Analysis for Sustainable Non-potable Water in Conjunction with OSU Facilities and Sustainable Water

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FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

THE OHIO STATE UNIVERSITY

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Executive Summary

The Ohio State University (OSU) is constantly seeking to be a cutting-edge university and that includes leading in sustainability. To this end, the university has developed a set of sustainability goals, grouped into four categories: Teaching and learning, research and innovation, outreach and engagement, and resource stewardship. OSU has begun to collaborate with a private company, *Sustainable Water*, to implement a water management and reclamation system on campus called the WaterHub® that could help OSU realize some of these goals.

The first objective of our project was to determine how partnering with *Sustainable Water* to build their WaterHub® facility on campus would impact the stated sustainability goals of the university. The second objective was to provide evidence and support for the partnership. The university has a total of 14 defined Sustainability Goals. Our team narrowed down to four goals that will be the most affected by this project. These four are (the main category of each is in bold):

1. **Resource Stewardship:** Reduce potable water consumption by 5% per capita every five years, resetting baseline every five years.
2. **Teaching and Learning:** Deliver a Curriculum that provides Ohio State students at all stages of instruction with opportunities to understand sustainability holistically, framed by the environment, science, technology, society, the economy, history, culture, and politics.
3. **Teaching and Learning:** Address the Complexities of Sustainability through a variety of learning formats, strategies, and occasions.

4. **Resource Stewardship:** Increase campus ecosystem services by 60%, by 2025 (Sustainability Goals, 2020).

One of the ways to accomplish these goals to develop sustainability projects on campus. One potential system, the WaterHub®, will take sewage wastewater, clean it to a non-potable level through hydroponic and biological reactors, and route it to McCracken Hall, the East Regional Chilled Water Plant, the South Campus Central Chiller Plant, and, after completion, the West Campus Combined Heat and Power Plant (CHP). The implementation of the WaterHub®, which will occur in 2023, will contribute to the sustainability goal to reduce potable water consumption on campus.

The WaterHub® will also influence the second and third goals outlined above. Since 2015, Emory University already has operated a WaterHub®, which has served as a living-learning laboratory, providing numerous opportunities for research, classes, internships, and more. One of the unique opportunities Emory provides its students is the chance to be a tour guide for visiting students, professors, researchers, and community members. The WaterHub® at Emory has also received numerous awards for its innovativeness and educational capabilities. A WaterHub® on OSU's campus would provide students new opportunities to learn sustainability.

Sustainable Water proposes to build and operate the WaterHub® on the OSU campus in exchange for payments made through a Water Purchasing Agreement (WPA). *Sustainable Water* installs the WaterHub® on Ohio State's campus at no upfront capital cost for the university. Ohio State then pays *Sustainable Water* to treat the water that is rerouted through campus systems. Cleaning the water to a non-potable level

instead of potable means that Ohio State will be able to avoid additional fees and higher rates that are charged by the City of Columbus.

From a long-term financial standpoint, the WaterHub® will yield an estimated $33.5 million savings over 30 years and $187 million over 50 years (Ohio State University & *Sustainable water*, 2020). The implementation of the WaterHub® on campus is estimated to help meet the resource stewardship goal by reducing potable water consumption in most years leading up to 2040 (Ohio State University & *Sustainable Water,* 2020). There is promise that the WaterHub® will contribute to the second sustainability goal we analyzed, which involves education. The WaterHub® simultaneously acts as a living laboratory that can provide students research opportunities, internships, tour guide positions, and unique classroom learning experience. These advantages also tie in to the third sustainability goal.

The WaterHub® will also contribute to Ohio State's Ecosystem Services Sustainability Goal, of which there are four initiatives. The main one that the WaterHub® will address is "stormwater management and water quality". Mining sewer water out of combined sewer and sanitary pipes will reduce stress on the City of Columbus' water system by reducing risk of untreated sewage discharge during heavy rainfalls. The WaterHub® at Emory has a 50,000-gallon water storage tank for emergencies, and Ohio State will have a similar storage tank.

Introduction

The Ohio State University department of Facility Operations and Development is proposing a partnership with *Sustainable Water* to potentially install a water reclamation system on campus called the WaterHub®. Ohio State predicts that water usage will increase significantly over the next few decades, largely in part to the new Combined Heat and Power plant on west campus, set to open in 2022. This water reclamation system will provide several services, the primary being that it will recycle sewer wastewater that will then be used in McCracken Hall, the East Regional Chilled Water Plant, the South Campus Central Chiller Plant, and West Campus Combined Heat and Power Plant (VanCleave, 2020). Ideally, this new installation will provide both monetary and water consumption savings over the coming years as well as contribute educational opportunities for students.

Sustainable Water's WaterHub® technology reclaims wastewater and cleans it to a safe enough level for specified practices. It does this by first mining wastewater from existing sewer pipes. The WaterHub® filters this wastewater through screens and equalization systems. An Equalization System (EQ) is a component of the water treatment process. It works by providing buffering and controls the amount of inflowing water and water concentration (Wastewater Mining and Primary Treatment Solutions, 2020). An EQ basin provides consistent influent flow by maintaining high flow fluctuations. In a raw wastewater treatment plant, EQ basins prevent the sewage from becoming septic (Barclay, 2020). The wastewater is cleaned by microorganisms in the biological treatment and hydroponics reactors. The water is then used in the steam and chiller plants. *Sustainable Water* provided an analysis of three existing plants and one

future plant on campus (VanCleave, 2020). The buildings on campus analyzed include McCracken Hall, the East Regional Chilled Water Plant (ERCWP), the South Campus Central Chiller Plant (SCCCP), and the New West-Central Plant that is in the construction stage of development (Ohio State University & Sustainable Water, 2020).

