FINANCIAL ANALYSIS OF THE BUSINESS CASE FOR AN AFFORDABILITY ENVIRONMENTAL IMPACT BOND

by
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Executive Summary

Public water utilities are challenged with maintaining affordable rate structures while facing increasingly strict regulatory requirements and rising operational, maintenance, and energy costs. Increased costs may be passed through to water rate payers through higher water bills that can create issues of water affordability for low-income customers and negative financial and reputational impacts for water utilities if bills remain unpaid.

Environmental Impact Bonds (EIBs) are highly regarded by impact investors due to innovative built-in outcome metrics that provide social and environmental benefits and financial returns. The Nicholas Institute of Environmental Policy Solutions (NIEPS) and outcome-based capital firm Quantified Ventures are investigating the structure and deployment of an Affordability Environmental Impact Bond (Affordability-EIB) that could both lower the burden of water bills on low-income customers through water affordability programs, and attract investors interested in green capital and social outcomes. Affordability outcomes of an Affordability-EIB bond would be evaluated using metrics of household affordability created by the Water Policy team at NIEPS.

Energy costs contribute up to 40% of the operating costs of water utilities and present an opportunity for a water utility to monetize cost savings through investment in energy efficiency technologies. A financial model was developed to evaluate the business case and potential cost savings at water and wastewater treatment plants from accelerating energy efficiency system upgrades funded by an Affordability-EIB. The model incorporates financial, operational, and environmental variables and analyzes cost of the accelerated system upgrades to costs of a base case with and without a future upgrade. Annual cost savings, cumulative savings over the evaluation period, discounted annual cost savings, and the net present value of cost savings are calculated for four financial settings:

- Annual cost without the cost of debt service
- Annual costs with the cost of debt service
- Capitalization of the social cost of carbon
- Annual costs with the cost of debt service and capitalization of the social cost of carbon.

Observed capital costs, and electricity use and price from an aeration system upgrade at the North Toronto Wastewater Treatment Plan were input in the Affordability-EIB model to evaluate cost savings from an accelerated system upgrade. The accelerated system upgrade modeled on the Toronto case study did not demonstrate a positive business case when compared to a base case without a system upgrade because the cost of debt service was greater than electricity cost savings. The accelerated system upgrade did demonstrate a positive business case when compared to a base case with a future system upgrade. A Monte Carlo outcome probability simulation for the NPV of net cost savings with the cost of debt service comparing the accelerated system upgrade to the base case with future upgrade was performed. The simulation determined that operational variables, particularly electricity reduction from the accelerated system upgrade, contributed most to the variance of NPV of cost savings.

The simplified Affordability-EIB model is limited by its inability to incorporate factors including the complicated nature of water and wastewater systems, operations and maintenance costs, electricity demand, and complex utility billing structures. The biggest limitation of the model is the engrained assumption that water utilities are rationally economic actors. Instead, water utilities make decisions to meet regulatory compliance and ensure customer health instead of prioritizing maximum operational and economic efficiency.

The positive business case for investment in energy efficiency technologies through an Affordability-EIB would be strengthened by sourcing and evaluating case studies across a variety of energy efficiency technologies and water systems to demonstrate positive cost savings and identify further sensitives within the model. Notwithstanding, the considerable number of financial, operational, and environmental variables within the Affordability-EIB model make it a flexible tool to demonstrate how positive net cost savings can be generated through accelerated system modernization while incorporating municipal and investor preferences through an Affordability-EIB.

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Introduction

Water Affordability’s Link to Energy

The cost of water and wastewater services is rising three-times faster than inflation, contributing to the pervasiveness of the water affordability issues for low-income households across the US (Cardoso & Wichman, 2020). The Water Policy team at Duke’s Nicholas Institute for Environmental Policy Solutions found that 10-30% of US households were unable to pay their water bills prior to the COVID-19 pandemic and that water-affordability will be a challenge to low-income customer for years to come (Patterson & Doyle, 2021). Revenues from residential customers often account for more than half of total utility revenues (Patterson & Doyle, 2021). Utilities that are unable to fully recover increased operating costs through billing higher water rates face a significant impact to their annual budgets (Leiby & Burke, 2011).

Utilities experience negative financial and reputational impacts if water bills are unaffordable and remain unpaid by customers. Utilities depend on revenues to pay for labor, energy, operations, maintenance, and capital improvements. Energy use and costs continue to rise at water utilities due to stricter regulations, advanced treatment technologies, aging infrastructure, supply chain challenges and population change (Leiby & Burke, 2011). Water and wastewater utilities have received funding for energy efficiency capital projects through state revolving loan funds, performance contracting from energy service companies and energy companies that provide incentives and rebates (Smith & Quebe, 2018). An Affordability-EIB would provide investment capital for energy efficiency system upgrades at water utilities to reduce energy use and costs while maintaining the same level of system performance.
These operational cost savings could be passed to water customers through affordability programs such as rate stabilization or Customer Assistance Programs (CAPs) to enable low-income customers to pay their water bills (US EPA, 2016).

Environmental Impact Bonds

Environmental Impact Bonds (EIBs) are an innovative bond structure highly regarded by impact investors due to built-in outcome metrics that provide social and environmental benefits and financial returns (Harvell et al., 2020). A bond receives an Environmental Impact Bond label by predicting at least one quantifiable outcome of the funded project, evaluating the outcome after project implementation, and disclosing results with investors and project stakeholders (Quantified Ventures, 2018). Adding a social or environmental outcome metrics to the traditional municipal bond structure aligns the interests of community stakeholders, municipal governments, and investors while providing a return on investment (Quantified Ventures, 2018). Additional benefits of EIBs for municipal governments include positive public relations, increased investor demand, and the demonstration of innovation, leadership, and accountability to community stakeholders (Quantified Ventures, 2021).

Like other general revenue bonds, EIBs are backed by the taxing ability of the local government or by utility revenue, depending on the entity addressing the challenge (Nicola, 2013). To date, the main purchasers of EIBs have largely been philanthropic organizations, impact investors, development finance institutions, large banks, and insurance agencies (Brand et al., 2020). EIBs have a third-party partner responsible for attracting investors, organizing debt service, and evaluating quantified outcomes (Harvell et al., 2020). The Water Policy Team at Duke's Nicholas Institute for Environmental Policy Solutions and Quantified Ventures will be the third-party partners responsible for structuring and deploying the Affordability-EIB.

Quantified Ventures has deployed EIBs to address water quantity and quality challenges associated with flooding through financing green stormwater infrastructure in Washington, D.C.; Atlanta, Georgia; Hampton, Virginia; Buffalo, New York; and Memphis, Tennessee. Disclosed outcome metrics utilized in these EIBs include reduced volume of stormwater, acres of impervious area, volume of aquifer recharge, water quality, and community health improvements (Brand et al., 2021). Some EIBs have linked performance outcomes of funded projects to investor returns through pay-for-success contract structures (Harvell et al., 2020) but this would not be the case with the Affordability-EIB. Investor interests have shifted toward an EIB model that quantifies and discloses one or more outcome metrics but does not tie investor repayment to a predetermined performance threshold.

Affordability-Environmental Impact Bond

The Water Policy team at Duke's Nicholas Institute for Environmental Policy Solutions have developed a proprietary tool to quantify the affordability of water services for US utilities (Patterson, 2022). The tool has been used to identify two outcome metrics that could measure how an Affordability–EIB affects the ability of low-income to pay household water bills. The first metric quantifies the percentage of households from the total serviced by a water utility that pay more than one day of household labor for monthly water services. The percentage of households within this low-income category would be compared across peer water utilities. The second outcome metric projects the first metric over time and measures how a utility that implements an Affordability-EIB improves water affordability in comparison to peer utilities.

The energy efficiency system upgrades funded by an Affordability-EIB would also produce environmental outcomes. Water and wastewater utilities are generally the largest energy user at local governments, often accounting 30-40% of total municipal energy use (US EPA, 2021). Environmental co-benefits of projects funded by an Affordability-EIB include reduced strain on the energy grid, lower emissions, meeting local and state energy reduction goals, and improved environmental stewardship. An Affordability-EIB would include an environmental outcome metric related to the reduction of greenhouse gas emissions from energy efficiency system upgrades. This metric would prove attractive to impact investors as reduction in GHG emissions is the disclosure metric that most interests them (International Finance Corporation, 2021).

The municipal sustainable debt market is expected to increase 34% year over year and reach $60 billion dollars in 2022 (Bredeson et al., 2021). Issuances of municipal bonds to finance water, wastewater, and stormwater projects have accounted for a one quarter of sustainable debt issuances in the US since the market was first quantified in 2013. Trends in ESG disclosure and socially-label bonds in the municipal sustainable debt market point to strong investor interest for an Affordability-EIB. The embedded social and environmental outcome metrics of the Affordability-EIB would meet demand for quantification, transparency and reporting and increased attention to social-labeled bonds. Social-label bond issuances continue to grow impressively, rising 148% from 2020 to 2021, and representing $16.9 billion dollars and 37% of the total sustainable debt market (Bredeson et al, 2021).

Affordability-EIB Reduces Costs by Accelerating System Modernization

Municipal water and wastewater systems rarely operate at maximum efficiency due to deferred maintenance, aging equipment, overbuilt systems, unmeasured performance, and high energy costs (Leiby & Burke, 2011). Utilities may not perform system upgrades at financially optimum time due to dependence on capital allocations from municipal budget that are stretched across competing departments and priorities. Increasing operating, maintenance and energy costs are compounded as utilities wait for a budget allocation or interest rates to lower and increased project costs and the cost of capital makes system upgrades more expensive (Smith & Quebe, 2018). Utilities that wait for financing to become available usually pay higher costs because the operating, maintenance and energy bills that could be reduced through systems improvements exceed the cost of financing the system upgrades (Smith & Quebe, 2018).

Like other municipal bonds, an Affordability-EIB can remove the financial barrier for system upgrades at water utilities by providing investment to the utility now instead of when the system breaks or fails, or the municipal budget allocates capital in the future. Capital investment from an Affordability-EIB would be used to accelerate system upgrade to monetize operational and maintenance cost savings forgone by waiting to upgrade water and wastewater system. Accelerating investment in upgraded energy efficient technologies also enables the utility to reduce the financial impact of increasing energy prices on ratepayers.

Energy Use and Cost at Water Utilities

Behind labor, energy is the highest cost category at water and wastewater utilities, representing their largest controllable cost (Hamilton et al, 2009). Up to 40% of operating costs at drinking water systems and 75% of operating costs at wastewater systems may be used for energy (US EPA, 2021). Energy cost savings at water utilities through investment in system upgrades present a significant opportunity for utilities to reduce overall operational costs and financial pressure on ratepayers.

The Water Research Foundation and Electric Power Research Institute mapped energy intensity of U.S. public water systems and found water treatment plants demand about 1% of total US electricity, and wastewater treatment plants demand 0.8% of total U.S. electricity (Pabi et al., 2013). Utility electricity use and costs are rising due to climate change impacts that require lower quality source water to be treated with more energy intensive technologies, stricter water quality regulations, movement of populations that require water to be transported across greater distances and to higher elevations, and aging infrastructure that increases energy consumption from water losses and inefficient system components (Leiby & Burke, 2011).

