Small Fixtures, Big Savings: The Economics of Efficient Showerheads

By

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ABSTRACT

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Showers account for roughly 20 percent of indoor residential water use in the United States and collectively consume nearly 1.2 trillion gallons of water each year (EPA, 2025). Despite the scale of this demand, relatively simple improvements in fixture efficiency remain underutilized as a tool for managing water resources and reducing operating costs. As municipalities face rising demand, aging infrastructure, and growing environmental pressures, traditional responses have focused on expanding supply through reservoirs, diversions, and desalination, projects that are expensive, environmentally disruptive, and politically difficult to implement. An alternative approach is demand-side efficiency through fixture retrofit. This paper examines the economic and environmental implications of efficient showerhead retrofits as a form of demand-side water management. Drawing on literature related to conservation programs and Energy Service Company (ESCO) models, the analysis explores how efficiency improvements can simultaneously reduce operating costs and resource consumption. To make these benefits more transparent to building owners, this project introduces FreeFixtures.com, an interactive calculator that converts fixture flow rates into projected savings in water consumption, energy use, greenhouse gas emissions, and financial metrics such as net present value and net operating income.

Table of Contents

1. Demand Side Reduction and the Economics of Water Efficiency.

1.1 Introduction:

Showers represent an average of 20 percent of domestic water usage (EPA Watersense, 2025). Collectively, showering alone accounts for nearly 1.2 trillion gallons of water consumed annually in the United States (EPA, 2025). Water for showers has three associated costs. Users pay to get the water, heat the water, and dispose of it as wastewater. The average cost of combined water and wastewater in the U.S is $16.83, making the total estimated cost of all showers over 20 billion dollars annually before accounting for heating costs (EPA, 2024). Efficient showerheads cost on average $20, and take only a few minutes to change with no skilled labor required, making them an ideal first step towards efficiency and savings.

Across the United States, municipalities experience dual pressures, to both meet demand, and to protect resources for future generations. This problem, historically, has largely been addressed through the supply side: new reservoirs, pipelines, and extractionary methods. While often effective, these projects are cost intensive, politically contentious, and most importantly, do not provide a sustainable solution. In recent decades, demand side reduction has shown impact in resource savings, while simultaneously providing long term cost savings.

Despite proven effectiveness, implementation of demand side action remains limited in scope compared to its potential. Barriers to demand side solutions include capital constraint and a lack of clearly explained cost savings. Energy Service Companies (ESCOs), have been a highly effective solution to these barriers. ESCOs provide efficiency upgrades, at no upfront cost to building owners, eliminating the need for capital from building owners. Through guaranteed savings contracts, ESCOs eliminate most cost saving skepticism. However, ESCO projects have focused predominantly on the public sector: hospital, schools, and government buildings, due to constraints (Goldman, 2005).

Retrofit at scale can eliminate the need for a new water source. Changing a water source is costly, environmentally harmful, and can cause health effects. Traditional water supply changes include methods such as river diversion, and dam construction. These methods require intentionally flooding areas, eliminating the existing ecosystem and displacing people (Gleick, 2018). More modern methods like desalination release brine discharge, harming marine life, and are extremely energy intensive (Gleick, 2011). Case studies analyzed in this paper show that many times, retrofit at scale, can prevent the need for this harm.

Taken together, these trends highlight a critical opportunity in modern resource management: reducing demand through efficiency rather than expanding supply through costly infrastructure. At the same time, building owners can reap financial benefits from these efficiency improvements. This research examines the economic and environmental potential of fixture efficiency retrofits, drawing inspiration from the performance-based structure of Energy Service Companies while focusing on smaller, modular upgrades. To facilitate adoption of efficient showerheads, through clearly communicating benefits, I created the website Freefixtures.com.

1.2 Overview of the Energy Service Company Industry.

The business model of an energy service company or ESCO seems too good to be true. Guarantee your customer savings on their energy bill at no cost to them and no upfront cost, while simultaneously making the world more sustainable by using less resources. So this begs the question, why would every entity on the planet not be retrofitted with the best cost and utility saving technology possible?