We established two main objectives for our project. The first was to identify which sustainability goals were most pertinent to this project. The second was to provide evidence to support the case for the WaterHub®. The bulk of our research focused on the existing WaterHub® at Emory University, to see what impacts it had on sustainability at that institution.

Emory University unveiled its WaterHub® in 2015. Since then, the WaterHub® has been showcased as a centerpiece of sustainability and received an abundance of awards. Over 5000 visitors from companies, universities, and governments have traveled to see the WaterHub® (Emory University). It is capable of reducing annual potable water consumption by 146 million gallons annually, benefitting not only the university, but also the City of Atlanta (Sustainable Water, 2019). Emory uses the reclaimed water for its steam and chiller plants as well as toilet water. Emory's WaterHub® is only 4800 ft^2, with 3200 ft^2 being the glasshouse and the remaining 1600 ft^2 as outdoor landscaping (Sustainable Water, 2019). Ohio State is anticipating a 12,500 ft^2 building space total for its facility, meaning that Ohio State's facility will be able to reclaim water at a faster rate and higher capacity than Emory's (VanCleave, 2020). Several academic courses at Emory have integrated the living lab into their curriculum providing a unique learning experience and will be further outlined in the Education and Learning Opportunity section.

Methods

The primary methods of research were personal interviews and online research. We interviewed Brenda VanCleave, Senior Water Engineer at Ohio State, Tony Gillund, Senior Sustainability Manager, and Mary Leciejewski, Senior Sustainability Coordinator with Facilities Operations and Development (FOD) at Ohio State. We planned to include a cost-benefit analysis; however, we shifted our focus away from that and more towards OSU's Sustainability Goals. We did multiple analyses to determine what extent Ohio State will be able to meet the Sustainability Goals set in place. The 4 goals we found to be the most relevant to the WaterHub® were analyzed.

The potable water reduction sustainability goal states: "Reduce potable water consumption by 5% per capita every five years, resetting baseline every five years" (Sustainability Goals, 2020). This baseline is what the progress will be compared against, to determine if the goal is met in each 5-year period. To calculate each baseline for this goal, we used the projected non-potable water demands given to us by the university and the WaterHub® percent resiliency for four different five-year groupings, from 2020-2040. The term "percent resiliency" refers to having a reliable water supply that can adapt and respond to future change (Hunterwater, 2020).

Each baseline is calculated using the previous year's actual non-potable water use. That number was multiplied by 1.05 to find a 5% increase in the non-potable water use, which mirrors a 5% decrease in potable water use. The 5% increase per 5-year period was chosen by OSU Facilities based on building audits and water meters. They track progress against established performance metrics and also compare with neighboring institutions (The Ohio State University OP-3: Building Operations and

Maintenance, 2019). This number was then compared to the expected output of non-potable water from the WaterHub® 5 years later, which determined if the 5-year goal was met.

The expected usage of non-potable water was calculated by multiplying the non-potable water demands by the percent resiliency, or percent that the WaterHub® can keep up with the demand of non-potable water. These numbers were then compared to determine whether or not Ohio State will meet their goal. This calculation is ultimately a projection for the water demand at the OSU chiller plants, and we then calculated to determine if the WaterHub® was able to produce the quantity of water needed for each time period.

Significant online research was conducted to learn about Emory's WaterHub® and predict how Ohio State could achieve their specific Sustainability Goals within Teaching and Education. Since Emory University has the only operational WaterHub®, our educational findings are based mainly on how Emory has integrated their facility into learning opportunities. Both the Emory and *Sustainable Water* websites contained useful facts and figures explaining the educational benefits. A docent, or tour guide, from the WaterHub® at Emory was also interviewed to get a student's perspective on the WaterHub®'s impacts (Musatti, 2020).

The university's Resource Stewardship Goal related to ecosystem services was analyzed through OSU's Building Design Standards (BDS) and the Ecosystem Services Assessment (ESA) tool. The Building and Design Standard is created and maintained by FOD to provide guidance for the preparation of construction documents. Division 18 - Sustainability under the BDS, that is effective December 2020, was reviewed to see

what aspects of campus's ecosystem services will be considered throughout the entire scope of the project. A strategic plan for advancing the university's Sustainability Goals through ecosystem services was developed by a University Panel on Ecosystem Services that was convened in 2017 (Ohio State University, 2018). Their recommendations for establishing long-term ecosystem services management practices on campus were analyzed and compared to the goals that could be met by the implementation of the WaterHub®.