Electricity use at water and wastewater systems is measured in kilowatt hours per million gallons (kWh/MG) and daily use is measured in kWh per million gallons per day (kWh/MGD). Public water and wastewater services in the US have an average energy intensity of 3,200–3,600 kWh/MG, with wide variation (Jones & Sowby, 2014). Electricity intensity of water and wastewater treatment facilities varies with climate, topography, water chemistry, and proximity to source waters. Water that needs to be pumped hundreds of miles and over mountain ranges in California is more energy intensive and expensive than water in Massachusetts where reservoirs and precipitation are plentiful (Jones & Sowby, 2014). Unlike water treatment, wastewater treatment processes exhibit considerable economy of scale for energy use. A wastewater treatment plant with ten MGD capacity requires 50–60% less energy than a one MGD facility to treat the same volume of wastewater. Most benefits of economies of scale occurs at wastewater treatment plants up to 20 MGD, with little difference in energy intensity at larger facilities (Jones and Sowby, 2014)

Strategies to control electricity costs at wastewater and water treatment plants include process improvements, managerial and operational capacity enhancement, and system upgrades that incorporate energy efficient technologies (Pabi et al., 2013). Equipment replacements, system upgrades and plant-wide improvements can deliver cost savings while achieving or exceeding current performance through integrating renewable energy resources, reducing energy demand, and capturing energy through recovery and generation (Pabi et al., 2013). Energy efficiency technologies can be divided into two categories: high-efficiency and energy recovery technologies that reduce overall energy demand, and technologies that modulate equipment output in response to variations in plant energy load conditions (Andrew, Cramer & Willis, 2017).

Energy efficiency upgrades that produce the greatest electricity and cost savings reductions differ between drinking water treatment systems and wastewater treatment systems. Pumping accounts for most energy use in drinking water treatment systems, ranging from 55-90% of total demand, depending on the configuration and hydraulics of distributions system (Pabi et al., 2013). Inefficiency in pumping systems comes from a mismatch between pump size and actual system requirements, and improper use of throttling valves and damper technologies to control water. Upgrading fixed drives that control the pumping system with variable speed drives to control the speed, pressure, and flow of the system can reduce the electricity demand of water treatment systems up to 20% (Gaudrel & Savreux, 2014).

More research has been completed on electricity cost and use savings for wastewater treatment systems than water treatment systems. Wastewater systems are larger and more consolidated and have a connection to the federal government through a history of funding through construction grants program. System upgrades that reduce energy use at wastewater treatment plants include aeration systems, pumping systems, Supervisory Control and Data Acquisition (SCADA) control systems, biosolids management, water conservation through enhanced reuse, and building improvements (Smith & Quebe, 2018). Wastewater treatment facilities view wastewater as a valuable secondary raw material as wastewater contains five to ten times the amount of energy needed for its treatment processes (Gandiglio et al., 2017).

Resource recovery processes and onsite energy generation methods include the production of methane biogas from anaerobic digestion, recovery of heat from methane biogas to generate power, and the capture of landfill gas to power plant operations (Smith & Quebe, 2018).

More than half of the energy used at wastewater facilities goes into providing oxygen for secondary treatment processes including aeration (Pabi et al., 2013). Upgrades to aeration systems increase oxygen transfer efficiency through technologies such as advanced membranes, more efficient pumps and blower systems, fine-bubble diffusers and advanced controls with dissolved oxygen or ammonia sensors (Smith & Quebe, 2018). Pumping systems are the second most energy intensive system at wastewater treatment plants, accounting for 10-15% of total energy use. Energy efficiency upgrades for pumping systems at wastewater treatment systems are like those at water treatment systems and include right-sizing equipment, optimizing distribution piping, eliminating valves, and installing variable frequency drives (Smith & Quebe, 2018). Computerized monitoring and optimization control systems such as SCADA maximize treatment process efficiency and overall performance and are usually upgraded alongside aeration and pumping technologies to further reduce energy use (Smith & Quebe, 2018).

Observed electricity use and cost savings from specific technology installations and integrations vary widely across industry and academic literature due to the bespoke and complex nature of water and wastewater systems. The EPA reports that water and wastewater plants can save up to 15-30% of energy costs by incorporating energy efficiency practices (US EPA, 2021). Depending on the system and synergies between system components, a total system retrofit at a wastewater treatment plant can reduce electricity use up to 50% (Smith & Quebe, 2018). The Department of Energy's Sustainable Wastewater Infrastructure of the Future (SWIFt) Accelerator partnered with 70 wastewater treatment facilities to accelerate system modernization and sustainable infrastructure between 2016-2019 (US Department of Energy, Better Buildings, n.d.a). The SWIFt program produced a list of energy savings associated with 23 energy conservation and resource recovery measures at wastewater treatment plants evaluated during phase one of the SWIFt program detailed in Exhibit 2 of the Appendix (US Department of Energy, Better Buildings, n.d.b).

Methods

Financial Evaluation for Capital Projects at Water Utilities

The level of sophistication for evaluating electricity cost savings from system upgrades varies with size and managerial proficiency of water utilities. Many utilities evaluate energy efficiency projects using a simple pay-back period that measures how long it takes to recoup dollars spent on the project (Willis et al., 2010). Despite widespread use within the industry, the payback period methodology does not calculate the net present cost savings of a project relative to its cost (Wisconsin Focus on Energy, 2020). The payback period methodology also ignores the magnitude of cash flows, the effect of timings and cost of capital on cash flows, and annual cash flows after the payback period (Willis et al., 2010). Maximum thresholds of payback periods used for decision making are often as short as three to seven years (S. Smart, personal communication, March 22, 2022) when a more reasonable payback period is often the lifetime of the asset which could be ten to forty years (Willis et al., 2010). Some utilities do use a return-on-investment capital budgeting model, but the financial analysis is generally not robust nor evaluated after the system has been upgraded (Badruzzaman et al., 2015).

Relying on the payback period methodology overemphasizes the importance of liquidity as a goal in financial decision-marking and may lead utilities to defer capital expenditures, resulting in higher lifetime costs (Willis et al, 2010). Utilities often choose equipment for system upgrades that meets technical requirements at the lowest bid price focusing on the initial capital costs instead of variables that could dramatically reduce costs and improve performance such as maintenance and energy (Senon et al., 2015), For example, the upfront capital costs of a water treatment pumping system is less than ten percent of its total lifecycle costs, while energy costs to operate pump may be greater than 70% of its lifecycle costs (Water Research Foundation, 2015).

Lifecycle cost analysis is a valuable method for evaluating the cost of energy efficiency system upgrades. The Hydraulic Institute has defined the elements of lifecycle costs for pumping systems that can be extended to other waste and wastewater system upgrades: equipment, design, engineering, installation, energy, operations, maintenance and repair, downtime, and decommissioning costs into the total lifecycle cost of the asset (Hydraulic Institute, 2001). By implementing a lifecycle cost analysis, a water utility can determine the most cost-effective system upgrade option (Xylem, 2015b). The model created to evaluate the positive business case of system upgrades that could be funded by the Affordability-EIB incorporates the spirit of lifecycle analysis by integrating energy costs and annual costs over the useful asset life of the system upgrade.

Affordability-EIB Financial Model

The Affordability-EIB financial model was created to quantify the scale of energy cost savings from system upgrades and evaluate if these cost savings are large enough to provide financial return and fund affordability programs. A major challenge of deploying EIBs at scale is accounting for the uncertainty of future system dynamics and stakeholder costs (Brand et al., 2021). The uncertainty of the Affordability-EIB model lies in the future energy prices and the reduced electricity use cost savings realized from energy efficiency system upgrades. Modeling operational cash flows, and environmental and financial risks enables the evaluation of the business case of accelerated system modernization funded by an Affordability-EIB. The positive business case for energy efficiency system upgrades funded by the Affordability-EIB would demonstrate that operational cost savings from reduced electricity costs exceed the cost of debt service so that additional cost savings can be passed onto water utility rate payers.

Within the model, the accelerated system upgrade case assumes an energy efficiency upgrade occurs in year one and results in decreased annual electricity use over the life of the upgraded asset. There are two scenarios that could create cost savings between a base case and an accelerated system upgrade. In the first scenario, the system in the base case does not receive a future upgrade and consumes the same amount of electricity year over year in the evaluation period. In this scenario, positive net cost savings exist if the cost of debt service of financing the accelerated system upgrade is less than the difference in electricity costs between the base case and the accelerated system upgrade. In the second scenario, the system in the base case is upgraded in a future year. This is a more likely scenario as the useful asset life of equipment in water and wastewater systems is typically ten to forty years, and utilities continually look to upgrade the operational efficiency of their systems. In the second scenario, positive net cost savings between the base case with a delayed system upgrade and the accelerated system upgrade depend on more variables, including: year of system upgrade in the base case, escalation of project costs, and the total reduction of electricity use in both the accelerated system upgrade and the delayed system upgrade in the base case.

The Affordability-EIB model requires financial, environmental, and operational variables for the base case and accelerated system upgrade case that can be adjusted for market conditions and investor expectations, detailed on the following page. Variables listed under the "Base Case with No Delayed Upgrade" and "Accelerated System Upgrade" subtitles are required inputs for the first scenario in which the costs of the base case without an upgrade are compared to the costs of the accelerated system upgrade. Variables listed under the "Base Case with Delayed Upgrade" and "Accelerated System Upgrade" subtitles are required inputs for the second scenario in which the costs of the base case with a future upgrade are compared to the accelerated system upgrade. The model requires at least four variables for the accelerated system upgrade case from an observed or expected utility energy efficiency upgrade: electricity demand in annual kilowatt hours, price paid per kilowatt hour, percentage reduction of electricity demand, and capital cost of the system upgrade.

The evaluation period for comparing the costs between the accelerated system upgrade and the base case with a delayed system upgrade is the replacement year of the delayed system upgrade in the base case plus the useful life of this system. The evaluation period for comparing the costs between the accelerated system upgrade and the base case without a system upgrade is the useful asset life of the equipment in the accelerated system upgrade. The model assumes no salvage value of the equipment from any system upgrade at the end of its useful asset life.

Model Variables

Model Variables, Base Case with No Upgrade

Financial Variables

Discount Rate **-** Interest rate used in discounted cash flow analysis to determine the net present value (NPV) of future cash flows. The discount rate was assumed to be the same in the base case and the accelerated system upgrade case.

Operational Variables
Annual Electricity Use - Total electricity demand from water or wastewater treatment system in kilowatt hours.

Electricity Price in Year 1 - Price paid by utility in dollars per kilowatt hour.

Electricity Price Escalator - Escalation occurs when growth in electricity rates outpace the rate of inflation. Department of Energy's Energy Information Association's forecasts a 2% per year nominal growth rate in the price of electricity between 2021 and 2050 (US Energy Information Administration, 2021).

Environmental Variables
Lbs CO^2/MWh by eGRID Region **-** The user selects the eGRID region in which the water utility is located to input lbs of CO^2/MWh from the utility's annual purchased electricity. Regional carbon emission from purchased electricity is tracked by the EPA in lbs of CO^2/MW for 27 eGRID regions to represent emissions from regional power generation (US EPA, 2022).