In the most basic sense, ESCOs are a third party, contracted by an entity that operates a building, to improve efficiency. What makes ESCOs and their business model unique, and differentiates them from other service providers is the way that they are paid. A traditional service provider for a building gets paid upfront, to do a certain task. For example, a painter is paid a set amount to complete a specific task. The ESCO model requires little to no upfront payment, and instead takes a percentage of the savings generated from implementing the project over a set contracted period (Sorell, 2007). Typically, the ESCO is not given a specific task to complete, instead, based on a preliminary audit, they identify inefficiencies and propose a series of changes based on industry knowledge. The ESCO is incentivized to achieve the highest reduction in costs, as it is paid back exclusively through a percentage of cost savings. The ESCO collects this percentage for the duration of the contract, which depends on the project size, and pre-implementation efficiency, but typically is 5-15 years (Sorell, 2007).

The following diagram is a visual representation of the ESCO business model. The "Before ESCO Contract" segment, shown in grey, represents the pre contract period. The height of the column represents the total energy and maintenance costs for the entity. The second column shows the breakdown, post ESCO contract and implementation. In this segment, the customer is still saving money, shown in green, but the ESCO is taking a large portion of the savings to repay the retrofit costs. The third column represents the period after the ESCO contract has expired. The customer now keeps all of the savings, and is only responsible for maintenance costs.

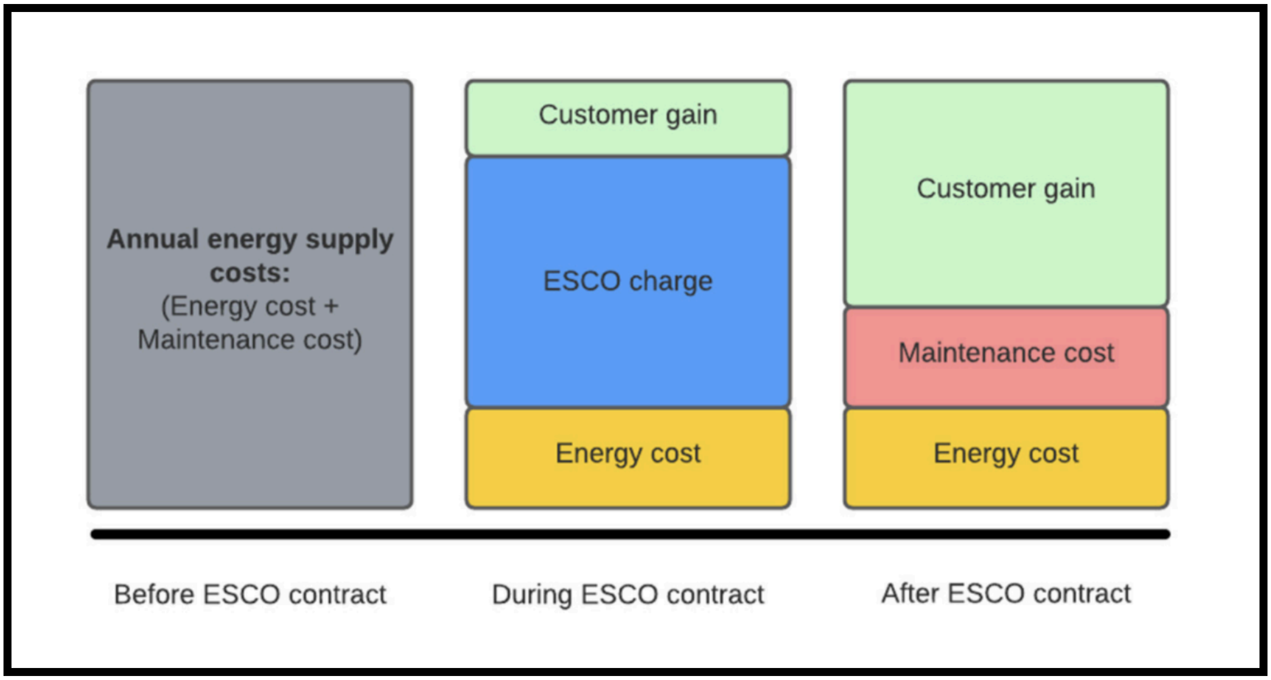


Figure 1: A visual representation of the ESCO model.

(Novkovic, 2022)

To give an idea of what this might look like here's a hypothetical example: Schenectady High School spends 100,000 dollars a year on its electricity bill. An ESCO would come in, usually free of charge, and audit the buildings' subsystems to figure out how much electricity each system is using. The ESCO then proposes a series of changes to systems and fixtures, for example, LED lights, Solar Panels, and a new HVAC system. With these changes, the ESCO predicts that Schenectady High Schools electricity bill will be lowered to 50,000 dollars per year. Based on the projected savings, the ESCO proposes a contract with the school in which the ESCO receives 70% of the bill reduction for 10 years, in exchange for implementing, operating, and financing the retrofit. Over the course of the contract the ESCO recovers the cost of the retrofit, and makes a profit.