Project Finances

Providing that the successful implementation of the WaterHub® on campus meets primary university Sustainability Goals outlined within this report, the completed project is beneficial for Ohio State in comparison to other campus developments. Through signing a Water Purchasing Agreement with *Sustainable Water*, the university is agreeing to allow *Sustainable Water* to build and operate the WaterHub® on campus. The Water Purchasing Agreement includes an operating lease, a Design Build Operate (DBO) Agreement, and a Performance Contract. By signing this contract, *Sustainable Water* agrees to pay for the building, offering long-term pricing stability, and essentially no operations and management responsibilities for OSU. This company has published 12 different case studies of their products, including 2 on the WaterHub®, showing their success. *Sustainable Water* is offering a guaranteed savings structure by selling back treated, non-potable water to the university at a lower cost than the City of Columbus sells the university treated water. The Water Purchasing Agreement covers key project design and development costs, utility savings tied to current market rates, a minimum 30-year contract, and additional pertinent information about the financing of the

WaterHub® (Leciejewski, 2020). Because the location for the WaterHub® on Ohio State's campus has not been determined yet, all of the financing for the WaterHub® was calculated at a low-estimated cost and a high-estimated cost.

The enrollment data for the university shows that the 2018-2019 academic year student body set a record for its size, with a total university enrollment increase of 2.5 percent from 2017-2018. The Ohio State Columbus campus had 61,170 total enrolled students for 2018, which is an increase of 2.2 percent from the previous fall (The Ohio State University, 2018). The square footage of building space on OSU's campus has increased in the last 5-6 years and is expected to increase each following year as well. Increased square footage of buildings on campus will increase their occupancy levels, allowing more students and faculty to reside within. The University is also planning on building a new power plant and making additions to the medical center (The Ohio State University, 2019). This expansion contributes to increased usage of potable water toilets and sinks, among other uses. The WaterHub® can provide non-potable water to multiple plants on campus that will significantly reduce the amount of potable water used now and throughout future buildout of the university (Figure 1).

Figure 1 below illustrates the anticipated increase in the square footage of buildings on OSU's campus from now until 2040. The large increase in water use projected by 2026 is mostly due to the new CHP plant the university is building, and medical center expansion. These increases will nearly double the area of building space, with a large increase in water use due to increases in employees and patients. Increases in area of building space beyond 2026 due to the Framework plan projected to further increase water use.