Social Cost of Carbon - The user selects the capitalization rate of the social cost of carbon in $/metric ton CO^2. The social cost of carbon quantifies the societal costs of climate change, such as changes in net agricultural productivity, human health, and property damages from increased flood risk (Pizer et al., 2014). The social cost of carbon is highly debated by policymakers, and Biden administration set the interim price for the social cost of carbon $51/metric ton (Joselow, 2022).

Social Cost of Carbon Discount Rate - The discount rate of the social cost of carbon is used to calculate the value of future damages from present-day CO^2 emissions. The current US administration uses discount rates of 3-7%, but questions of intergenerational equity have policymakers advocating for a discount rate less than 3% for cost-benefit analysis and decision-making (Erb, 2021).

Additional Model Variables for Base Case with Delayed Upgrade

Financial Variables
Project Capital Costs – Landed cost of the capital project including total cost of design, planning, equipment, and installation.

Upgrade Year – Year the delayed system upgrade is installed or integrated.

Annual Project Escalation – Annual percentage increase to construct the system upgrade. Delaying a project usually increases its costs, due to increased equipment material and labor costs, inflation, supply and demand, environment policies, and advances in technology.

Interest Rate **–** Rate of municipal bond used to finance the system upgrade in the base case. Generally, interest rates of municipal bonds are currently between 1-3% (Electronic Municipal Market Access, 2022).

Loan Tenor **–** Number of years the date of loan disbursement to date of loan closure. Municipal bonds generally have loan tenors from 10-40 years in 5-year increments.

Annual Debt Service – Total cost of annual financing to the utility, calculated from project capital costs, interest rate and loan tenor.

Useful Asset Life - Number of years the equipment of delayed system upgrade is likely to remain in service.

Operational Variables

Electricity Savings – Expected or observed percentage of total reduction in electricity demand with delayed system upgrade.

<u>Model Variables, Accelerated Upgrade Case</u>

Financial Variables

The accelerated system modernization case requires the system upgrade's landed capital cost, interest rate, loan tenor, annual debt service and useful asset life. Because the capital project is assumed to occur in year one, replacement year of system upgrade is not required as in the base case. The discount rate is assumed to be the same in the base case and the accelerated system upgrade case.

Operational Variables

The accelerated system upgrade case requires the observed or expected percentage reduction in total electricity use from the accelerated system upgrade. The model links year one energy price and annual energy price escalator from the base case to the accelerated system upgrade case. The model calculates annual electricity demand from the accelerated system upgrade from annual electricity demand in the base case and the total percentage of electricity reduced in the accelerated system upgrade. A similar or greater percentage reduction of total electricity use should be assumed in the accelerated upgrade case as the Affordability-EIB model seeks costs savings through the acceleration of energy efficiency upgrades.

Environmental Variables

The model links the same Lbs CO^2/MWh, social cost of carbon and discount rate of the social cost of carbon from the base case to the accelerated system upgrade case. The model calculates the MT CO^2 for purchased kWh and the social cost of carbon from annual purchased electricity.

Outputs of Affordability-EIB Model

The model calculates annual costs from electricity use and debt service for the base case and accelerated system upgrade case. Annual net cost savings created by the Affordability-EIB is the annual costs from the base case less the annual costs from the accelerated system upgrade case. Cumulative net cost savings is the sum of annual net cost savings over the evaluation period. Annual net cost savings are discounted and summed to provide the net present value (NPV) of cost savings from the accelerated system upgrade. The model sensitizes the NPV of cost savings for all input variables except capital costs and annual electricity use. Annual cost savings, cumulative savings over the evaluation period, discounted annual cost savings, and the net present value of cost savings are calculated for four financial settings:

- Annual cost without the cost of debt service
- Annual costs with the cost of debt service
- Capitalization of the Social Cost of Carbon
- Annual Costs with the cost of debt service and capitalization of the Social Cost of Carbon.

The model calculates the social cost of carbon for the base case and accelerated system upgrade by multiplying annual electricity use by the average metric tons of CO^2 from purchased electricity and the social cost of carbon. Annual net cost savings from the social cost of carbon are calculated by subtracting the social cost of carbon in the accelerated system upgrade from the social cost of carbon in the base case. It’s important to note that the social cost of carbon does not create real cost savings that could be used to fund affordability programs. Some municipal governments use the social cost of carbon to integrate environmental impacts into cost-benefit analysis and financial decision-making (Orange Water and Sewer Authority, 2020). Avoided social cost of carbon is also an attractive outcome metric for impact investors.

Results

Case Study: North Toronto Wastewater Treatment Plant

North Toronto’s wastewater treatment plant, one of four operated by the city of Toronto, was required to upgrade the denitrification processes of its secondary process equipment (Suez, 2021). Toronto evaluated various system upgrades that would optimize treatment performance and reduce electricity consumption. Suez’s Membrane Aerated Biofilm Reactor (MABR) was compared to traditional activated sludge treatment and chosen to restore the overall capacity of the plant to 12 MGD. Contracted engineering consultants concluded that MABR technology would reduce total electricity use by about 40% compared to the original system (Suez, 2021).

Results: Base Case with No Upgrade vs. Accelerated System Upgrade (Scenario 1)

Financial, operational, and environmental variables detailed in Suez’s case study of the North Toronto Treatment Plant were entered into the Affordability-EIB model as the accelerated system upgrade case. Input variables for the base case were taken from the Toronto case without a system upgrade. The US national average of 834.2 lbs. of CO^2 per MWh was input to reflect the damages and social cost of carbon of CO^2 emitted in the US. The full list of inputs of variables for the base case with no system upgrade and the accelerated system upgrade case are found in the Appendix, Exhibit 3.

The model calculated the non-discounted difference in annual electricity costs between the base case and accelerated system upgrade case to rise from $333,000 in year one, to $575,000 in year twenty-five (Figure 1).

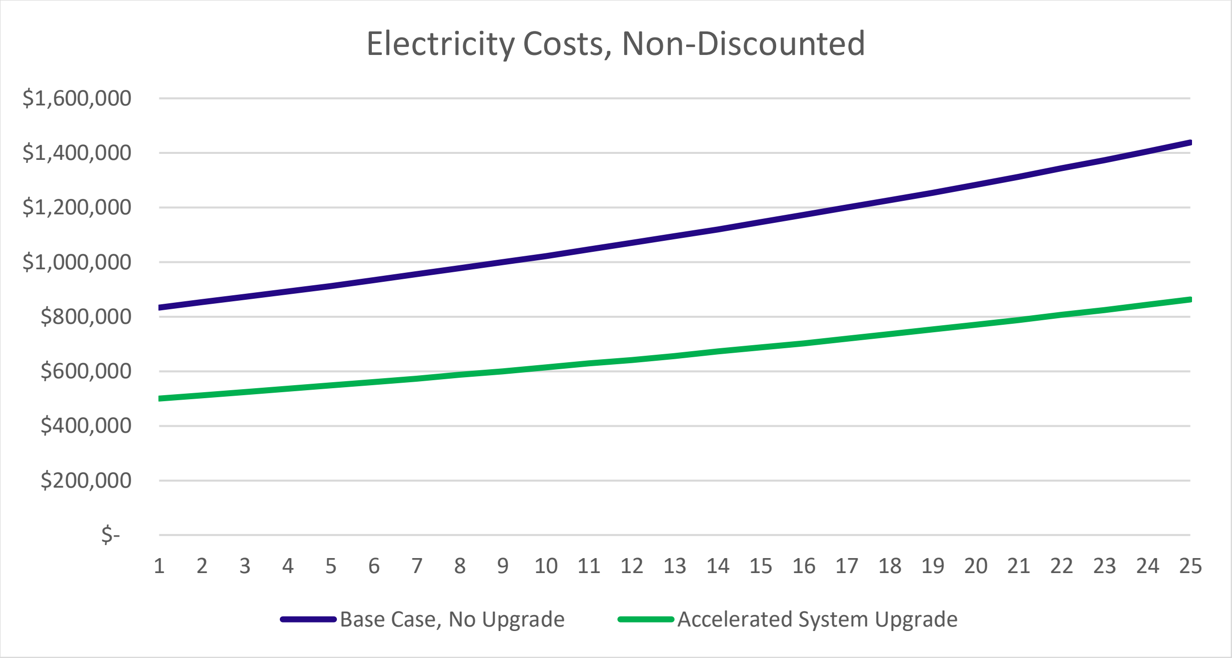


Figure 1. Non-discounted electricity costs for base case and accelerated system upgrades

Electricity cost of the base case and accelerated system upgrade case were added to the costs of debt service to calculate the total costs of the two cases (Graph 2). Total costs of the accelerated system upgrade remain above the base case until the cost of debt service to fund the accelerated system upgrade is paid off in year twenty. The model demonstrates that the reduction of electricity use from the accelerated system upgrade is less than the cost of debt service to fund the accelerated system upgrade.

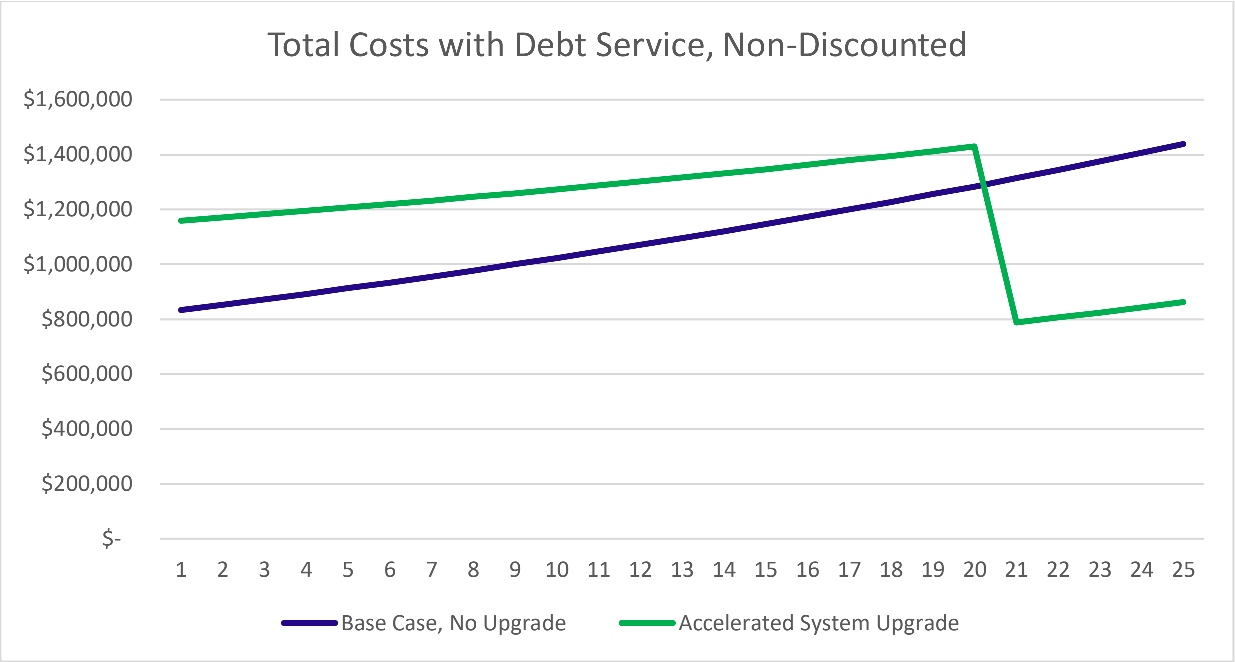


Figure 2. Non-discounted total cost (including debt service) for base case and accelerated system upgrades

The positive $7,687,844 net present value (NPV) of electricity cost savings between the base case and the accelerated system upgrade drops to -$2,417,167 when the cost of debt service is integrated. The NPV of net cost savings with the cost of debt service is sensitive to all financial and operational variables, see Appendix, Exhibit 4 for detailed analysis. The NPV of net cost savings with the cost of debt service rises to 0 when the annual electricity price escalator rises 4.6%, replacing of 2.3% as modeled in the scenario. The NPV of net cost savings with the cost of debt service rises to 0 when the price per kWh in year one rises to $0.184, replacing $0.14 as modeled in the scenario.

