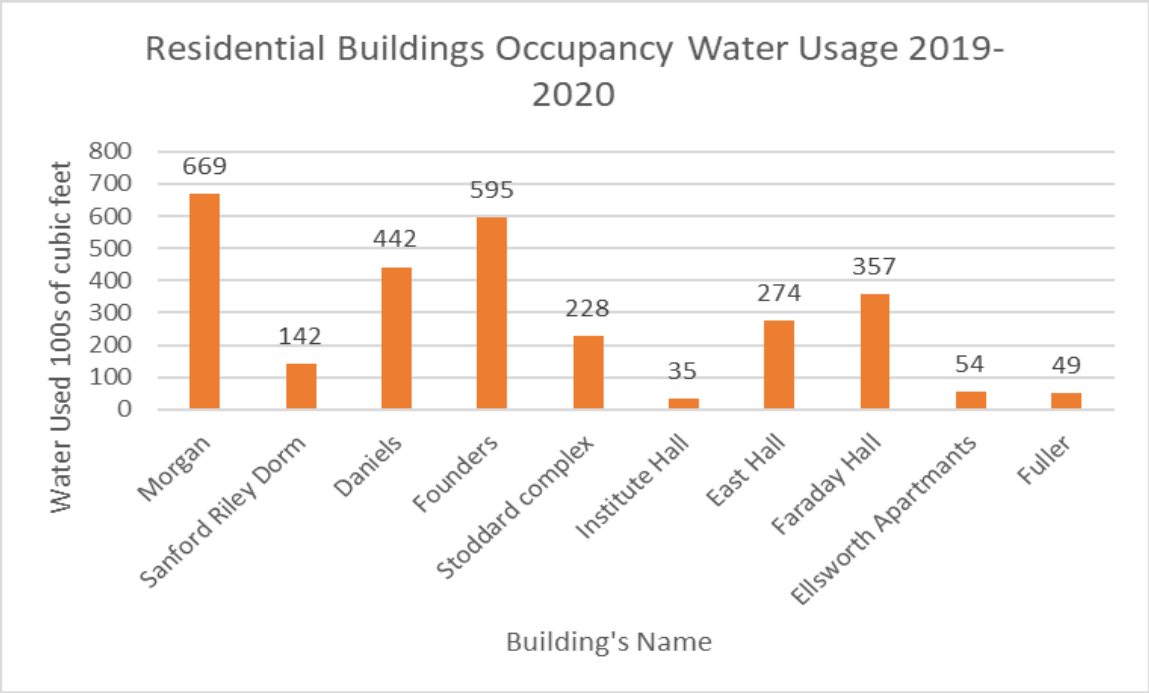

Figure 10: Residential Buildings Occupancy Water Usage.

4.1.4 Key Findings from Data Readings

From our data analyses, we found some important findings for future consideration from the water usage data. First, based on our data readings from **Figure 1**, WPI should pay more attention to academic buildings than residential buildings because academic buildings have higher annual water usage. Second, there is not a huge gap between academic and residential buildings' water usage, and residential buildings consume more water per month during the study period, based on **Figure 2**. WPI community used more water in the 22-23 period than in 21-22, but the water usage was even higher in COVID peaks. From **Figure 3**, we can note that the highest water usage per month is at the beginning of the A term. Third, we found that SCE may be helpful for academic buildings that are primarily used for classes, but it is not an effective parameter to measure water usage per person for some buildings such as the campus center, recreation center, Gordon library, innovation studio, and unity hall. One of the buildings with the highest consumption is Goddard Hall and Higgins.

4.2 Interviews

Interviews were conducted to collect different points of view on water sustainability from experts on the topic of sustainability in the Worcester area. We interviewed four people, all of whom had professional roles pertaining to sustainability. In addition, we spoke with one faculty member from WPI, who two other sustainability professionals from colleges in the Worcester area (Holy Cross and MCPHS (Massachusetts College of Pharmacy and health sciences), and a water expert from a state government agency. From these interviews, we collected data on what is needed to create a sustainable living environment to help create recommendations based on the collected data. These interviews lasted 15-20 minutes. We asked the questions detailed in **Appendix B, Questions for Experts**. These questions went through WPI Institutional Review Board. All the responses were voluntary, and participants were made aware of their right of refusal.

The first interview was with a sustainability expert from Holy Cross College. She has a bachelors in environmental studies and a master's degree in higher education. She has been working in these fields for about eight years. The program chief of water management in Massachusetts was the second interviewee. He has been working in this position since the 1990s and mainly maintains regulations and requirements in the use of water efficiency. In the third interview, a faculty member from WPI provided insight from WPI's perspective on the water conservation issue. She has been involved in the sustainability field for about 9 years. Finally, the fourth interview consisted of two subjects of the matter from Umass Chan Medical School. The first expert is tasked with moving sustainability plans ahead. The other expert is the assistant director of sustainability and campus services.

4.2.1 Issues That Stem from Poor Water Conservation Habits

Many issues stem from having poor water conservation habits, but specific issues pertain to certain locations; for example, Holy Cross College is located on a hill. The Worcester Blackstone Canal is located at the bottom of the hill. When it rains on the hill, the hail does not infiltrate into the ground. Instead, it flows directly into the Blackstone Canal. This means that when they are using pesticides, herbicides, or salting, they must be careful, or it can end up in the Blackstone River. The program chief explained how water always comes from a source, and when we take that source away, it negatively impacts biological life. All experts also stated that if the

campus needs to maintain its water consumption levels, it can be very costly to the college. Also, if there is not enough rainfall, there can be a drought in that location.

4.2.2 Higher Education's Role in the Fight for Water Sustainability

All experts believe higher education plays a unique role in the fight to become more sustainable. Students can learn good sustainability habits through schools and take that knowledge with them throughout the rest of their lives. The younger generation is our future, and through educating them, they will know how to be more water sustainable. The number of people going through different paths can bring their knowledge of water sustainability to the world.

The campus also holds a tremendous number of students using a large amount of water. Different implementations and technologies can be integrated on campuses to conserve better the amount of water used. A repetitive example throughout the conducted interviews was that schools could collect rainwater and treat it to use around the school, such as for heating buildings. Other technologies that WPI has are low shower and bathroom sink flows, Dual flushing toilets, landscaping water management, permeable parking lots, and sub-meters to measure water levels at small levels, such as in a classroom. Many colleges can participate in a public partnership to try new technologies. Experts from Umass Chan Medical School mention how Emerson College uses a technology that takes sewer water and treats it to a point where it is clean enough to use in cooling towers. It has the possibility to bring 200 million gallons of potable water to 100 million gallons of potable water saving colleges thousands of dollars on water.