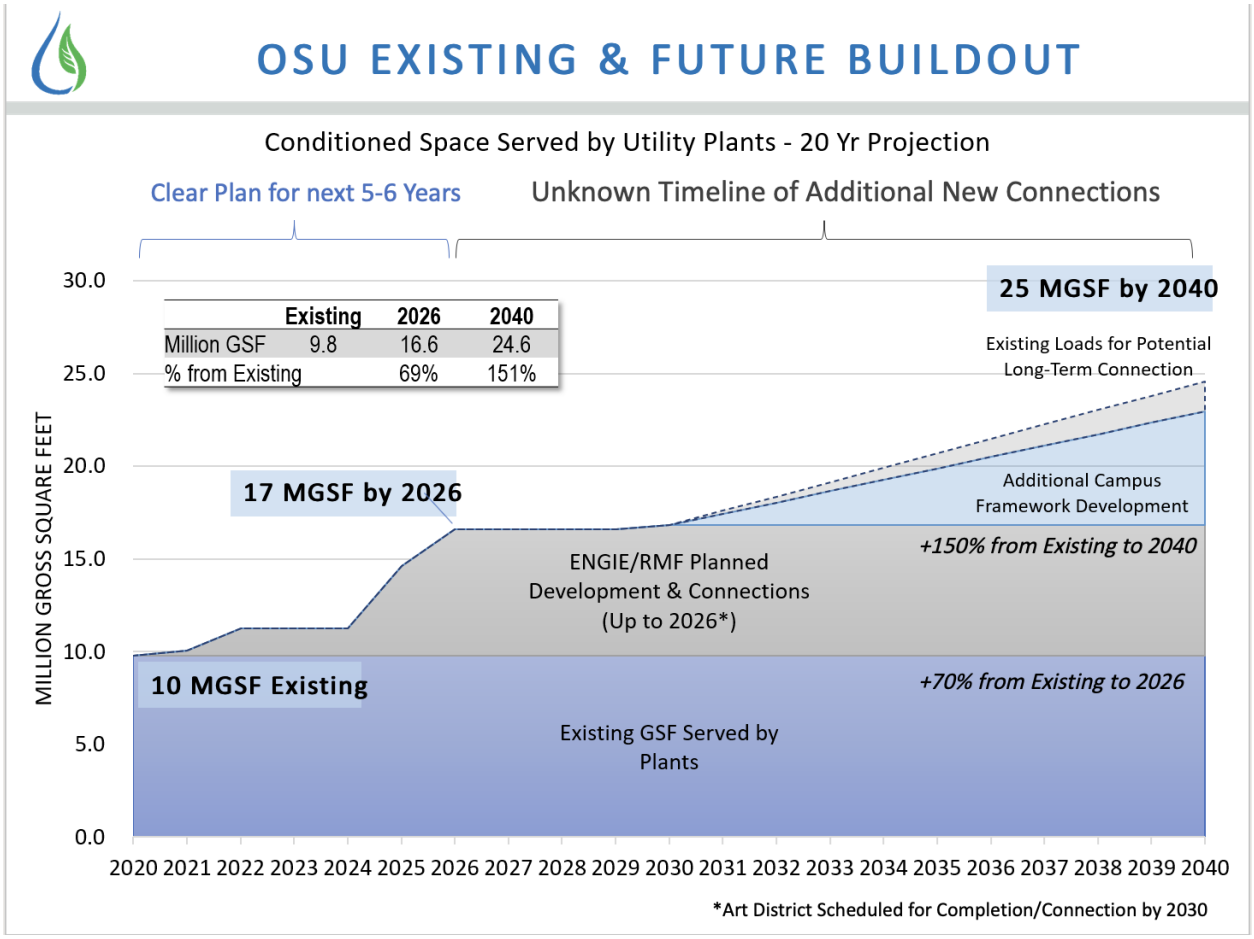

Figure 1. OSU Existing & Estimated Future Buildout

In addition to increased water use, the water and sewage rates in the City of Columbus are expected to increase each year, driving up potable water and sewage treatment costs for the university. Predicated in reference to historical rates in Columbus, the water rates in the city are expected to grow by 5.0% annually, while the sewer rates are expected to grow by 4.3% annually (Ohio State University, & *Sustainable Water*). In 2020, water purchasers must pay $9.14 per 1,000 gallons of water that the City of Columbus treats. For comparison, in the year 2000 it cost $3.58

per 1,000 gallons of water treated and in 2010 it cost $6.77 per 1,000 gallons of water. As observed in Figure 2 below, if water and sewage rates rise 5% per year, the implementation of the WaterHub® on Ohio State's campus is expected to save the university $37 million over 30 years (Sustainable Water, 2019). If water and sewage rates increase only 3%, the university would still save an estimated $23 million over a 30-year time period, which amounts to a $6.14 million savings in present value terms at an interest rate of 4.5% (University Investment Policy, 2020). With a water and sewage increase of 7% over the next 30 years, the university could expect to save up to $60 million, or $16 million in present value terms with the implementation of the WaterHub®.

An accredited construction and engineering company provided Ohio State with a 40-year road map outlining future goals of capacity, reliability, efficiency, and emissions by establishing baseline data, modeling, and developing life cycle cost analyses (Burns, & McDonnell, 2016). According to an Architectural Master Plan provided by Burns and McDonnel 2016, the university's total square footage is anticipated to grow by nearly 55% by 2050.

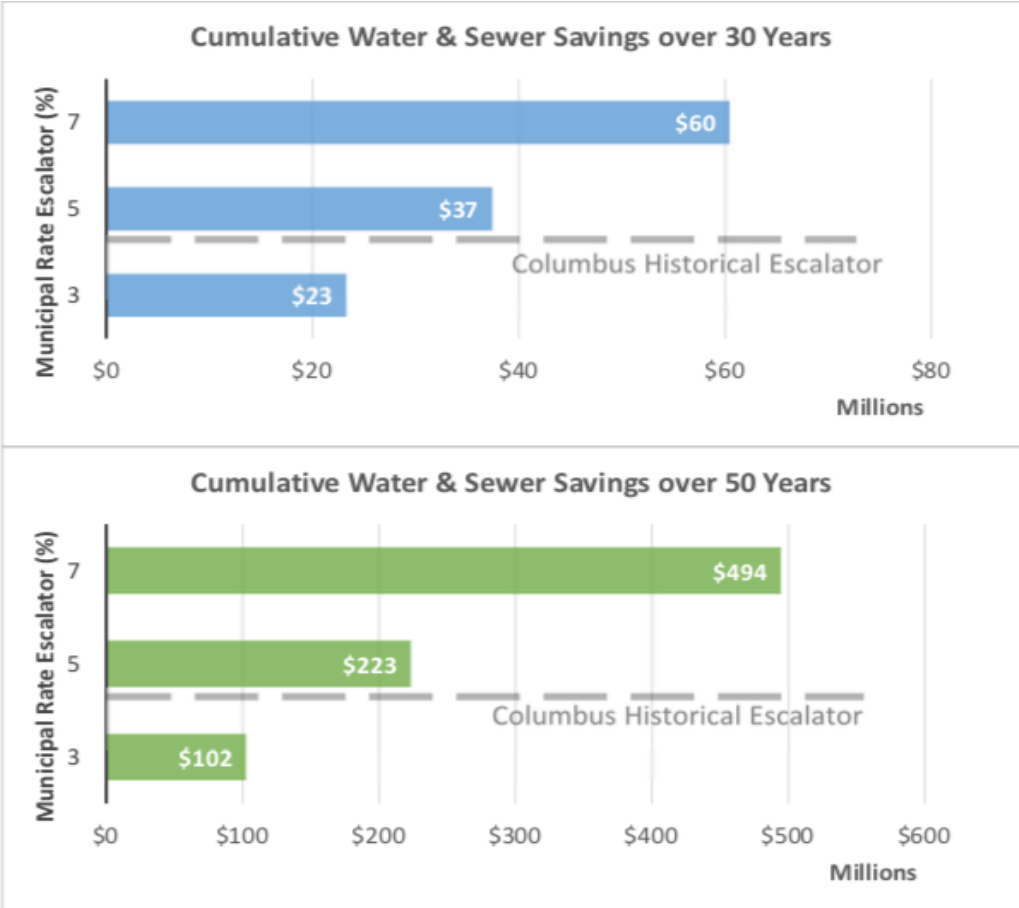

Figure 2. Potential Water & Sewage Savings for Ohio State (Ohio State University, & Sustainable Water, 2020).