The Origin and Growth of the Energy service company Model

The origin of the ESCO business model of Guaranteed Energy Savings Contracts (GESP) can be traced back to the oil crises of the 1970s. Both crises were started due to conflict in the Middle East which prevented oil exports to the United States. The sudden surge in oil prices revealed glaring inefficiencies in usage. The first known company to use the guaranteed savings model was Time Energy, based out of Texas. Time had developed a line of switches to automatically turn off lights and machinery when not in use, to save energy. Initially, these devices sold poorly, with many skeptical on the actual saving potential that they had. This led Time Energy to start an offer in which they would install their devices for no upfront cost, and instead take a portion of the savings generated through using their product. This began as more or less of a marketing stunt, but ended up turning into a business model, setting the framework for GESPs to come (Bullock & Caraghiaur, 2001).

After the initial oil shocks in the 1970s, energy prices remained volatile, while simultaneously, entities were becoming more conscious of their resource usage. Additional firms began to adopt similar models to Time Energy's guaranteed savings contracts. These companies expanded beyond simple lighting controls and began offering comprehensive building efficiency audits, equipment upgrades, and operational improvements. The defining feature of these early ESCOs was their compensation structure: rather than being paid for installing equipment, they were paid based on the measurable reduction in energy consumption achieved after implementation. This alignment of incentives between service provider and building owner became the core innovation of the ESCO model.

During the 1980s and 1990s, the ESCO industry matured alongside the emergence of federal and state policies designed to encourage energy efficiency. In the United States, the federal government began using Energy Savings Performance Contracts (ESPCs) to retrofit public buildings, allowing agencies to implement efficiency improvements without requiring congressional appropriations for upfront capital costs. Under this structure, private ESCO firms financed the upgrades and were repaid through the resulting reductions in energy expenditures (Goldman et al. , 2020). These contracts allowed governments to modernize infrastructure while maintaining budget neutrality, further accelerating the growth of the industry.

From its conception, as a promotional mechanism, the ESCO industry has grown substantially. The global ESCO market in 2024 was valued at 33.6 billion, and is projected to grow to 59.7 billion dollars globally by 2032 (Kroon, 2024). ESCOs have historically, primarily focused on schools and government buildings. These entities typically lack the upfront funding needed to make improvements and generally have missions that align with reducing global environmental impact.

The growth and success of the ESCO industry proves the key concept of this thesis: efficiency improvements can simultaneously help the environment and save money. The existence and profitability of these companies shows the incredible potential for cost savings, as there is so much inefficiency that ESCOs can take a large percentage of savings and still provide cost savings to the building from day one.

Limitations of Energy Service Companies:

Despite the ESCO industries growth, the majority of their activity remains in a few key sectors. The most recent, peer reviewed, industry wide study, found that 74 percent of ESCO activity was in the public sector (Goldman, 2005). Out of that, 30 percent of total ESCO projects were at K-12 schools, 20 percent from government buildings, and 12 percent from hospitals (Goldman, 2005). These three industries are ideal targets for the ESCO industry because they rarely, if ever, change hands, have consistent occupancy rates, and are often aging. In order for an ESCO to be able to guarantee savings, a clear and consistent baseline must be measured for an entity able to take on a 5 to 15 year contract. The ESCO industry has been tremendously successful in these sectors, driving positive change. However, these sectors represent only a small portion of the total building stock in the United States. For example, K-12 schools account for roughly 389,000 buildings, only about 6–7 percent of the nation's commercial buildings, while hospitals represent less than 1 percent of the total (U.S. Energy Information Administration, 2018). This means the vast majority of the commercial and residential market has been inaccessible for traditional ESCOs. This underscores the need for an outward facing tool, to allow buildings outside of those categories to access a portion of the cost and resource savings that ESCOs provide.