4.2.3 Awareness of Water Sustainability on Campus

Schools we have interviewed express how water is on their radar but is not a primary concern due to Massachusetts having a vast amount of water supply. According to the program chief, In Massachusetts, water is an undervalued resource people believe there is a never-ending supply. People need to be made aware of the matter at hand in general. This is the same matter on campus. The expert from Holy Cross believes students may need to be made aware that water conservation needs to happen. MCPHS experts believe the students are very mindful of water consumption due to issues that come with using water conservation technologies. For example, their school cannot use low-flow technologies in their academic buildings because, being healthcare facilities, the low flows are not efficient enough to kill legionella, something that

contaminates the water supply. They also cannot use low-flow toilets in older buildings because toilets would get clogged often.

Water conservation is included in WPI's sustainability plan, but it is not high on the list, such as energy and waste. WPI does make efforts in water conservation. WPI uses low flows, dual flush toilets, etc. The WPI faculty member expert mentions that even with the low-flow showers, 20 minutes still uses too much water, so 10 minutes is a good average for a shower. WPI has also been focusing on the UN's sustainability developmental goals. WPI students are required to participate in an Interactive Qualifying Project, IQP. Students who are doing this project have the opportunity to travel to other parts of the world to conduct their research.

Since some students travel to other parts of the counties where water could be scarce, taking knowledge of water sustainability with them can come in handy. WPI uses a power plant to heat buildings on the main campus, creating steam to heat buildings. This uses a tremendous amount of water. The power plant is located in front of the project center. WPI is now partnering with Harrison Street to become carbon neutralized and redesign the power plant. Students need to be made aware of required water conservation habits. Water signage needs to be more consistent in WPI, and students will be more knowledgeable with more fun, consistent signage. Another way to bring attention to water conservation is by shower timers. Also, peer education will motivate more students to conserve water.

4.2.4 Interview Findings

With more awareness, communities can take individual roles in making whole communities more water sustainable. This first starts with making students aware of how important water conservation is. Through what colleges teach and peer education, students can obtain better water-sustainable habits, helping decrease water usage. Students seem to respond more through engaging signs or what students can teach other students. Water is a very undervalued resource, so the importance of water must be made known. Water-saving technologies such as low-flow fixtures, water hubs, water reuse systems, and mini-water meters were also recommended. Some schools are not able to use or afford expensive water technologies due to infrastructure, so keeping students aware is essential. Hence, they are able to conserve water on their own is very important.

4.3 Surveys

To assess how student water conservation habits affect water sustainability at WPI, a series of surveys were created intended for the WPI community to take. A total of 178 participants, 38 on-campus students, 28 off-campus students, 23 faculty, and 80 staff were able to participate in this survey. The survey questions can be found in Appendix C. This survey aims to compare the WPI community's water conservation habits to WPI's water usage data to assess water sustainability on WPI's campus. This survey consisted of 9 questions for on-campus students, 7 questions for off-campus students, and 8 questions for Faculty and Staff. Students, faculty, and staff were sent a link or QR code to their email and could anonymously partake in the survey. Since this survey only takes 3-5 minutes, is anonymous, and is voluntary, there is minimal risk to the participants. Through the results, credible recommendations can be made on areas where water conservation can be improved and what implementations can be in place to ensure water sustainability on WPI's campus. The survey question went through WPI's IRB Institutional Review Board.

The surveys were divided into four groups to compare the water conservation habits that different groups on campus have. Live on-campus and live off-campus surveys were made because students who live on campus use water from their residence hall while off-campus students do not. For both these surveys, the question "*What year are you?"* was asked to see response trends for freshman, 2nd year, 3rd year, 4th year, and graduate students. This was done to assess what group had more sustainable water habits. The Staff and Faculty surveys consisted of the same questions, separated to see trends in staff responses versus faculty responses. The figure below displays that we surveyed a total of 178 participants. It was important for us to understand the different roles and positions people had and get diverse roles. As you will see below, there are 38 on-campus students, 28 off-campus students, 23 faculty, and 80 staff were able to participate in this survey.

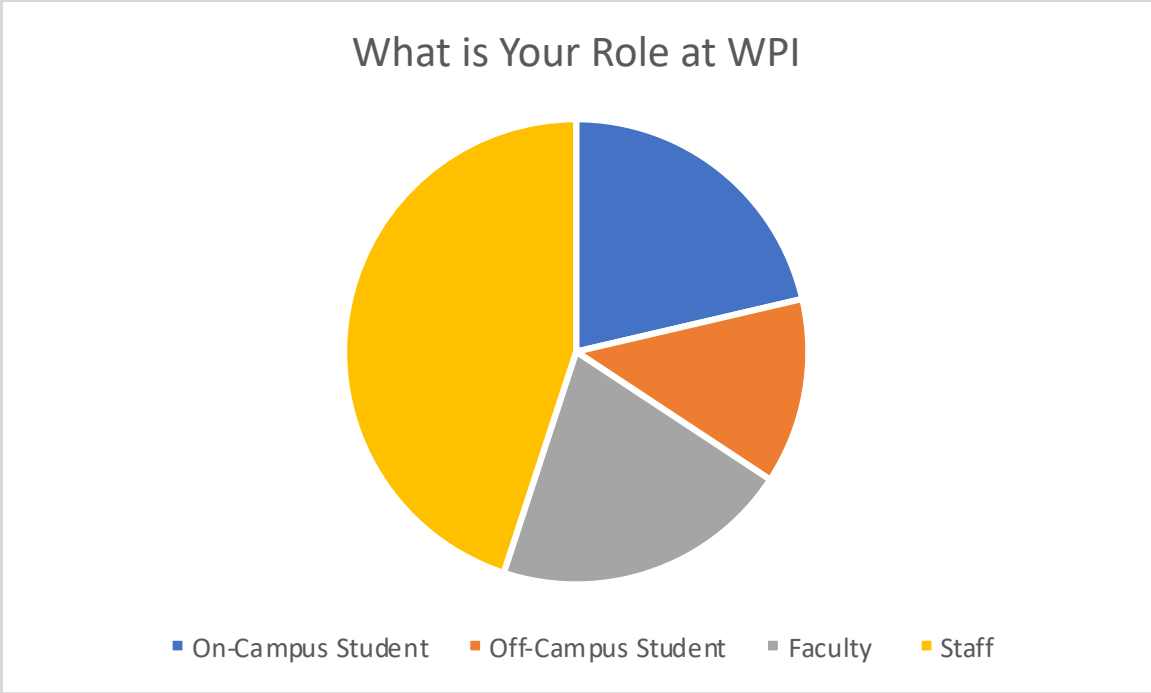

Figure 11: Display of the participants.