NPV Net Cost Savings, No System Upgrade vs. Accelerated System Upgrade

Without Debt Service (Electricity Costs Only)	$7,687,844
With Cost of Debt Service	($2,417,167)
Capitalization of Social Cost of Carbon	$824,065
With Debt Service and Social Cost of Carbon	($1,593,102)

The Toronto case study does not show positive cost savings from an accelerated system upgrade compared to the base case without a system upgrade because the cost of debt service is greater than the electricity cost savings generated. The Affordability-EIB model demonstrates that if the cost of debt service is greater than electricity cost savings from accelerated system upgrade, cost savings would not be realized, and an affordability program could not be funded.

Results: Base Case with Delayed Upgrade vs. Accelerated System Upgrade (Scenario 2)

The Affordability-EIB model was used to calculate costs of the accelerated system upgrade illustrated by Toronto's wastewater treatment plant aeration upgrade to costs of a base case with a delayed upgrade by inputting several major assumptions for the base case. The delayed system upgrade in the base case was assumed at year five, capital cost at $9,000,000 and total reduction in electricity use at 30% to reflect a delayed capital project that was slightly cheaper and realized less electricity savings than the accelerated system upgrade. The full list of inputs for variables in the base case with delayed system upgrade case and accelerated system upgrade case are found in Appendix, Exhibit 3.

The model calculated the difference in non-discounted annual electricity costs between the base case with delayed upgrade and accelerated system upgrade top drop from $333,000 in the first year to $161,000 in year 30 (Figure 3).

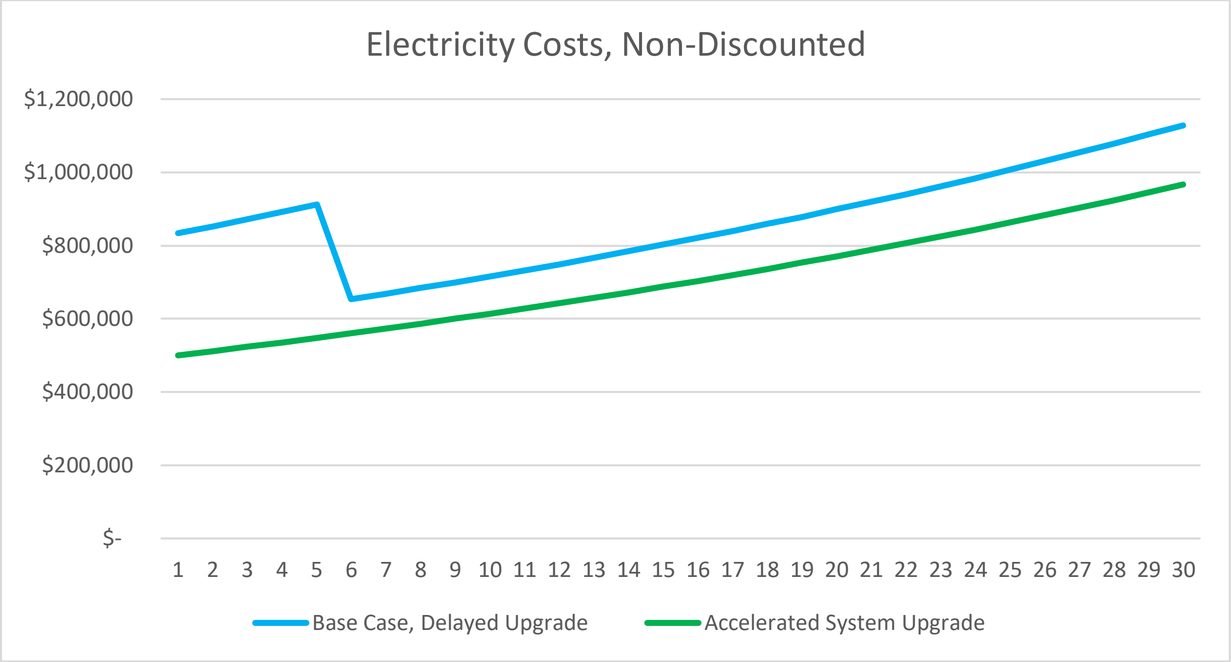


Figure 3. Non-discounted electricity costs for base case and accelerated system upgrades

Total non-discounted costs of the accelerated system upgrade case are higher than the base case until the delayed upgrade in the base case occurs in year five (Figure 4). Costs of the base case spikes in year five when the cost of debt service is capitalized, but electricity costs savings are not yet realized. After year five, total annual net cost savings from the accelerated system upgrade are about $136,000 and rise to $171,000 in year twenty (Figure 4).

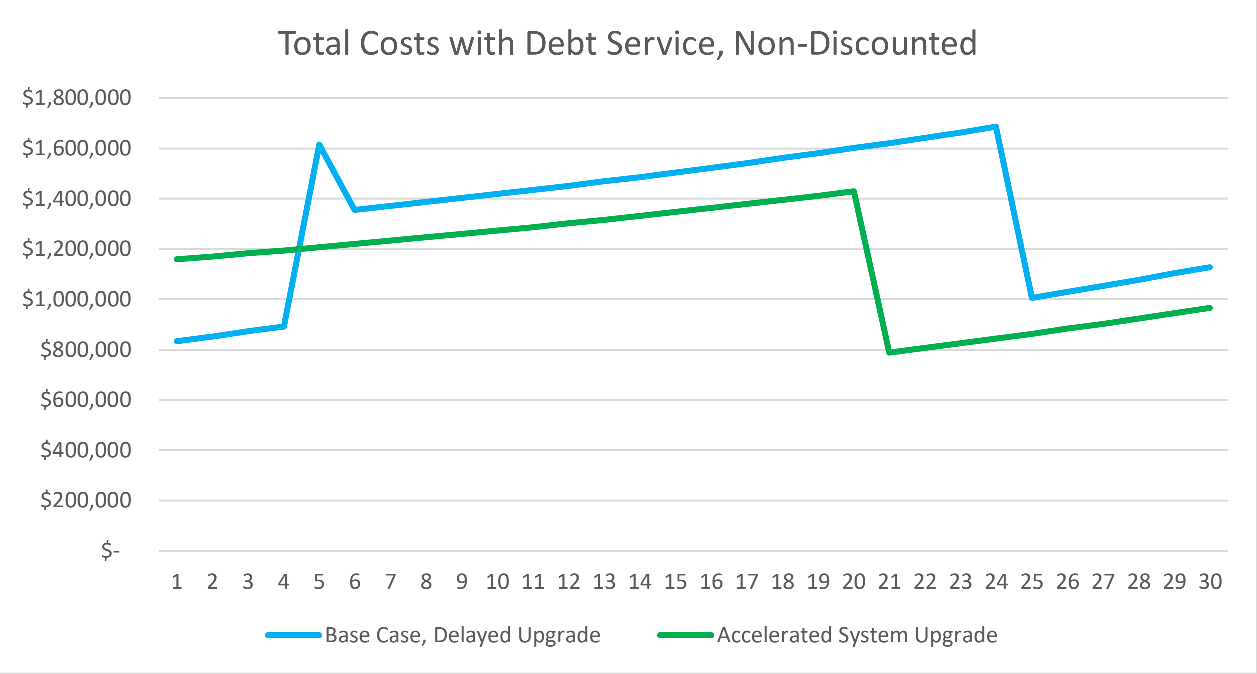


Figure 4. Non-discounted total cost (including debt service) for base case and accelerated system upgrades

These cost savings could be used to fund affordability programs and point to a positive business case for the Affordability-EIB model in this scenario. Because costs are greater in the accelerated system upgrade than the base case during the first five years, the net present value of discounted net cost savings over the thirty-year evaluation period must be evaluated to determine whether the accelerated system upgrade is a cost-effective and demonstrates a positive business case. The $3,501,699 NPV of electricity cost savings between the base case with delayed upgrade and accelerated system upgrade drops to $2,959,905 when the cost of debt service is integrated. The positive NPV of discounted net cost savings from the accelerated system upgrade highlights the cost-effectiveness of a system upgrade and ability of the accelerated system upgrade to fund affordability programs.

NPV Discounted Net Cost Savings, 30 Year Evaluation Period

Without Debt Service (Electricity Costs Only)	$3,501,699
With Cost of Debt Service	$2,959,905
Capitalization of Social Cost of Carbon	$437,711
With Debt Service and Social Cost of Carbon	$3,397,615

Monte Carlo Simulation, Base Case with Delayed Upgrade vs. Accelerated System Upgrade (Scenario 2)

A Monte Carlo outcome probability simulation for the NPV of net cost savings with the cost of debt service was completed for eight variables. The specific variables and the assumed distributions, minimum, most likely, and maximum values for the Monte Carlo simulation are found in Exhibit 6 of the Appendix. The Monte Carlo simulation completed 10,000 trials and produced a log-normal distribution with less than 10% of possible outcomes producing a negative value for the NPV of net cost savings with the cost of debt service (Appendix, Exhibit 7). This finding is noteworthy given the quantity and range of values for the operational and financial variables entered in the Monte Carlo simulation. The small percentage of negative outcomes for NPV of discounted net cost savings with debt service indicates that an accelerated system upgrade is resilient to financial and operational risks.

The Monte Carlo simulation estimates the percentage of variance in the outcome probability forecast that is caused by each variable. The contribution to variance results are estimates and calculated by squaring the rank correlation coefficients of each variable and normalizing them to 100%. Variables with the strongest contribution to variance of the forecast outcome of NPV of net cost savings with the cost of debt service are the percentage of total electricity reduction from the accelerated system upgrade case (50.4%), year of delayed system upgrade in the base case (10.8%), percentage of total electricity reduction from the base case delayed system upgrade (-10.4%), and the discount rate (-10.1%).