Looking at the savings from the 50-year savings plan on the lower half of figure 2, the university could save up to a cumulative of $102 million at a 3% increase in water and sewage rates, $233 million at a 5% increased rate, and up to $494 million at a 7% increased municipal rate. The 50-year savings plan, discounted at the university's rate of 4.5%, shows the present values of the 50-year savings plan at 3% being $11.29 million, 5% being 24.69 million, and 7% being 54.69 million.

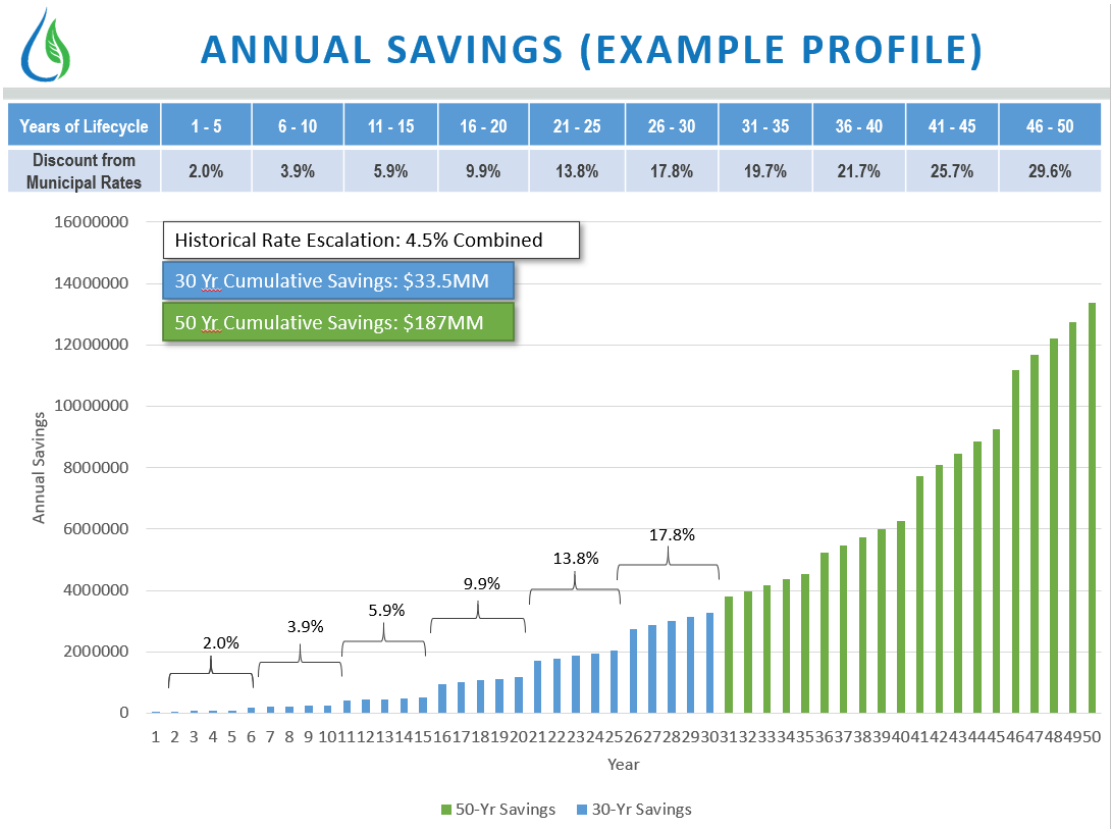

Figure 3. Annual Savings with Combined Historical Water Rate (Ohio State University, & Sustainable Water, 2020).

With the implementation of the WaterHub® in the next fiscal year, the facility is expected to treat over 266.5 million gallons of water per year (MGY) in the year of 2023, 379 MGY in the year of 2025, and up to 492.4 MGY in the year of 2040. As observed in Figure 3, Sustainable Water could offer the 266.5 million gallons of water in the year 2023 for 2% less than the university would have to pay the city for the same water. By 2026, Sustainable Water will be able to provide water at a 3.9% discounted rate, with continued increases as water and sewage rates continue to increase in Columbus. After the WaterHub® has been in operation for 30 years, Sustainable Water will offer a discounted rate of up to 30% off the price charged by the City of Columbus for the

millions of gallons of water used per year at OSU's existing power plants, as outlined in Figure 3. If Ohio State invests in the WaterHub® with *Sustainable Water*, they will be paying *Sustainable Water* a lower rate in comparison to the City of Columbus. Over time, the university saves increasing amounts of money because rates increase and the WaterHub® provides an increasing amount of water. Although Figure 3 is just an example profile, not the actual contract, and the terms of the Water Purchase Agreement still need to be negotiated, it does offer some financial insight.

This analysis was mainly provided by *Sustainable Water* and shared to OSU officials who will be deciding if OSU should proceed with the partnership. However, this does not include any long-term costs and the costs that the university, not *sustainable water*, will have to cover. *Sustainable Water* promises to cover the upfront building costs, rerouting of water costs, and operation and maintenance costs, with the promise that Ohio State will pay them back using their water savings (Sustainable Water, 2018). They do guarantee savings on water prices past one year and lasting through the agreement term, however at first, most of the money saved will be going back to sustainable water. Ohio State will not experience any actual saving until later in the WPA, once they have paid back the building cost.