4.3.1 On-Campus Survey

Questions for the on-campus survey are in Appendix C under the student on-campus questionnaire. This questionnaire consisted of 20 First year students, 8 Sophomores students, 7 juniors, and 3 seniors. No graduate students participated in this questionnaire. The first question is: How important is water conservation to you? 10% of students thought water conservation was not important, 27% thought it was slightly important, 37% thought it was moderately important, 23% thought it was very important, and 3% thought it was extremely important. When accessing what buildings students use most when using the restroom facilities when they fill their reusable water bottles up, and when they responded, it was found that students on-campus use their residence hall to perform these daily activities. The top 3 Residence Hall that made the most occurrence is Morgan Hall, Daniel Hall, Stoddard Complex, and Founders Hall, which makes sense since this survey consists of mostly first and second-year students, and these buildings hold mostly first and second-year students. However, since the participants were not more evenly distributed in the school year, it is impossible to tell which residence buildings students use most in terms of water use.

Question 4 asks students how often they usually fill up their reusable water bottles per day on campus. This question was asked to assess how often each student uses water bubbles on average, as seen in **Figure 12**.

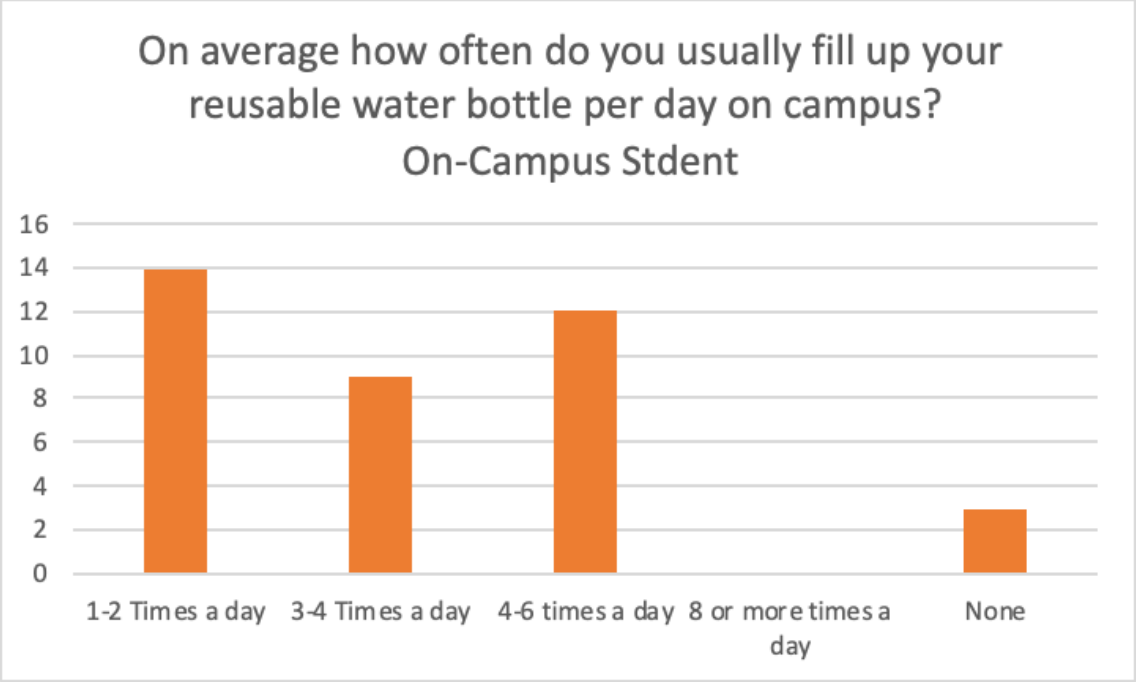

Figure 12: Display of water bottle fills per day for on-campus students.

The average bottle size is 16.9 oz. That means if a student is filling their water bottle up 6 times per day, they are using 101.4oz of water to fill their water bottle. This is necessary; everyone should be able to fill their water bottle as often as possible. However, to be able to do this, water conservation needs to happen in other areas, such as reducing the number of times one shower. **For example, figure 13** shows that the average shower among on-campus students is 10-20 minutes, and **Figure 14** shows that students shower once daily.

Figure 13: Students' average shower length

Figure 14: Times-a-day students shower.

4.3.2 Off-Campus Survey

Questions for the off-campus survey can be found in Appendix C under the off-campus student questionnaire. This questionnaire consisted of 0 First year students, 7 Sophomores students, 9 juniors, and 7 seniors. The first question How important is water conservation to you? 0% of students thought water conservation was not necessary at all, 10 percent thought it was slightly important, 52% thought it was moderately important, 38% thought it was very important, and 0% thought it was extremely important. Next, we found the top 4 buildings students use the restroom facilities in and fill their reusable water bottles consistent with each other. The top 4 buildings are Unity Hall and Higgins Lab. Olin Hall, and Goddard Hall. Question 5 asks students how often they usually fill up their reusable water bottles daily on campus. This question was asked to assess how often the water bottles are used averagely filled by each student, as seen in **Figure 15**.

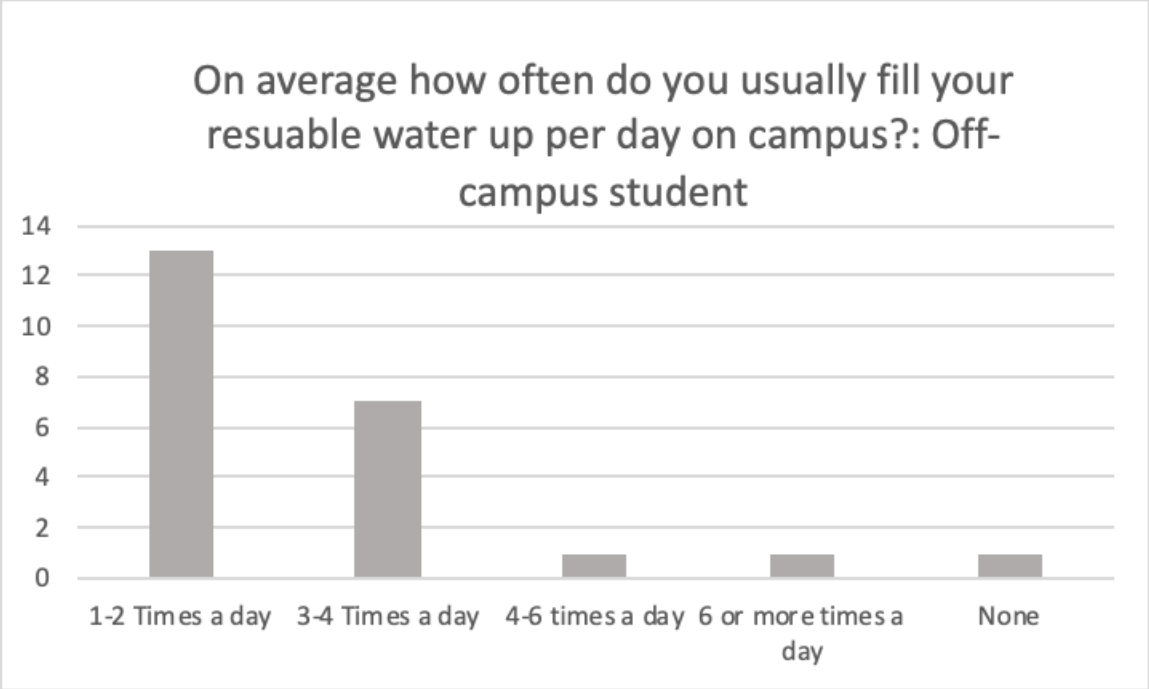

Figure 15: Display of water bottle fills per day for off-campus students.