Monte Carlo Analysis, Variable Contribution to Variance

Percentage Total Electricity Savings (Accelerated Case)	50.4%
Upgrade Year (Base Case)	10.8%
Percentage Total Electricity Savings (Base Case)	-10.4%
Discount Rate	-10.1%
Annual Project Price Escalation (Base Case)	8.4%
Electricity Price Escalator	4.3%
Interest Rate (Base Case)	-3.2%
Interest Rate (Accelerated Case)	2.5%

The NPV of net cost savings with the cost of debt service from the accelerated system upgrade is sensitized to financial and operational variables in Exhibit 7 of the Appendix. A two-way data tables sensitize the NPV of net cost savings with the cost of debt service to the percentages of total electricity reduction from system upgrades in the accelerated case and base case in Exhibit 8. This sensitivity analysis demonstrates that the NPV of net cost savings with the cost of debt service drops below zero only if the total percentage of electricity savings in the base case is larger than the total percentage of electricity reduction in the accelerated case, violating the assumptions of the model. The Affordability-EIB model was not built to exclude cases that violate this assumption, and these cases may represent a large portion of the ten percent of forecasted outcomes with a negative NPV in the Monte Carlo analysis.

The annual electricity price escalator is the environmental variable that contributes the most variance to possible outcomes within the Monte Carlo simulation, and surprisingly contributes only 4.3% to total variance. Nevertheless, Figure 5 demonstrates the annual electricity price escalator positively contributes non-linearly to the NPV of net cost savings with the cost of debt service. The NPV of net cost savings with the cost of debt service is resilient to negative annual electricity price escalation, as the NPV remains positive even when annual electricity price escalation drops to -5%. A two-way data tables sensitize the NPV of net cost savings with the cost of debt service to the percentages of total electricity reduction from the accelerated system upgrade and the annual electricity price escalator in Exhibit 9 of the Appendix. This analysis exhibits that the NPV of net cost savings with the cost of debt service remains positive for all annual electricity price escalations, even if the percentage of total electricity reduction from the accelerated system upgrade declines from 40% to 30%.

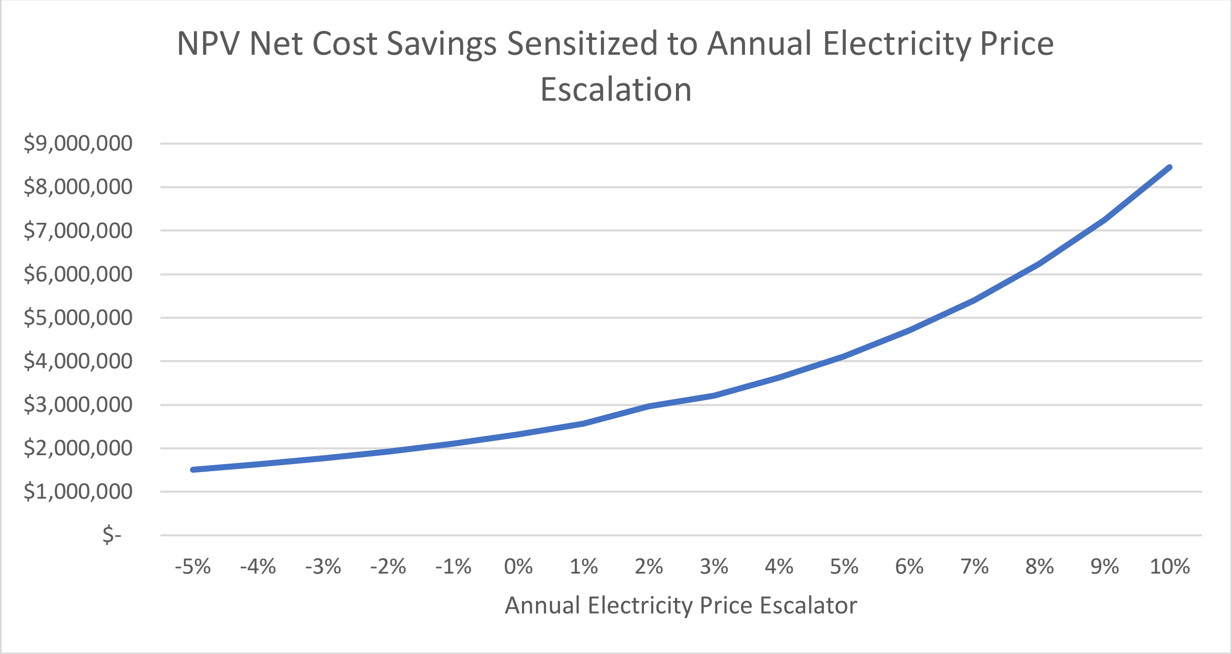


Figure 5. NPV total net cost savings with the cost of debt service by rate of annual electricity price escalation

The difference in total costs and positive NPV of net cost savings with the cost of debt service between the base case with delayed system upgrade and the accelerated system upgrade using inputs of the Toronto North Wastewater Treatment Plant point to a positive business case that could fund affordability program. The Monte Carlo contribution to variance analysis displays that operational variables are more significant than environmental variables in contributing to the NPV of net cost savings with the cost of debt service from the accelerated system upgrade. This finding is important because operational risk can be overcome more easily than financial and environmental risk as engineering consultants can evaluate water utility systems and forecast expected electricity savings from system upgrades.

Discussion

Limitations of the Affordability-EIB Model

Simplifications and assumptions built into the Affordability-EIB model yield important limitations that must be considered when evaluating how annual costs and the net present value of cost savings from accelerated system upgrade may play out in a real-world scenario. The complicated nature of water utility systems, operations and maintenance costs, system electricity demand, and complex utility billing structures will influence the actual financial performance of energy efficiency system upgrades at water utilities.

The interrelated and complex nature of system components within water and wastewater treatment plants creates difficultly in generalizing how electricity efficiency system upgrades will reduce electricity demand energy across systems (Cramer & Willis, 2017). Comparable system upgrades at similarly sized facilities may not yield parallel reduced electricity use and cost savings due to the types of processes, influent load, effluent requirements and the type, number, and size of equipment at each utility system (Xylem, personal communication, March 30, 2022). Energy efficiency system upgrades are not completed in a siloed manner; multiple system components are almost always upgraded at the same time. System components that are upgraded together almost always produce synergistic energy savings. This makes the quantification and generalization of reduction in electricity use from one system to another even more challenging. Most water utility systems do not submeter electricity use by equipment, and utilities do not try to measure reduced electricity use by system component after system upgrades.

In addition to electricity cost savings, energy efficiency system upgrades generally realize operational and maintenance cost savings through reduction in costs such as contracted service hours, labor, and replacement parts (Smith & Quebe, 2018). Generalizable percentage reductions of total operation and maintenance cost savings from specific energy efficiency technologies are extremely limited within industry, think tank, and academic literature. To quantify the net cost savings of reduced operations and maintenance costs from accelerated system upgrades the Affordability-EIB model would need to incorporate additional variables, including: 1) observed or assumed annual operation and maintenance costs in the base case, 2) expected escalation of operation and maintenance costs, 3) percentage total reduction of observed or assumed operation and maintenance costs in the base case and accelerated system upgrade case.

Calculating avoided energy cost savings as a function of demand in kWh multiplied by price of kWh leaves out several elements of the complicated rate structures used to bill industrial electricity customers. Electricity demand charges at water utilities are based on the peak demand for a given month or season and can have significant impacts on total electricity costs (US EPA, 2017). Most water and wastewater energy bills include a fixed customer charge based on the size of the connection; time-of-use charges for peak or off-peak hours; ratchet clauses; cost-of-fuel adjustments; customer service charges; national, regional, and local taxes; and a power factor penalty that deducts power that was delivered but not billed due to equipment with an apparent power factor less than active power (Gaudrel & Savreux, 2014). Energy efficiency technologies that modulate energy may shift demand from on-peak to off-peak hours, which may yield significant electricity cost savings and reduce green-house gas emissions (McGuckin et al., 2013). Reductions in electricity use may also produce cost savings by allowing the utility to negotiate new contract terms with the electric utility (Orange Water and Sewer Authority, 2020).

The biggest limitation of the model is the engrained assumption that water utilities are rationally economic actors. Water utilities make decisions to meet regulatory compliance and ensure customer health instead of prioritizing maximum operational and economic efficiency

(Smith & Quebe, 2018). Decisions to invest in equipment for system upgrade depend on the capacity of existing staff to operate the equipment (S. Smart, personal communication, March 22, 2022). Likewise, equipment determined as most cost-effective by staff depend on the sophistication of financial and energy optimization expertise of staff members at water utilities and the ability of staff to operate the equipment (V. Leiby, personal communication, March 22, 2022).

Further Research

The business case for electricity cost savings from energy efficiency technologies would be strengthened by sourcing and evaluating case studies across a variety of energy efficiency technologies and water systems to identify further sensitives within the Affordability-EIB model. Finding case studies to test the Affordability-EIB model with annual electricity use, observed total percentage of electricity savings from a system upgrade and the capital cost of the system upgrade was challenging. Equipment prices and expected electricity savings from branded equipment are proprietary information for water and wastewater equipment manufacturers. Even if equipment prices are obtained from equipment manufacturers, the landed price of design, planning and installation of the equipment is only obtained from utility post system upgrade. Case studies from Department of Energy and think tanks such as the Water Research Foundation largely pre-date 2008 and were deemed out of date due to significant advances in energy efficiency technologies and increased capital equipment prices. Almost all energy efficiency case studies evaluate system upgrades of multiple system components, making the need to evaluate many case studies necessary. Contacting utilities directly and connecting with the Build Better Plants initiative at the Department of Energy are two possible ways to gather reliable and detailed case study information.

Special attention should be paid to the Water Research Foundation's current study #5091 "Developing a Framework for Quantifying Energy Optimization Reporting." The project is evaluating and quantifying energy, emissions, and cost savings reductions from system upgrades at water and wastewater treatment plants to improve the water utility sector's dearth of energy savings estimation procedures. The project is leveraging the Efficiency Valuation Organization's 2012 International Performance Measurement and Verification Protocol (Water Research Foundation, 2021). This framework is a best-in-class energy use estimation tool and could be used to predict, evaluate, and verify environmental outcomes from an Affordability-EIB.