Ohio State Sustainability Goals Met

Ohio State's goal of reducing potable water consumption by 5% per capita every five years is the main reason for the WaterHub®. As the water demands on campus increase year by year, Ohio State needs a way to keep its potable water use down. The baseline is re-established every 5 years by using the previous potable water

consumption number the year before the reevaluation (Sustainability Goals, 2020). That number needs to then decrease by 5% in order to meet the goal. Calculating from the years 2020-2025, 2025-2030, 2030-2035, and 2035-2040, this goal is only met in the first 5 years and the last 10 years. The full numbers and calculations are shown in appendix 1.

If the WaterHub® becomes operational in 2023, a 266.5 Million Gallons per Year (MGY) demand on campus is predicted by various chiller plants. The WaterHub® will be able to cover that full amount, which is roughly 20% of Ohio State's total water use (Ohio State University and *Sustainable Water*). As a result, in 2025 when the goal is revisited, the goal will have been met. When the baseline is re-established in 2025, Ohio State will need to increase non-potable water use from the WaterHub® an extra 5%. The new for the period of 2025-2030 (5 years after the reevaluated baseline) will 399 MGY of non-potable water. Based on the improved ability of the WaterHub® to produce water as time goes on, in 2030 OSU can be supplied with 373 MGY of recycled water. This amount will not meet the sustainability goal during that period, as it is about 26 million gallons short. From 2030-2035, Ohio State will need about 410 MGY to reach the goal, and about 413.5 MGY will be supplied from the WaterHub®. In the years from 2035-2040, Ohio State will need to use 472.5 MGY to meet its water goals, and the WaterHub® can provide 492.3 MGY, meaning OSU will meet the goal. If Ohio State wants to meet the goal from 2025-3030, the only year grouping where they do not, they will have to find other methods to produce non-potable water or reduce potable water use on campus.

The analysis above assumed that existing and new chiller plants utilize most of the water from the proposed WaterHub® but increases in the population of students and employees at Ohio State could drive additional demand for non-potable water. The key difference is that this additional use of non-potable water will have to be supplied to buildings and more distributed uses, such as bathrooms. While we did not undertake an assessment of this expansion in the use of non-potable water, it is critical to recognize that the opportunity exists to save on potable water use through alternative designs of new buildings that can take advantage of a stream of non-potable, but safe, water supplied by WaterHub®.

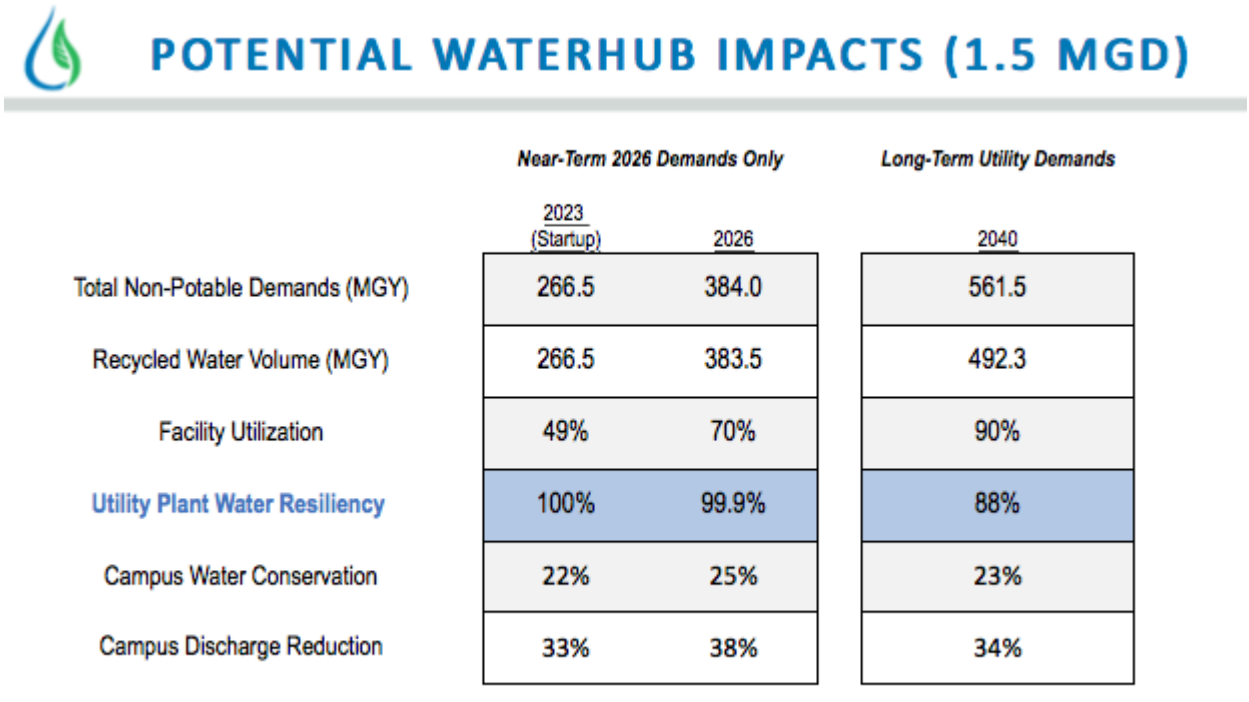

Figure 4. Potential WaterHub® Impacts (Ohio State University, & *Sustainable Water*, 2020).