4.3.3 Faculty and Staff Survey

The Faculty/Staff survey questions are in Appendix C under the off-campus student questionnaire. The questions for Faculty and Staff were the same but split into two groups to assess

whether staff and faculty had different levels of knowledge and water habits. Unfortunately, there was not any significant. This questionnaire consisted of 0 First year students, 7 Sophomores students, 9 juniors, 7 seniors, and 1 graduated student. The first question is, how important is water conservation to you on a scale of 1-5? Figure 6 shows that 0% thought water conservation was not important at all, 10% percent thought it was slightly important, 52% thought it was moderately important, 38% thought it was very important, and 0% thought it was extremely important. If we compare these findings with First-year sophomores, juniors, seniors, and graduated students, the average level of importance rises with grade level. We found the top 4 buildings students use the restroom facilities in and fill their reusable water bottles consistent with each other. The top 4 buildings are Gateway, Higgins Lab, Salisbury Labs, and the Bartlett Center. Question 5 asks faculty and staff: How often do you usually fill up your reusable water bottle per day on campus? As seen in **Figure 16**.

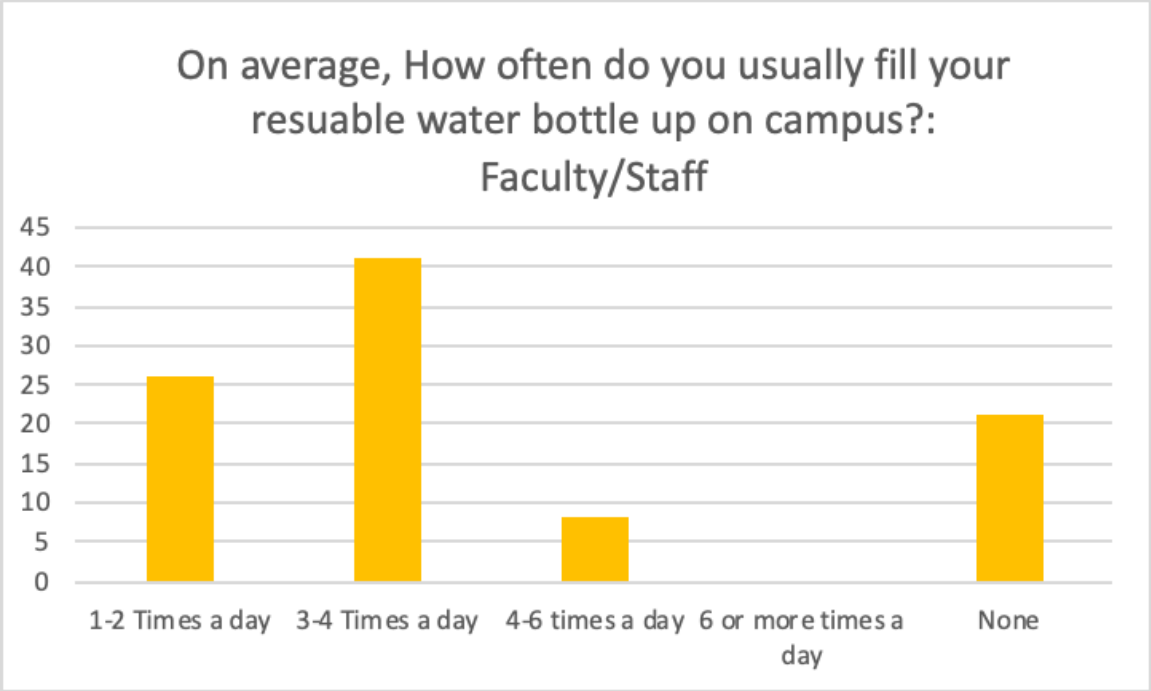

Figure 16: Display of water bottle fills per day for on-campus students.

Do you believe water consumption is an issue on WPI's campus was also asked in this questionnaire, and the majority did not know if it was even an issue on campus? The results are in **Figure 17**; 26% said Yes, 56% said Maybe, and 18% said No. Do you feel like you understand what is needed to ensure sustainable water use of WPI's campus questions results are shown in **Figure 18? Again,** 16% of participants said yes, and 85% said no.

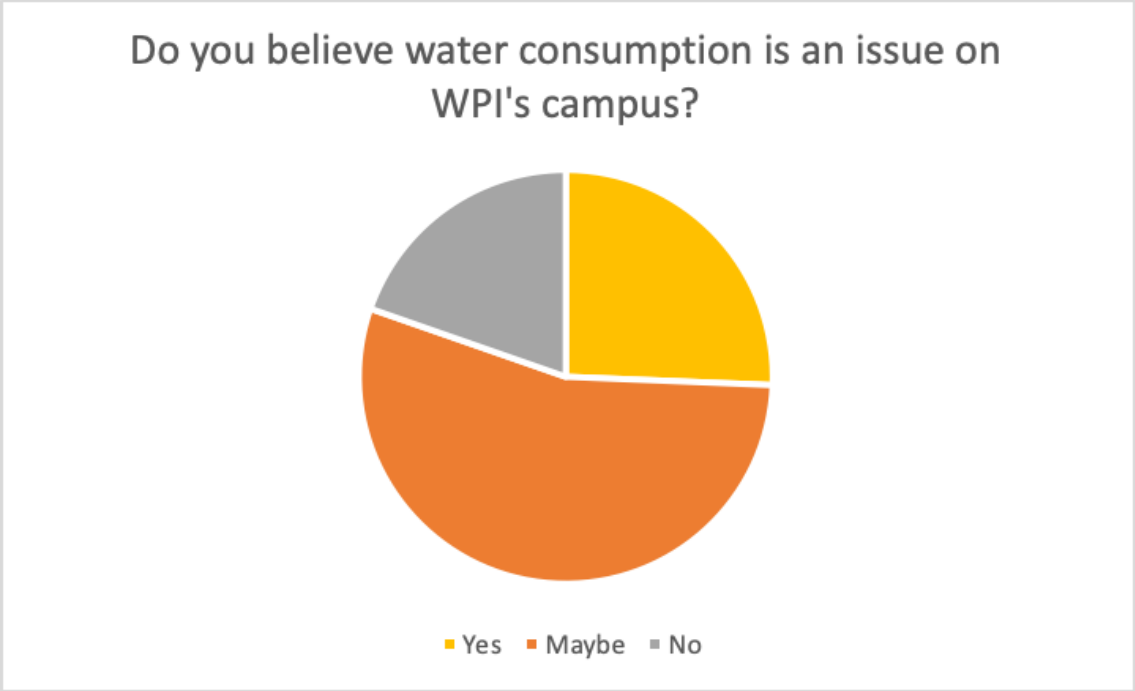

Figure 17: Faculty/Staff belief if water consumption is an issue on campus.