Conclusions

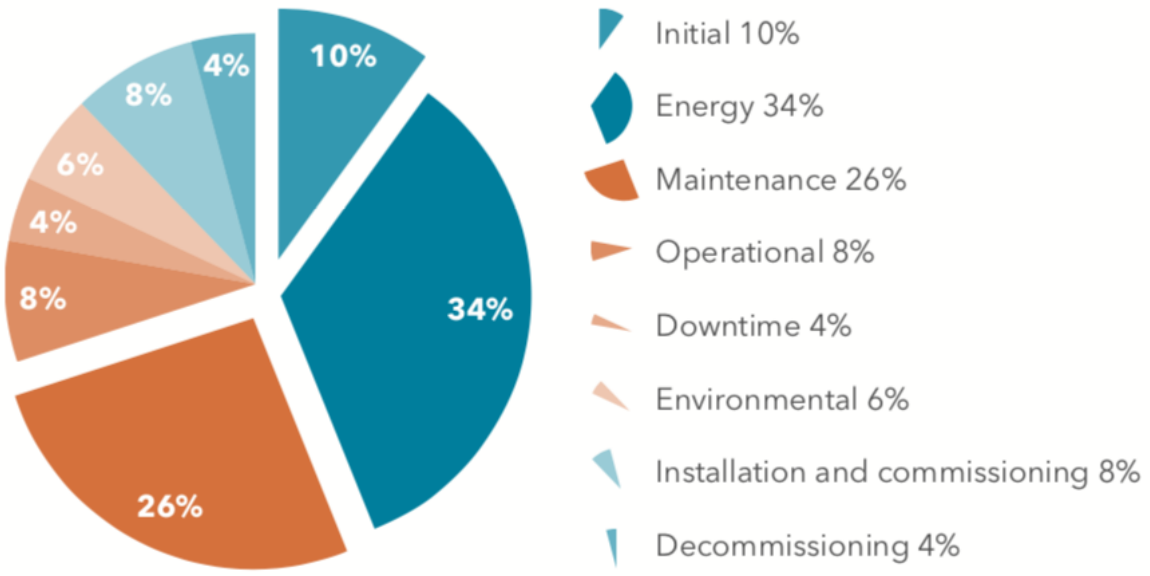
Appropriate choices in energy management at water utilities depend on system characteristics, availability of funding and financing, and managerial and staff capacities to realize technological and operational changes (Pabi et al., 2013). The Affordability-EIB model is a first step to evaluate the cost-effectiveness of energy efficiency system upgrades and how accelerating system upgrades could create annual cost savings to fund water affordability programs. Financial analysis of the Toronto wastewater treatment does not show a positive business case for an accelerated system upgrade if the utility does not require a system upgrade in the future, as the cost of debt service to fund the accelerated system upgrade is greater than the net cost savings it generates from reduced electricity use. The Affordability-EIB model yields positive annual cost savings and NPV of discounted net cost savings with debt service over the evaluation period for an accelerated system upgrade modeled after the Toronto case when compared to base case with a delayed system upgrade. The Monte Carlo probability outcome analysis performed on the NPV of net cost savings with the cost of debt services with inputs from the Toronto case study exhibits that operational variables have the strongest impact on variance to the NPV of net cost savings. The percentage of total electricity use reduced by the accelerated system upgrade and the delayed system upgrade in the base case will largely determine the amount of cost savings that can be generated by the utility to fund affordability programs.

Ultimately, whether an Affordability-EIB is a feasible solution for funding accelerated system modernization through investment in energy efficiency technologies will depend on the cost of the system upgrade, realized electricity cost savings, and tolerances for risk of stakeholders and investors. It is not possible to demonstrate a positive business case for all types of system upgrades due to the large variation of water and wastewater treatment plants and energy efficiency technologies. Notwithstanding, the considerable number of financial, operational, and environmental variables within the Affordability-EIB model make it a flexible tool to demonstrate how positive net cost savings can be generated through accelerated system modernization while incorporating municipal and investor preferences.

Appendix

Exhibit 1

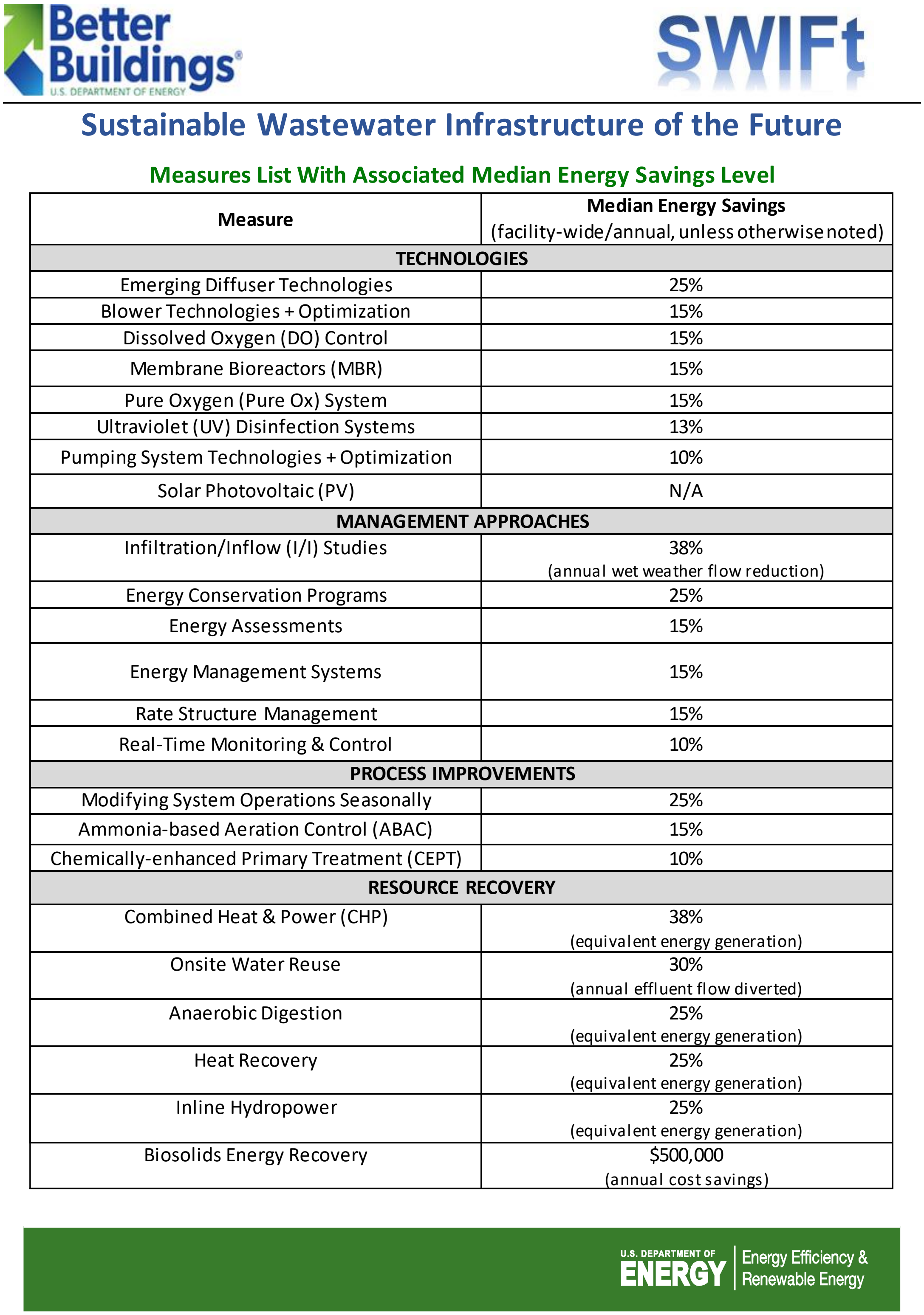
Lifecycle Costs of Typical Wastewater Pumping System



(Xylem, 2015b)

Exhibit 2

Observed Reduction in Electricity Use, SWIFt Program



Better Buildings

U.S. DEPARTMENT OF ENERGY

SWIFt

Sustainable Wastewater Infrastructure of the Future

Measures List With Associated Median Energy Savings Level

Measure	**Median Energy Savings** (facility-wide/annual, unless otherwise noted)
TECHNOLOGIES	
Emerging Diffuser Technologies	25%
Blower Technologies + Optimization	15%
Dissolved Oxygen (DO) Control	15%
Membrane Bioreactors (MBR)	15%
Pure Oxygen (Pure Ox) System	15%
Ultraviolet (UV) Disinfection Systems	13%
Pumping System Technologies + Optimization	10%
Solar Photovoltaic (PV)	N/A
MANAGEMENT APPROACHES	
Infiltration/Inflow (I/I) Studies	38% (annual wet weather flow reduction)
Energy Conservation Programs	25%
Energy Assessments	15%
Energy Management Systems	15%
Rate Structure Management	15%
Real-Time Monitoring & Control	10%
PROCESS IMPROVEMENTS	
Modifying System Operations Seasonally	25%
Ammonia-based Aeration Control (ABAC)	15%
Chemically-enhanced Primary Treatment (CEPT)	10%
RESOURCE RECOVERY	
Combined Heat & Power (CHP)	38% (equivalent energy generation)
Onsite Water Reuse	30% (annual effluent flow diverted)
Anaerobic Digestion	25% (equivalent energy generation)
Heat Recovery	25% (equivalent energy generation)
Inline Hydropower	25% (equivalent energy generation)
Biosolids Energy Recovery	$500,000 (annual cost savings)

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(US DOE Better Buildings Initiative, n.d. b)

Exhibit 3

Model Inputs, North Toronto Wastewater Treatment Plant

Base Case with No System Upgrade (Scenario 1)

Financial Parameters

Discount Rate	3.0%

Operational Parameters

Annual Electricity Use (kWh)	5,952,380
Electricity Price Year 1 ($/kWh)	$0.1467
Electricity Price Escalator	2.3%

Environmental Parameters

Lbs. CO^2/MWh by eGRID Region	834.2
MT CO^2 for purchased electricity	2252.25
Social Cost of Carbon	$51.00
Social Cost of Carbon for purchased electricity	$114,865
Social Cost of Carbon Discount Rate	3%

Base Case with Delayed System Upgrade (Scenario 2)

Financial Parameters

Capital Costs (Total Investment)	$9,000,000
Upgrade Year	5
Annual Project Escalation	4.0%
Useful Asset Life	25
Interest Rate	2.5%
Loan Tenor	20
Annual Debt Service	$802,300
Discount Rate	3.0%
Evaluation Period	30

Operational Parameters

Annual Electricity Use (kWh)	5,952,380
Electricity Price Year 1 ($/kWh)	$0.1467
Electricity Price Escalator	2.3%
Electricity Savings	30.0%

Environmental Parameters

Lbs CO2/MWh by eGRID Region	834.2
MT CO2 for purchased electricity	2252.25
Social Cost of Carbon	$51.00
Social Cost of Carbon for purchased electricity	$114,865
Social Cost of Carbon Discount Rate	3%

Accelerated System Upgrade

Financial Parameters

Capital Costs (Total Investment)	$10,280,000
Interest Rate	2.5%
Loan Tenor	20
Annual Debt Service	$659,432.48
Useful Asset Life / Evaluation Period	30
Discount Rate	3%

Operational Parameters

Electricity Savings	40%
Annual Electricity Use (kWh)	3,571,428
Electricity Price Year 1 ($/kWh)	$0.1467
Electricity Price Escalator	2.3%

Environmental Parameters

Lbs CO2/MWh by eGRID Region	834.2
MT CO2 for purchased electricity	1,351.35
Social Cost of Carbon	$51.00
Social Cost of Carbon for purchased electricity	$68,919
Social Cost of Carbon Discount Rate	3%

Exhibit 4

Sensitization NPV Net Cost Savings with Cost of Debt Service
Base Case with No System Upgrade vs Accelerated System Upgrade (Scenario 1)

Annual Electricity Price Escalator

	($2,417,167)
-5%	(6,381,917)
-2%	(5,217,443)
-1%	(4,710,316)
0%	(4,126,498)
1%	(3,452,871)
2.3%	(2,417,167)
3%	(1,771,679)
4%	(724,518)
4.6%	0
5%	492,691
10%	10,370,973