Education and Learning Opportunity

The WaterHub® at Emory University has been successful at promoting educational opportunities. It acts as a living, learning laboratory that provides students from a multitude of disciplines a new experience (Emory University, 2019). Christine Moe, a professor at Emory, has students analyze water samples for bacteria before and after treatment to see how efficient the process is (Williams & Slavens, 2020). A variety of classes such as Performance Landscaping, Urban Planning, Water Quality, Social Equity, Environmental Science, Health Science, Microbial Ecology, and more have utilized this facility (Emory University, 2015). Ohio State offers a plethora of diverse classes that could benefit from a system like the one at Emory. Some potential courses are Exploring Water Issues, Energy and the Environment, Intro to Sustainability, Water Quality Management, Water Policy and Governance, and others. We interviewed a tour guide at Emory, named Rachel Musatti, who informed us that Emory offers extra credit for Chemistry students who visit the WaterHub®, further illustrating its interdisciplinary nature (Musatti, 2020).

Students at Emory university had the opportunity to utilize the facility for research during its construction phase by monitoring the microbiology of wastewater samples at various stages. Emory Professors Christine Moe and Eugene Gangarosa expressed that the hands-on experience in the learning lab exposed these students to the kind of field work that many of them would be conducting after graduation (University, E, 2018). Professor Moe feels that the WaterHub® has provided greater possibilities for research, scholarship and water conservation applications that were far beyond Emory's campus. The research opportunity provided during construction, "provided the experience of

collecting real data, interpreting results and writing reports, “says Moe (University, E, 2018).

In addition to acting as a research lab, Emory students have the opportunity to obtain internships at the WaterHub® and act as tour guides. Before the COVID-19 pandemic, the WaterHub® at Emory was a spectacle that brought in over 5,000 visitors and students had the opportunity to showcase their knowledge (Emory University). Acting as a tour guide for visitors will require students to have an in-depth knowledge of the WaterHub®. They can develop communication and interpersonal skills by interacting with visitors and answering questions.

Rachel Musatti, who has been a docent for the WaterHub® since fall of 2019, said that her experience as a tour guide is “an experience like no other.” She has led groups of students, alumni, community members, and researchers from outside Emory. One of her favorite parts of being a docent is sharing meaningful information that “educates and empowers individuals to make more sustainable choices in their daily lives” (Musatti, 2020).

Emory has also received several awards for the WaterHub® system that further uphold its educational merit. One such award is the U.S. Water Prize from the U.S. Water Alliance which is awarded for policies and programs that advance a sustainable future for water. Additional academic awards include the 2016 SCUP Excellence in Landscape Architecture-General Honorable Mention Award and the 2018 Campus Sustainability Achievement Award (WaterHub® at Emory Awards, 2019). Ciannat Howett, director of the Office of Sustainability Initiatives at Emory explained, “I think it also shows an important role the university can play in advancing sustainability and

engaging in this idea of the campus as a living laboratory, a place of experimentation and engagement and learning," (University, E, 2018).

Ecosystem Services

The Ohio State University's Ecosystem Services Sustainability Goal includes four initiatives, each of which contains an "Innovative Design" element. The four initiatives are 1) Protection and Conservation of Core Ecosystems, 2) Stormwater Management and Water Quality, 3) Vegetation, Soil and Biodiversity, and 4) Quality of Life. The initiative that the WaterHub® could have a significant impact on is Stormwater Management and Water Quality. The WaterHub® is going to mine water from a combined sewer which contains both sanitary water and stormwater together. If a combined sewer exceeds capacity during a period of heavy rainfall, untreated sewage will be discharged into the environment, causing damage. Because the WaterHub® draws from combined sewers, which have stormwater and sewer waste, the WaterHub® will reduce the risk of untreated sewage discharge into the environment by directly decreasing the amount of sewage. The sewage will be rerouted through the WaterHub® (Gillund, 2020). The city of Columbus and the Ohio EPA require that new buildings treat the stormwater that falls onto its property. Ohio State is looking into using the EcoPure BioFilter, which is a filter designed to remove any pollutants and toxins in stormwater. It has a high inflow rate with a small footprint. (Advanced Drainage Systems, Inc, 2020). This device would further help the ecosystem services goal, limiting water that would runoff into the environment or need to be treated somewhere else.

According to Andrew Neil, a GIS Analyst within the university's Planning, Architecture and Real Estate (PARE) department, the Ecosystem Services (ES) Assessment Template is a tool that will assess pre- and post-development site metrics and Ohio State's Ecosystem Services Index to calculate how the implementation of the WaterHub® will impact the Ecosystem Services Sustainability Goal. Some of these metrics include analysis of development on farmland, green infrastructure, or affected tree canopy. The ES Assessment Tool utilizes the university's Ecosystem Services Index (ESI) campus numbers to calculate how the WaterHub® impacts Ohio State's Sustainability Goals. This tool grades the four initiatives of the Ecosystem Services Goal, i.e., A, B, C, etc. The collective score for a new development must be a grade of B or higher to positively impact the university's goal related to ecosystem services. Any projects with scores of C's or lower must further adapt to fulfill the University's Sustainability Team's outlined standards. Areas of improvement for a project of a score of C or lower will be required to identify key areas of improvement or initiate a waiver process.