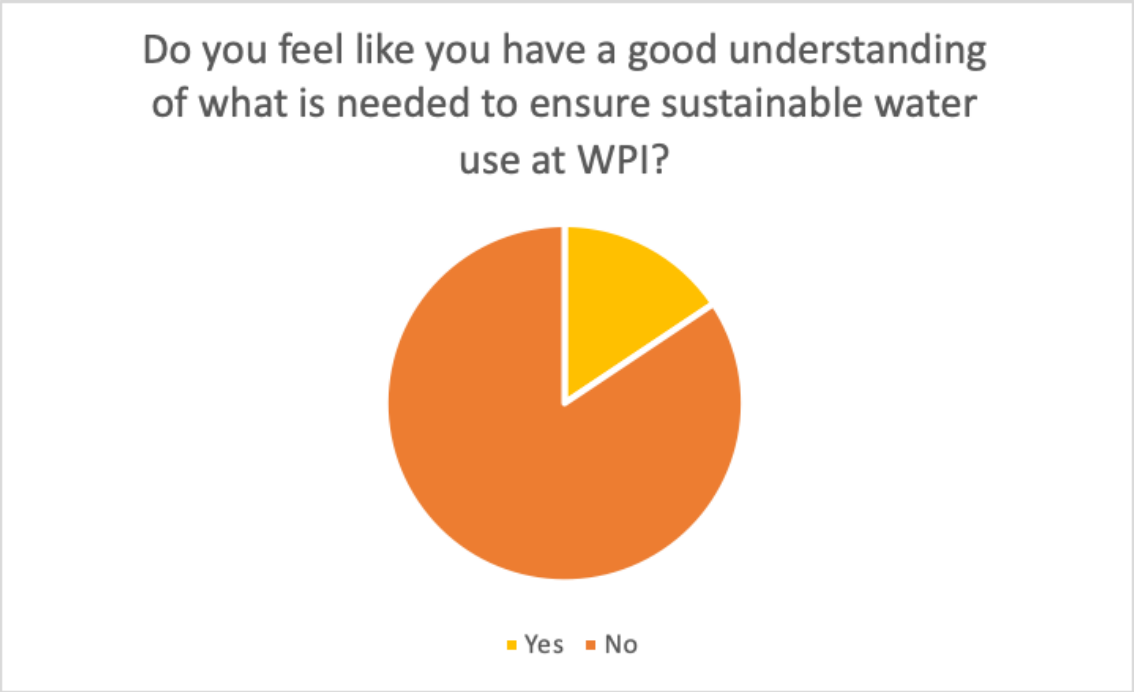

Figure 18: Faculty/staff distribution of who knows what is needed to ensure sustainable water use at WPI.

4.3.3 WPI Community's Perception of Water

The surveys show that most of the WPI community is unaware of how important water is. Students who reside on campus take showers for 20 minutes or more and shower twice a day using large amounts of water per day. The importance of water conservation is not as high as everyone should think of water conservation as extremely important. Even some faculty and staff do not believe water consumption is an issue on campus, but WPI data shows that buildings sometimes use a huge amount of water. This all comes down to awareness. The WPI community needs to be more aware of how their water use habits affect overall water usage and conservation for the university.

4.4 Summary and Discussion of Findings

Based on our analysis, the WPI community should focus on academic and residential buildings' water usage even though academic buildings have higher annual water usage, based on **Figure 1**. Because academic buildings have higher water usage, there should be efforts to ensure there is no leakage, loss, or inefficient use of the systems. It is important to realize that water usage control in residential and academic buildings is different because water usage in residential buildings mostly depends on students' awareness and behavior. At the same time, these two factors play less role in academic buildings' water consumption. It means that people's awareness can significantly decrease water consumption in residential buildings. For example, the students can shower in much less time than 20 minutes, and only through that change will the annual water consumption be much less. However, it is important to consider some more facts. First, residential buildings consume an even higher volume of water in the study period during some months than academic buildings, based on **Figure 2**. Second, overall, people's awareness of the water conservation problem will affect water consumption everywhere, whether to be academic buildings or residential. According to the survey, most students do not consider water conservation extremely important, as shown in **Figures 19, 20, 21, and 22**. The survey asked a question based on water conservation's level of importance. As grade level increases, the importance of water conservation to the participants' levels increases as well. There needs to be more awareness when it comes to water. 56% of the teachers do not know if water conservation is an issue on campus, and 18% believe it is not an issue.

According to the data, there is more significant water consumption in the 22-23 academic year compared to the 21-22 academic year. However, in COVID peaks, the water consumption was even larger because people needed to wash their hands more frequently and follow sanitation norms. After all, WPI was not closed for fully remote classes (The COVID-19 Pandemic: A Timeline.). Also, based on **Figure 3**, the possible reason for the highest water consumption each year at the beginning of A term is that freshman-year students do not get used to new environments and WPI community water conservation habits.

We found that SCE cannot be a very effective parameter to measure water usage per person for some buildings such as the Campus Center, Recreation Center, Gordon Library, Innovation Studio, and Unity Hall. The possible reason is that many students use the gym daily and spend their free time in these buildings. Also, many students prefer to do class assignments and study in academic buildings. One of the buildings with the highest consumption is Goddard Hall and Higgins. The reason could be that students usually hang out there in their free time. Goddard Hall's water consumption is so high because it has many labs for the physical, biomedical, and chemistry departments. Higgins has one of the biggest amounts of consumable water per year because it has one of the highest SCE parameters and also some labs. However, the campus center has a larger water consumption due to many students relaxing in that building; the same cases can be applied to the recreation center, innovation studio, and Unity hall. Unity Hall was built according to the last water/energy standards, so it should be efficient. In the survey, Unity Hall and Higgins Lab are the most used buildings throughout campus for students' academic buildings. Olin Hall, and Goddard Hall. This consistently lines up with the data for academic water usage.