Year 1 Electricity Price

	-$2,417,167
$0.05	(7,359,352)
$0.07	(6,261,089)
$0.09	(5,162,825)
$0.11	(4,064,562)
$0.13	(2,966,299)
$0.15	(1,868,035)
$0.17	(769,772)
$.184	0
$0.19	328,492
$0.21	1,426,755
$0.23	2,525,019
$0.25	3,623,282
$0.27	4,721,545

Exhibit 5

Monte Carlo Simulation Input Variables NPV of Net Cost Savings with the Cost of Debt Service

Delayed System Upgrade vs. Accelerated System Upgrade (Scenario 2)

Base Case with Delayed System Upgrade

Financial Parameters

Variable	*Distribution Type*	*Minimum*	*Likeliest*	*Maximum*
Upgrade Year	Uniform	3		10
Annual Project Escalation	Triangular	1.5%	4.0%	7%
Interest Rate	Triangular	1.5%	2.5%	3.5%
Discount Rate	Triangular	2%	3.5%	6%

Operational Parameters

Variable	*Distribution Type*	*Minimum*	*Likeliest*	*Maximum*
Annual Electricity Price Escalator	Triangular	0.5%	3%	8%
Percentage Total Electricity Savings	Triangular	20%	30%	35%

Accelerated System Upgrade

Financial Parameters

Variable	*Distribution Type*	*Minimum*	*Likeliest*	*Maximum*
Interest Rate	Triangular	1%	2%	3%

Operational Parameters

Variable	*Distribution Type*	*Minimum*	*Likeliest*	*Maximum*
Percentage Total Electricity Savings	Triangular	20%	40%	45%

Exhibit 6

Monte Carlo Outcome Probability
NPV of Net Cost Savings with the Cost of Debt Service
Delayed System Upgrade vs. Accelerated System Upgrade (Scenario 2)

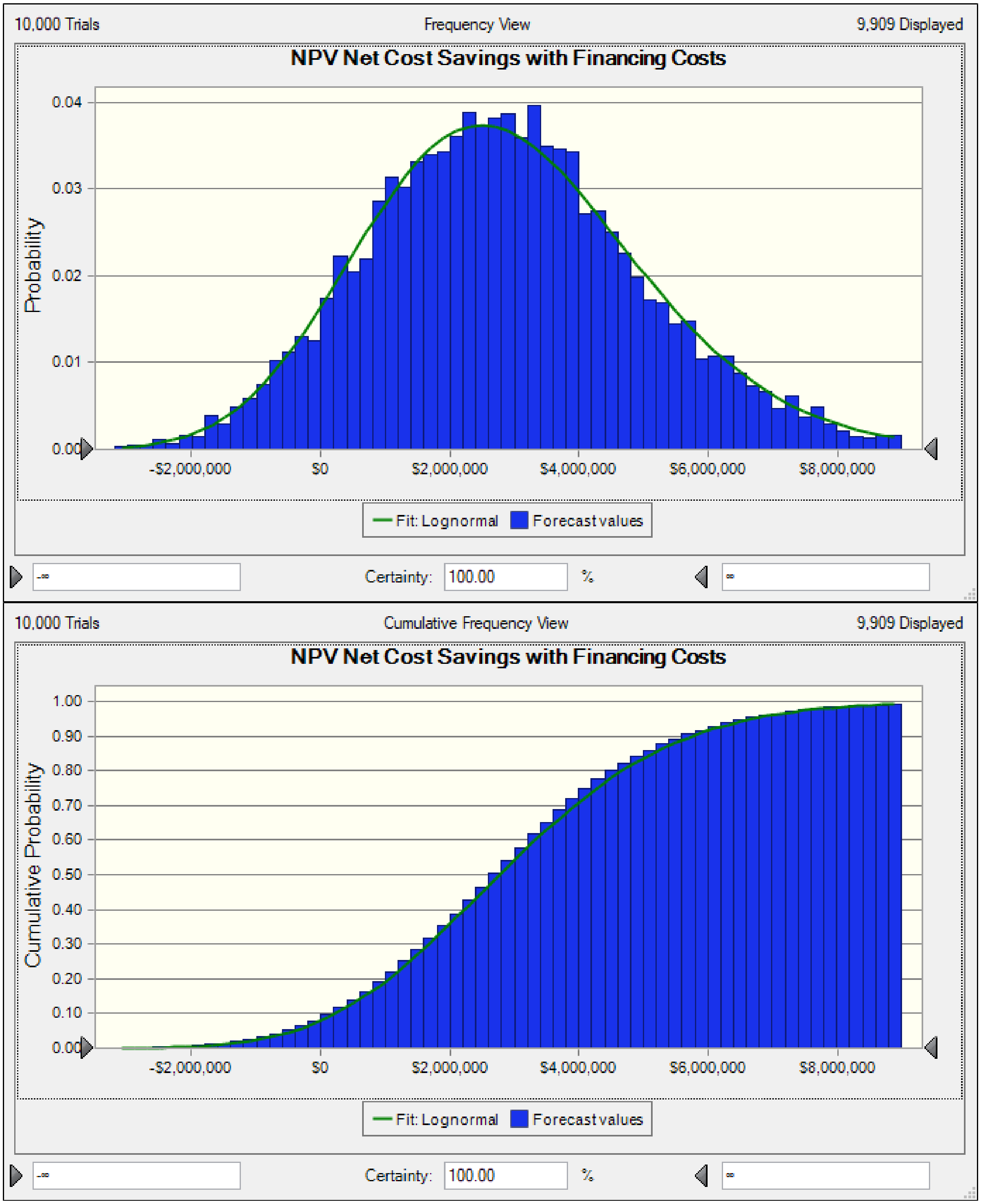

Exhibit 7

Sensitization of NPV Net Cost Savings with Cost of Debt Service
Base Case with Delayed System Upgrade vs Accelerated System Upgrade

Discount Rate

	$2,959,905
2%	3,691,510
3%	2,959,905
4%	2,364,349
5%	1,877,481
6%	1,477,786
7%	1,148,285
8%	875,528
9%	648,823
10%	459,637

Annual Project Escalation, Base Case

	$2,959,905
0.0%	1,256,955
1.0%	1,657,908
1.5%	1,864,428
2.0%	2,075,058
2.5%	2,289,859
3.0%	2,508,892
3.5%	2,732,220
4.0%	2,959,905

Year 1 Electricity Price

	$2,959,905
$0.05	708,812
$0.07	1,209,055
$0.09	1,709,298
$0.11	2,209,541
$0.13	2,709,783
$0.15	3,210,026
$0.17	3,710,269
$0.19	4,210,512
$0.21	4,710,755
$0.23	5,210,997
$0.25	5,711,240
$0.27	6,211,483

Year of Delayed Upgrade in Base Case

	$2,959,905
1	1,337,893
2	1,745,315
3	2,151,442
4	2,556,297
5	2,959,905
6	3,362,287
7	3,763,467
8	4,163,468
9	4,562,312
10	4,960,024
11	5,356,625
12	5,752,139
13	6,146,589
14	6,539,999
15	6,932,390

Annual Electricity Price Escalation

	$2,959,905
-10%	1,078,771
-5%	1,506,576
-2%	1,923,472
-1%	2,106,713
0%	2,319,851
1%	2,569,116
2.3%	2,959,905
3%	3,208,205
4%	3,618,746
5%	4,107,702
10%	8,478,849

Exhibit 8

Sensitization of NPV of Net Cost Savings with Cost of Debt Service
Delayed System Upgrade and Accelerated System Upgrade (Scenario 2)

Percentage Reduction of Total Electricity Use, Accelerated System Upgrade

Percentage Reduction Total Electricity Use

Base Case Delayed System Upgrade

$2,959,905	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**
10%	(130,753)	1,003,534	2,137,822	3,272,109	4,406,397	5,540,684	6,674,972	7,809,259	8,943,546
15%	(1,059,520)	74,768	1,209,055	2,343,343	3,477,630	4,611,917	5,746,205	6,880,492	8,014,780
20%	(1,988,286)	(853,999)	280,288	1,414,576	2,548,863	3,683,151	4,817,438	5,951,726	7,086,013
25%	(2,917,053)	(1,782,766)	(648,478)	485,809	1,620,097	2,754,384	3,888,672	5,022,959	6,157,246
30%	(3,845,820)	(2,711,532)	(1,577,245)	(442,957)	691,330	1,825,617	2,959,905	4,094,192	5,228,480
35%	(4,774,586)	(3,640,299)	(2,506,012)	(1,371,724)	(237,437)	896,851	2,031,138	3,165,426	4,299,713
40%	(5,703,353)	(4,569,066)	(3,434,778)	(2,300,491)	(1,166,203)	(31,916)	1,102,372	2,236,659	3,370,946
45%	(6,632,120)	(5,497,832)	(4,363,545)	(3,229,257)	(2,094,970)	(960,683)	173,605	1,307,892	2,442,180
50%	(7,560,886)	(6,426,599)	(5,292,312)	(4,158,024)	(3,023,737)	(1,889,449)	(755,162)	379,126	1,513,413

Exhibit 8 (continued)

Percentage Reduction of Total Electricity Use, Accelerated System Upgrade

Annual Electricity Price Escalator

$2,959,905	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**
-5%	(1,427,545)	(938,525)	(449,505)	39,515	528,535	1,017,556	1,506,576	1,995,596	2,484,616
-2%	(2,069,156)	(1,403,718)	(738,280)	(72,842)	592,596	1,258,034	1,923,472	2,588,910	3,254,348
-1%	(2,368,979)	(1,623,030)	(877,082)	(131,133)	614,816	1,360,764	2,106,713	2,852,662	3,598,610
0%	(2,727,262)	(1,886,077)	(1,044,891)	(203,706)	637,480	1,478,665	2,319,851	3,161,036	4,002,222
1%	(3,156,448)	(2,202,187)	(1,247,926)	(293,666)	660,595	1,614,856	2,569,116	3,523,377	4,477,638
2.3%	(3,845,820)	(2,711,532)	(1,577,245)	(442,957)	691,330	1,825,617	2,959,905	4,094,192	5,228,480
3%	(4,291,794)	(3,041,794)	(1,791,794)	(541,795)	708,205	1,958,205	3,208,205	4,458,205	5,708,204
4%	(5,039,351)	(3,596,335)	(2,153,318)	(710,302)	732,714	2,175,730	3,618,746	5,061,762	6,504,778
5%	(5,942,303)	(4,267,302)	(2,592,301)	(917,300)	757,701	2,432,701	4,107,702	5,782,703	7,457,704
10%	(14,287,541)	(10,493,143)	(6,698,744)	(2,904,346)	890,053	4,684,451	8,478,849	12,273,248	16,067,646

References

Andrew, N., Cramer, J., & Willis, J. (2017). *Water Watts: A Modern Look at Wastewater Power-Metering Data.* Water Research Foundation, NYSERDA, Brown and Caldwell.

Badruzzaman, M., Cherchi, C., Oppenheimer, J., Bros, C.M., Jacangelo, J.G., Bunn, S., Gordon, M., Pencheva, V., Jay, C., & Darcazallie, I. *Optimization of Energy and Water Quality Management Systems for Drinking Water Utilities.* (2015). Water Research Foundation, California Energy Commission.