The university will also utilize an Ecosystem Services Building Standards Document that describes how the Ecosystem Services Goal fits into the building design standards that would be applied to this project. Within the new Buildings and Design Standards, the university will implement an updated Sustainability Division as of December 2020 (Building Design Standards, 2020). This unique division will be tasked with reviewing the scope and the application of partnering with *Sustainable Water* to build the WaterHub® on campus in compliance with city and state codes/regulations, building materials, a life-cycle cost analysis, and an energy efficiency analysis.

Furthermore, the Ecosystem Services Design Standard requires all new developments on campus to conduct an Environmental Site Assessment (ESA) to best determine how to support the ecosystem services unique to Ohio State's campus and surrounding areas.

Achievable Areas of Improvement:

Although the implementation of the WaterHub® would contribute to several OSU Sustainability Goals, the project will not clearly help the university meet its goal to reduce building energy use by 25% by 2025 (Sustainability Goals, 2020). Energy consumption in buildings accounts for most of the energy consumed on campus. Much of the potable water being used for on campus is coming from the Hap Cremean Water Plant on Morse Road in Easton. The energy it takes to pump the water this far is substantial. While the WaterHub® does not directly help OSU meet its energy goals, it does decrease overall energy use by decreasing the amount of potable water that must be pumped from this plant. Since the WaterHub® is not a typical building on campus, we must categorize it as either mixed or lab/research. If it is considered mixed it could have an energy usage intensity of around 112 kBTU/sf/year whereas a lab is around 200. However, these are both still lower than a typical hospital which is about 400 to 500 kBTU/sf/year. Since the WaterHub® is constantly consuming energy, it would most likely be consuming energy between 200 and 300 kBTU/sf/year. The WaterHub® at Emory University uses 38,000 kWh/month or 456,000 kWh/year (Howett, 2020). Additionally, it has two solar panels on site that generate about 30% of the needed energy to operate (Emory University). In order to help make this energy use as sustainable as possible, Ohio State should evaluate whether installing solar panels on

site would be feasible. The impacts of the WaterHub® construction and operation on OSU's energy goals are uncertain. However, the progress made toward OSU's other sustainability goals cannot be understated.

Recommendations

Through this analysis, we have several recommendations for Ohio State to consider with respect to the WaterHub®. First, we recommend that Ohio State University build the WaterHub®. Based on the information detailed in this report, the long-term impacts will be beneficial for the environment, which will help the university achieve many sustainability goals. There are also potentially large financial savings. Although a full cost-benefit analysis has not been completed by the university, the likely large rate increases for potable water by the city suggest that there is merit to the estimated net cost savings.

We also recommend the university find additional uses for the non-potable water that the WaterHub® will be creating in order to meet the reduced water use sustainability goals. In most years, 100% of the WaterHub® water will go to the campus power plants in order to fulfill their needs. However, in one of the 5-year groupings, the WaterHub® can produce more water than the plants need. In this case, Ohio State should look into alternate uses for this water. Some ideas of alternate uses are; in toilets, in the sprinklers around campus, to clean floors, and laundry in the on-campus dorms. Low-flow, dual-flush toilets should be the primary selection for any new building development. Further analysis will need to be done in the future to calculate the cost of transporting this water elsewhere on campus, as OSU would have to pay for that.

The last recommendation is to look into the idea of a new solar array to help power the WaterHub®. If solar panels are economically feasible, they would be very helpful in meeting even more of the university's Sustainability Goals, by offsetting the massive amount of energy used by the WaterHub® to create recycled water. Although the upfront costs are high, in the end it would be worth it to look into it and consider the possibility of solar energy.

Conclusion

Our team has concluded that the implementation of the WaterHub® on campus and a partnership with *Sustainable Water* is an innovative technological advancement in wastewater reclamation and would further assist Ohio State in improving upon its Sustainability Goals. By producing water on campus with *Sustainable Water* WaterHub® technology, instead of purchasing it from the City of Columbus, the university is will reduce its potable water use on campus, potentially reduce sewer overflows during rainfall events, and increase the sustainability of future development on campus. The WaterHub® also will put less strain on the city's infrastructure and reduce energy use. The university will experience long-term water and sewage utility cost savings throughout the entire lifecycle of the plant.

We identified four Sustainability Goals on which the WaterHub® can have a potential positive impact. Subsequently, we researched how each of these goals would be affected by the WaterHub® system and other evidence to support the case for adopting the WaterHub®. Our results indicate a generally positive impact on each targeted sustainability goal. Ohio State will reduce its potable water usage and provide new learning and research opportunities to students. Based on all the accolades Emory

has received, Ohio State can also boost its image as a leader in sustainability. The Water Purchasing Agreement is a financial tool that will allow Ohio State to save money over time. However, the Water Purchasing Agreement is complex, and we recommend that Ohio State more closely analyze potential costs that have not been evaluated before proceeding with building the WaterHub®. For example, more information needs to be collected about the engineering and costs of piping non-potable water throughout campus, as well as who Ohio State will partner with to develop the infrastructure. At this point, we were not able to estimate the cost of the pipes that transfer the water from the WaterHub® to the plants on campus and extending that service to the dorms and other buildings on campus.

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