In order for water conservation efforts to be successful, the activities and associated interventions need to be realizable and realistic. It is impossible to rebuild all the buildings on the campus according to the newest standards in water consumption, so student behavior and awareness are very important to consume less water as a WPI community. For example, Figure 10 shows that Founders Hall consumes less water than Morgan Hall, while Founders Hall has higher occupancy. That may be because the Morgan Hall cafeteria requires Hall cafeteria requiring much more water than the 4% of students difference between the SCE parameter of these buildings. Therefore awareness of water consumption needs to be implemented. One purpose of the survey was to collect levels of understanding of sustainable water habits in First-year students, sophomores, juniors, and seniors. Below, the figure shows the data collected in these four groups.

It shows the importance of water conservation is mostly moderately important or below. Although it is also shown that with grade level increase, the importance level also increases. This may be due to knowledge gained about sustainability throughout students' college years, proving that awareness is necessary to obtain water-sustainable habits.

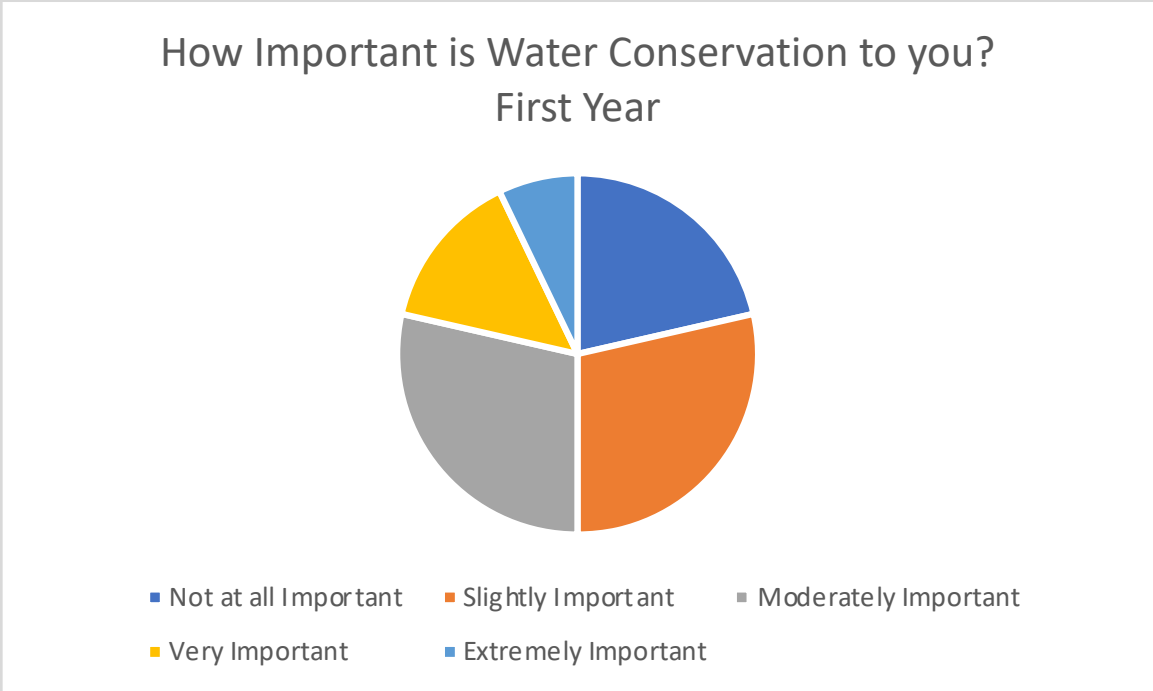

Figure 19: How vital water conservation is to first-year students

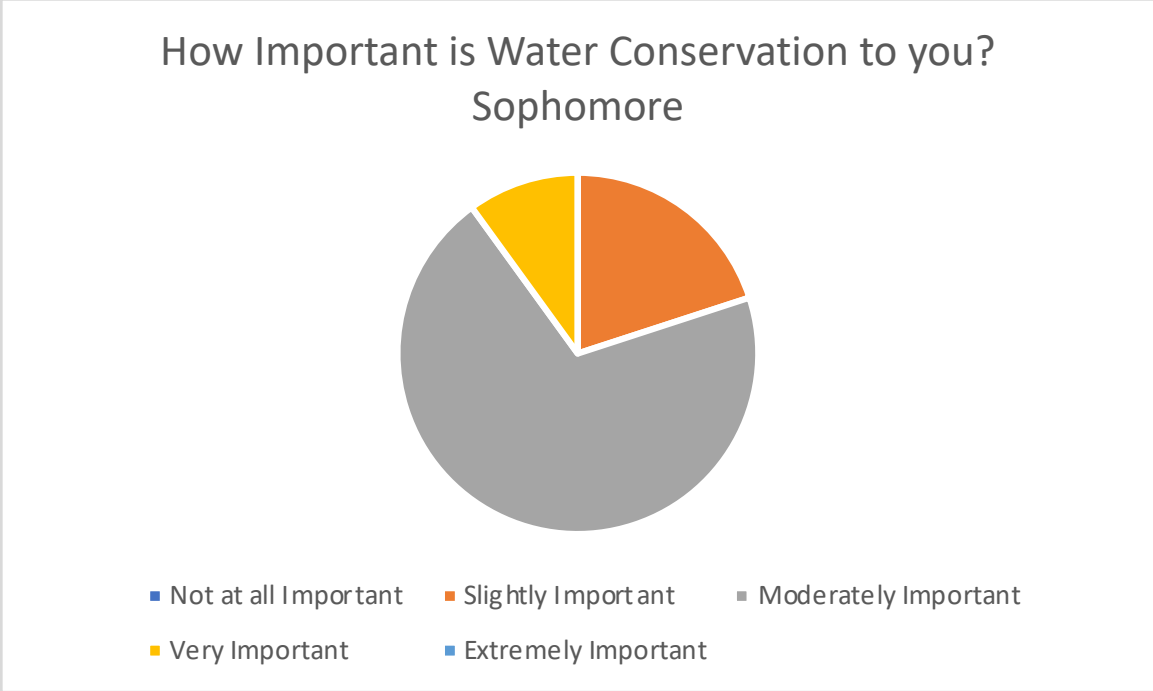

Figure 20: How important water conservation is to Sophomores.