Brand, M. W., Gudino-Elizondo, N., Allaire, M., Wright, S., Matson, W., Saksa, P., & Sanders, B. F. (2020). Stochastic hydro-financial watershed modeling for environmental impact bonds. *Water Resources Research, 56*. https://doi.org/10.1029/2020WR027328

Brand, M.W., Quesnel Seipp, K., Saksa, P., Ulibarri, N., Bomblies, A., Mandle, L., Allaire, M., Wing, O., Tobin-de la Puente, J., Parker, E.A., Nay, J., Sanders, B.F., Rosowsky, D., Lee, J., Johnson, K., Gudino-Elizondo, N., Ajami, N., Wobbrock, N., Adriaens, P., Grant, S.B., Wright, S., Gartner, T., Knight, Z., & Gibbons, J.P. (2021) *Environmental Impact Bonds: A Common Framework and Looking Ahead. Environment Research: Infrastructure Sustainability 1* (2). https://doi.org/10.1088/2634-4505/ac0b2c

Brandt, M. J., Middleton R. A., Wang S., (2010). *Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies.* Global Water Research Coalition.

Bredeson, A., Burke, E., Forsgren, K., Meernik, T., & Nair, S., (Feb 16, 2021) *2021 Sustainable Finance Outlook: Large Growth in Green, Social Sustainable Labels as Municipal Market Embraces ESG.* S&P Global. https://www.spglobal.com/ratings/en/research/articles/210216-2021-sustainable-finance-outlook-large-growth-in-green-social-sustainable-labels-as-municipal-market-embra-11828597

Cardoso, D. S., & Wichman, C. J. (2022). *Water affordability in the United States* (Working Paper). https://www.diegoscardoso.com/files/papers/Cardoso_Wichman_Water_Affordability_US.pdf

Electronic Municipal Market Access. *Municipal Yield Curves and Indices.* Last updated April 22, 2022. Accessed April 22, 2022. https://emma.msrb.org/ToolsAndResources/MarketIndicators

Erb, T. (2021, March 31). The Social Cost of Carbon – Going Nowhere But Up. *Center for Climate and Energy Solutions.* https://www.c2es.org/2021/03/the-social-cost-of-carbon-going-nowhere-but- up/#:~:text=Currently%2C%20the%20government%20uses%20discount,and%20ethical%20point%20of%20view.

Gandiglio, M., Lanzini, A., Soto, A., Pierluig,i L., & Massimo, Santarelli. (2017) Enhancing the Energy Efficiency of Wastewater Treatment Plants through Co-digestion and Fuel Cell Systems. *Frontiers in Environmental Science.* https://doi.org/10.3389/fenvs.2017.00070

Gaudrel, L., & Savreaux, S. (2014). *Three Steps for Reducing Total Cost of Ownership in Pumping Systems.* Schneider Electric.

Hamilton, G., Arzbaecher, C., Ehrhard, R., Murphy, J., (2009) *Driving Energy Efficiency in the U.S. Water & Wastewater Industry by Focusing on Operating and Maintenance Cost Reductions* Global Energy Partners.

Harvell, L., Riggs, E., Thompson, A., Kirk, E., Mullins, Elsemarie., Lapp, S., Katula, R., & Barr, O., (2020). *Identifying Water Infrastructure Funding and Financing Options to Assure Safe, Clean, Affordable Water for All Michigan Citizens and Communities.* Environmental Finance Center at the University of North Carolina at Chapel Hill.

Hydraulic Institute. (2001). *Pump Life Cycle Costs: A Guide to Life Cycle Cost Analysis for Pumping Systems.* https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/pumplcc_1001.pdf

International Finance Corporation. (2021) *Green Bond Technical Assistance Program. Green Bond Funds - Impact Reporting Practices*. https://www.environmental-finance.com/assets/files/reports/green-bond-funds-impact-reporting-practices-2021.pdf

The International Bank for Reconstruction, Energy Sector Management Assistance Program. (2012). *A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities. Technical Report.* https://www.esmap.org/sites/default/files/esmap-files/FINAL_EECI-WWU_TR001-12_Resized.pdf

Jones, S.C., & Sowby, R.B. (2014). Quantifying Energy Use in the U.S. Public Water Industry – A Summary. *Environmental and Water Resources Institute Currents (16)* 4. https://www.hansenallenluce.com/wp-content/uploads/2015/11/Energy-Use-Water-Sector.pdf

Joselow M., (2022, February 21). Court ruling on social cost of carbon upends Biden's climate plans. *Washington Post*. https://www.washingtonpost.com/climate-environment/2022/02/21/social-cost-of-carbon-biden/

Kenway, S., Conrad S., Jawad M. P., Gledhill J., Bravo, R., McCall J., Strazzabosco, A., Howe, C. (2019) *Opportunities and Barriers for Renewable and Distributed Energy Resource Development at Drinking Water and Wastewater Utilities*. Water Research Foundation.

Leiby, V.M., & Burke M. E. (2011). *Energy Efficiency Best Practices for North American Drinking Water Utilities.* Water Research Foundation.

McGuckin, R., Oppenheimer, R., Badruzzaman, M., Contreras A., Jacangelo J.G., (2013). *Toolbox for Water Utility Energy and Greenhouse Gas Emission Management.* Water Research Foundation, New York State Energy Research and Development Authority, Global Water Research Coalition.

Nicola, D.J. (2013). *Environmental Impact Bonds.* Duke University, Fuqua School of Business. http://cpicfinance.com/wp-content/uploads/2017/03/CASEi3_EIB_Report_FINAL-links.pdf

Orange Water and Sewer Authority. (2020). *2020 Energy Management Plan Update.* https://www.owasa.org/wp-content/uploads/2020/11/Energy-Management-Plan-Update-2020-FINAL.pdf

Pabi S., Amarnath A., Goldstein R., Reekie L., (2013) *Electricity Use and Management in the Municipal Water Supply and Wastewater Industries.* Electric Power Research Institute and Water Research Foundation.

Patterson, L., (2022). *Affordability.* Nicholas Institute for Environmental Policy Solutions. https://nicholasinstitute.duke.edu/water-affordability/affordability.html

Patterson, L. & M. Doyle. (2021). Measuring water affordability and the financial capability of utilities*. AWWA Water Science*. https://doi.org/10.1002/aws2.1260

Pizer, W. Adler. M., Aldy, J., Anthoff, D., Cropper, M., Gillingham, K., Greenstone, M., Murray, B., Newell, R., Richels, R., Rowell, A., Waldhoff, S., & Weiner, J. (2014). *Using and improving the social cost of carbon. Science 346* (6214). p 1189-1190. https://www-science-org.proxy.lib.duke.edu/doi/10.1126/science.1259774

Quantified Ventures. (2018). *Sharing Risk, Rewarding Outcomes: The Environmental Impact Bond*. https://www.quantifiedventures.com/blog/what-is-an-environmental-impact-bond

Quantified Ventures. (2021). *Environmental Impact Bonds on Leading Edge of ESG Bond Market Evolution.* https://www.quantifiedventures.com/blog/environmental-impact-bonds-on-leading-edge-of-esg-bond-market-evolution

Senon, C., Badruzzaman, M., Contreras A., Adidjaja J., Pascua E., S. Mark A., & Jacangelo, J. G. (2015). *Drinking Water Pump Station Design and Operation for Energy Efficiency.* Water Research Foundation.

Smith, L., & Quebe P. (March, 2018) *Energy Savings Performance Contracting for Water Resource Recovery Facilities.* US Department of Energy, Office of Energy Efficiency and Renewable Energy.

Suez Water Technologies. (2021). ZeeLung* demonstrates low energy, small footprint treatment at the North Toronto Treatment Plant. www.suezwatertechnologies.com

Tarallo, S., Shaw, A., Kohl, P., & Eschborn, R. *A Guide to Net-Zero Energy Solutions for Water Resource Recovery Facilities.* Water Environment Research Foundation and New York State Energy Research and Development Authority.

US Department of Energy, Better Buildings Initiative. (n. d. a) *Key Accomplishments and Results Sustainable Wastewater Infrastructure of the Future.* https://betterbuildingssolutioncenter.energy.gov/sites/default/files/SWIFt%20Measures%20%26%20Median%20Energy%20Savings_FINAL_revised.pdf

US Department of Energy, Better Buildings Initiative. (n. d. b) *Sustainable Wastewater Infrastructure of the Future Energy Conservation and Resource Recovery Measures List.* https://betterbuildingssolutioncenter.energy.gov/sites/default/files/SWIFt%20Measures%20%26%20Median%20Energy%20Savings_FINAL_revised.pdf

United States Energy Information Administration. *Short-Term Energy Outlook, November 2021 and Annual Energy Outlook 2022. National Energy Modeling System Projections.* https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3- AEO2022&cases=ref2022&sourcekey=0

United States Environmental Protection Agency. *Energy Efficiency for Water Utilities*. Last updated September 23, 2021. Accessed March 27th, 2022. https://www.epa.gov/sustainable-water-infrastructure/energy-efficiency-water-utilities

United States Environmental Protection Agency. (2017). *Reducing Operating Costs and Energy Consumption at Water Utilities with Water-Source Heat Pump Systems.* https://www.epa.gov/sites/default/files/2017-04/documents/water_utility_heat_pump_brochure_508.pdf

United States Environmental Protection Agency. (2016). *Drinking Water and Wastewater Utility Customer Assistance Programs.* https://www.epa.gov/sites/default/files/2016-04/documents/dw-ww_utilities_cap_combined_508.pdf

Water Research Foundation. (2015). *Drinking Water Pump Station Design and Operation for Energy Efficiency, Project Summary.* https://www.waterrf.org/research/projects/drinking-water-pump-station-design-and-operation-energy-efficiency

Water Research Foundation. (2021). *Developing a Framework for Quantifying Energy Optimization Reporting, Project Summary.* https://www.waterrf.org/research/projects/developing-framework-quantifying-energy-optimization-reporting

Willis, J., Stone, L., Durden, K., Walch, M., Hainosz, A., Elenbaas, M., & Patil, A. (2010). *Reframing the Economics of Combined Heat and Power Projects: Creating a Better Business Case Through Holistic Benefit and Cost Analysis.* Water Environmental Research Foundation, Brown and Caldwell, Black & Veatch.

Wisconsin Focus on Energy. (2020). *Water & Wastewater Industry Energy Best Practices Guidebook* https://www.focusonenergy.com/sites/default/files/inline-files/Best_Practices_Guide_Water_Wastewater_2020_FINAL_web.pdf

Xylem Inc. (2015a). *Global greenhouse gas abatement opportunities from energy efficiency in wastewater treatment prepared by Vivid Economics.* https://www.wwdmag.com/sites/wwd/files/2020-03/XB040-Xylem_Abatement_Opportunities_sm.pdf

Xylem Inc. (2015b). *Life Cycle Costs for Wastewater Pumping Systems.* https://www.xylem.com/siteassets/support/tekniska-rapporter/white-papers-pdf/life-cycle-costs-lcc-for-wastewater-pumping-systems.pdf