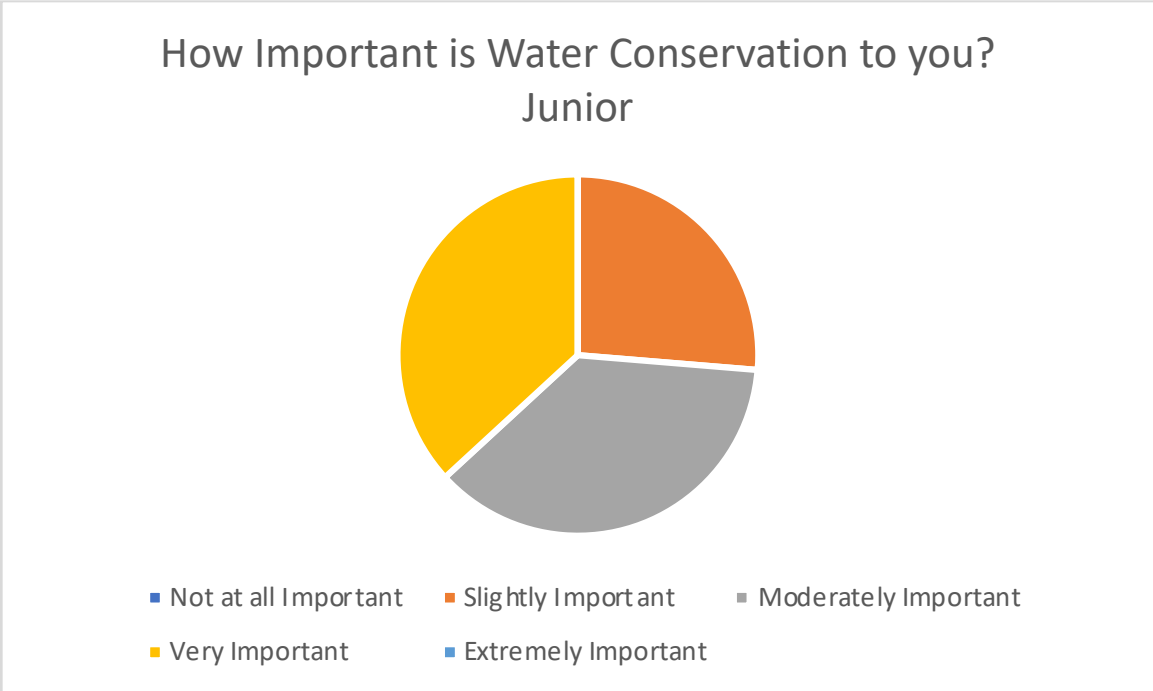

Figure 21: How important water conservation is to Juniors.

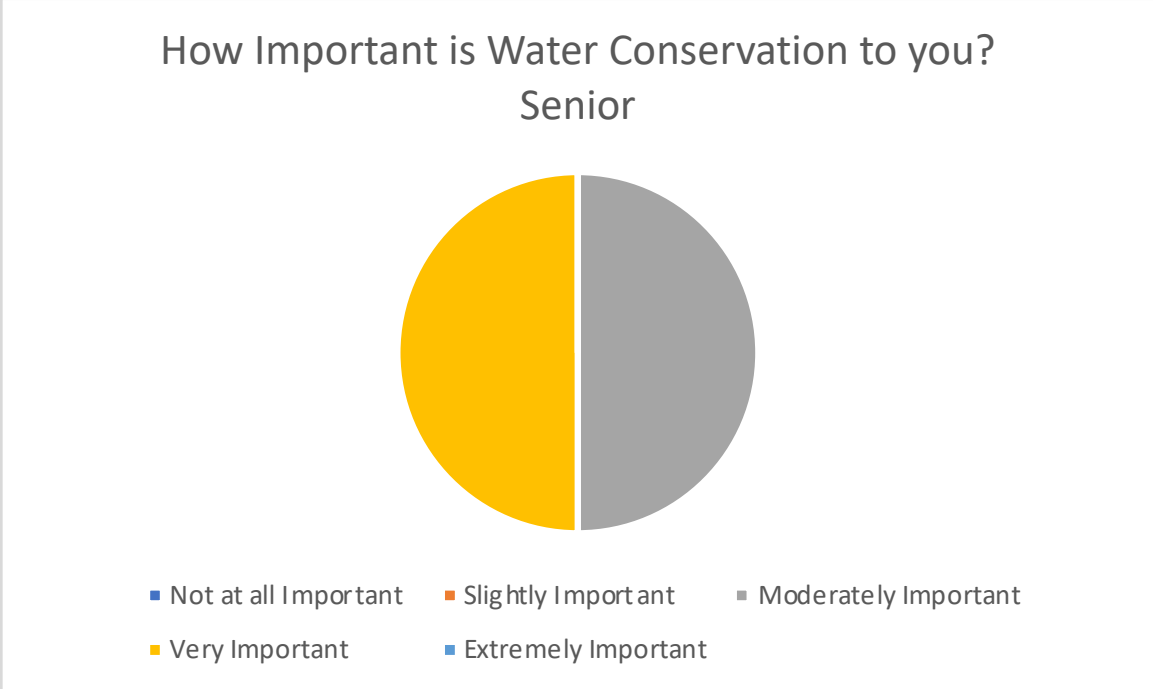

Figure 22: How important water conservation is to Seniors.

5.0 Recommendations

This section discusses recommendations that were created from data collected from interviews and surveys. It was found that students are not as aware as they should be of water conservation habits and the importance of water. A class on water sustainability and promoting water conservation through signs around the school is an excellent way to get students to be more aware. Technology implementations were discussed during interviews, and the recommended choices were made based on what WPI already implemented on campus. WPI has low-flow fixture technologies already on campus. The recommended technologies could not only help WPI conserve water but also help WPI save on the cost of water in the long run. These technologies include water reuse technology, an upgraded heating system, and investment in submeters.

5.1 Recommendation 1: Awareness / Consistent Signage

In the interviews, it was brought to attention that WPI needs to use consistent signage around WPI to encourage water conservation habits. More fun signage throughout campus would engage students in the help to make WPI more water sustainable. Through surveys, it was realized that students should be more aware when it comes to water. There are a few clubs on campus that work with environmental issues, such as the Green Team, and if they were to make these signs, it would encourage other students to want to save water through peer education.

5.2 Recommendation 2: GPS Course

From survey data and interview data, it is found that students are unaware of issues stemming from poor water conservation habits. Every student who comes to campus is different and learns different things before coming to college. The college's job is to ensure that what students learn will benefit the future. WPI offers Great Problem Seminar (GPS) classes where first-year students focus on solving problems focused on themes of global importance. WPI should create a GPS course on the water to educate students on why water is important and how we can conserve it.

5.3 Recommendation 3: Rainwater Collection and Water Reuse System

Rainwater reuse has become a trend on campus that can save money and reduce water consumption levels. Rainwater harvesting is when schools can collect a large amount of rainwater from roofs on campus. This can result in non-potable water use, such as for plumbing, irrigation, and heating buildings on campus. This method can also help to reduce overflows and other pollution from stormwater runoff. There are many different rainwater collecting systems, so WPI can design one to work well on campus. For example, WPI has a stormwater reuse system that was installed for the Recreation Center and could not be used as initially anticipated. However, that system can still support the irrigation system on Campus. Also, other water reuse systems can take grey water and use it for other purposes, but finding the proper system is a hard process, and most of them are expensive.

5.4 Recommendation 4: Upgrade of Water Distribution System

WPI currently uses a power plant that emits steam to heat many of the buildings on campus. This requires a lot of water, so it is recommended that WPI find a more efficient heating system throughout campus or use reused water to heat the buildings. This will save WPI money on water. WPI has had some proposals to convert their steam heating system to hot water. Princeton University has done something like this, where they installed a hot-water energy system driven by electric heat pumps. Using a hot water energy system is more energy efficient and easier to control.

5.5 Recommendation 5: Sub-meters

WPI already uses water meters to see water levels in buildings. WPI could invest in sub-meters, which are mini water meters that can give water level data on a small scale, such as in a classroom or on a floor. The benefit of this is that if there is ever a small leak in a building, the exact location of the leak can be found immediately. Small leaks can make a big difference in water numbers; this will reduce the number of leaks there could be around the school.

6.0 Conclusion

Water conservation must be a priority for higher education in order to provide essential water resources for all and to help meet the UN Sustainable Development Goals. Our project endeavored to understand the priority that students, faculty, and staff at one institution place on water conservation and potential source solutions for the future. Through surveys, interviews, and direct data collection, actionable, credible recommendations were created based on awareness and new innovations. We discovered most of the academic and residential buildings for water usage for the past three years and defined the buildings with higher water consumption than the others. Also, we defined that the SCE parameter can be ineffective for some of the buildings, like the Campus Center and Recreation Center, the most significant water usage parameter specificity. The surveys gave insight into WPI's community's water conservation habits and were compared to actual water usage data at WPI. It was discovered that community awareness plays a big part in water sustainability at WPI. If everyone is aware of water conservation and knows what habits are needed in order to maintain water sustainability on campus, this could decrease water usage levels. Water is a necessity in everyday life but is a very undervalued resource. Awareness is the key to ensuring water sustainability stays in good standing on campus. Through fun, consistent signage throughout the school, peer education, and colleges, knowledge can teach students about sustainability and can ensure better conservation habits. With good water conservation habits, schools can focus solely on converting to water-sustainable technologies. There is no guarantee that Massachusetts will be able to provide the amount of water it has been providing forever, especially if actions are not taken to protect our water resources better. Water conservation needs to be taken more seriously because even though it is an undervalued, often taken-for-granted resource, it is one of the most valuable resources humans need.

Resources

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Appendices

A. Data collection timeline

Week 1	All the background research is completed. Survey and Interview Questions are starting to be created.
Week 2	Methodology Outline is created.
Week 3	Survey and Interview data collection is started. Qualtrics created the survey. The Interview questions were created to interview five experts on their expertise. WPI water usage data on campus was collected to compare to student behaviors.
Week 4	Data collection is continued.
Week 5	Data collection is finished. Final graphs and combined results were put together. Then, a final draft of the paper is started.
Week 6	The final draft of the paper is completed.
Week 7	The project is completed.

B. Questions for Experts:

1. Can you tell us a bit about your current role?
2. How would you define your role in sustainability/sustainability research?
3. For how long have you been working on issues of sustainability?
4. How would you characterize your organization's efforts in water conservation and clean water? What are the issues that stem from not having efficient water conservation on campuses?
5. What role does higher education play in participating in the fight for sustainable water use, as this is a global issue?
6. What are some of the most efficient water technologies that can be integrated on campuses, and are there new directions to manage water consumption on campuses?
7. How much do you believe that students are aware of efficient water consumption and its importance?

8. What steps can be taken to increase awareness among the students about freshwater conservation?
9. What are the hardest challenges that universities have on the path to a water-efficient campus?
10. Is there anything else you've come across in your experiences that you believe can help water conservation on WPI's campus, or is there anything I missed that I need to know about campus water efficient usage?

C. Survey Questions:

What is your role at WPI?

- Full-Time Student
- Part-Time Student
- Full-Time Staff
- Part-Time Staff
- Full-Time Faculty
- Part-Time Faculty

Student On-Campus Questionnaire

What year are you at WPI? (If you are not a student, please answer NONE)

- First Year (1)
- Sophomore (2)
- Junior (3)
- Senior (4)
- Graduated Student

How important is water conservation to you, on a scale of 1 to 5? [SS5] 1 represents little importance, while 5 represents great importance.

- 1 - It is not important to me
- 2- It is barely important to me
- 3 - It is somewhat important to me
- 4 - It is very important to me
- 5 - It is extremely important to me

On average, how often do you usually fill your water bottle up per day on campus?

- 1-2 times a day
- 3-4 times a day
- 4-6 times a day
- 6-8 times a day
- 8 or more times a day

When using the restroom facilities, What building do you use most?

- Type in the Answer

What buildings do you use to fill your reusable bottles with water most?

- Type in the Answer

On average, how many times a day do you shower?

- Once a day
- Twice a day
- 3 times a day

What buildings do you shower in most often?

- Type in the Answer

How long is your average shower?

- 5- 10 minutes a day
- 10 - 20 minutes a day
- 20 - 30 minutes
- 30 minutes or more

Student off Campus Questionnaire

What year are you at WPI? (If you are not a student, please answer NONE)

- First Year (1)
- Sophomore (2)
- Junior (3)
- Senior (4)
- Graduated Student

How important is conserving water to you, on a scale of 1 to 5? 1 represents little importance, 3 represents mild importance, while 5 represents great importance.

- 1 - It is not important to me
- 2- It is barely important to me

- 3 - It is somewhat important to me
- 4 - It is very important to me
- 5 - It is extremely important to me

When using the restroom facilities, what building do you use most?

- Type in the Answer

When are you on campus? Which two buildings are you in most often?

- Type in the answer

How often do you usually fill your reusable water bottle up per day on campus?

- 1-2 times a day
- 3-4 times a day
- 4-6 times a day
- 6-8 times a day
- 8 or more times a day
- I do not have a water bottle

What buildings do you use to fill your reusable bottles with water most?

- Type in the Answer

Staff/Faculty Questionnaire

How important is conserving water to you, on a scale of 1 to 5? 1 represents little importance, 3 represents mild importance, while 5 represents great importance.

- 1 - It is not important to me
- 2- It is barely important to me
- 3 - It is somewhat important to me
- 4 - It is very important to me
- 5 - It is extremely important to me

Do you believe water consumption is an issue on WPI's Campus

- Yes
- No

When using the restroom facilities, What building do you use most?

- Type in the Answer

How often do you usually fill your reusable water bottle up per day on campus?

- 1-2 times a day

- 3-4 times a day
- 4-6 times a day
- 6-8 times a day
- 8 or more times a day
- I do not have a water bottle

What buildings do you use to fill your reusable water bottle up with water most?

- Type in the Answer

Does your position include knowledge of sustainable water use?

- Yes
- No

If you answered yes to the question above, please provide a short description of your perspective on how important water consumption is on WPI's campus.

- Type in the Answer