Traditional ESCO strategy has focused mainly on electricity savings, as these represent a larger portion of total utility costs (Goldman, 2005). However, in multifamily properties, electricity costs are often submetered and passed on directly to tenants, making building owners less incentivized to create efficiency. Water costs are structured differently. Submetering water in multifamily buildings is significantly less common, and most properties continue to operate under a master-metered system in which the building owner pays the entire water and wastewater bill. Surveys of multifamily housing indicate that a majority of properties, often estimated at roughly 70–80 percent, remain master-metered for water, meaning that tenants typically do not directly pay for their own consumption (U.S. Environmental Protection Agency, 2025)

(American Water Works Association, 2024). This makes water efficiency in residential housing an ideal market for improving efficiency, that is not accessible by ESCOs.

1.3: The Current State of Fixture Use Regulations

Cost savings from retrofits, whether it be from independent retrofit, or ESCO style contract, depend heavily on the current state of the infrastructure. If fixtures are already highly efficient with up-to-date technology, there is less money to be had. State and federal policy, when combined with construction date, can provide a good estimate of the current state of infrastructure, allowing inefficient buildings to be identified for cost saving retrofits.

The Energy Policy Act of 1992, signed into law by President George H. W Bush, marks the last, and most influential environmental policy act to date. The Energy Policy Act, was a multifaceted bill which included promotion of renewable energy, stricter resource extraction regulations, and crucially efficiency standards for water usage. The act set new maximum usage rates for a variety of water using fixtures including toilets and showerheads. Prior to the act, there were no federal regulations on the usage of such fixtures. The Energy Policy Act set national maximums on newly produced and installed fixtures at: 1.6 Gallons per flush (GPF) for Toilets, 2.2 GPM for Faucets and 2.5 Gallons per Minute (GPM) for showerheads. These regulations were not to be applied retroactively to current fixtures, for example, old toilets would not need to be replaced if they exceeded the new maximums. This bill shaped our current water infrastructure, reducing usage by an incalculable amount, forging the path for future policy measures.

The majority of U.S states provide no additional regulatory requirements beyond those presented in the Energy Policy Act of 1992. However, some states, particularly those with less access to fresh water have seen increased regulations in order to reduce household consumption. In 2014, after extended periods of drought and increased water usage, California implemented additional regulations to reduce domestic water use. New standards were set at: 1.28 GPF for Toilets, 1.8 GPM for showerheads, with no changes to faucet flow (City of Dublin CA, 2014). Regulations are enforced via a no sale, no install framework. This includes ending sales of higher usage fixtures in brick and mortar stores throughout the state as well as enforcement via permitting on building updates. Unlike the 1992 Energy Policy Act, California's measures include replacement of non-compliant fixtures in any building being updated, with a construction date after 1994. When permits are provided and final inspections are done, California State code enforcers ensure fixtures meet regulations (City of Berkeley, 2014) . These standards were codified by a 2014 Civil Code update, and remain in place to date. While regulations such as these have improved baseline fixture efficiency, many buildings continue to operate with older infrastructure, highlighting the economic and environmental potential of voluntary retrofit strategies.

Limitations to Regulations and Economic Rationale

Government policy is a powerful tool in resource saving, but it has several key flaws. Regulations are not enforced retroactively, meaning buildings can, and often will continue to have inefficient fixtures long after the codification date. Additionally, enforcing these regulations poses a massive challenge, as without measuring each fixtures usage rate, it is difficult to actually tell if they are compliant. In the case of fixture efficiency, the government should not even need to have to enforce rates. If building owners were simply aware of how much additional money they are spending by having inefficient fixtures, rationale owners would make retrofits.

Government regulation of plumbing fixtures can be understood through a standard economic rationale. Water consumption generates several negative externalities, including environmental depletion, infrastructure strain, and the long-term cost of expanding supply systems, costs that are not always fully reflected in retail water prices. In theory, these externalities could be addressed through higher water prices that better reflect the marginal social cost of consumption. However, water pricing is often politically constrained and typically set by public utilities that prioritize affordability and stability rather than strict efficiency pricing (Olmstead and Stavins, 2009). As a result, efficiency standards such as the fixture requirements introduced under the Energy Policy Act of 1992 represent a regulatory approach to reducing consumption when price signals alone are insufficient. Enforcement also presents practical challenges, as verifying fixture performance requires direct measurement of flow rates. These limitations highlight the potential role of informational tools that help building owners identify the financial benefits of efficiency improvements, even in the absence of regulatory mandates.

1.4. Case Studies Showing the Power of Large Scale Fixture Improvements: Boston Massachusetts

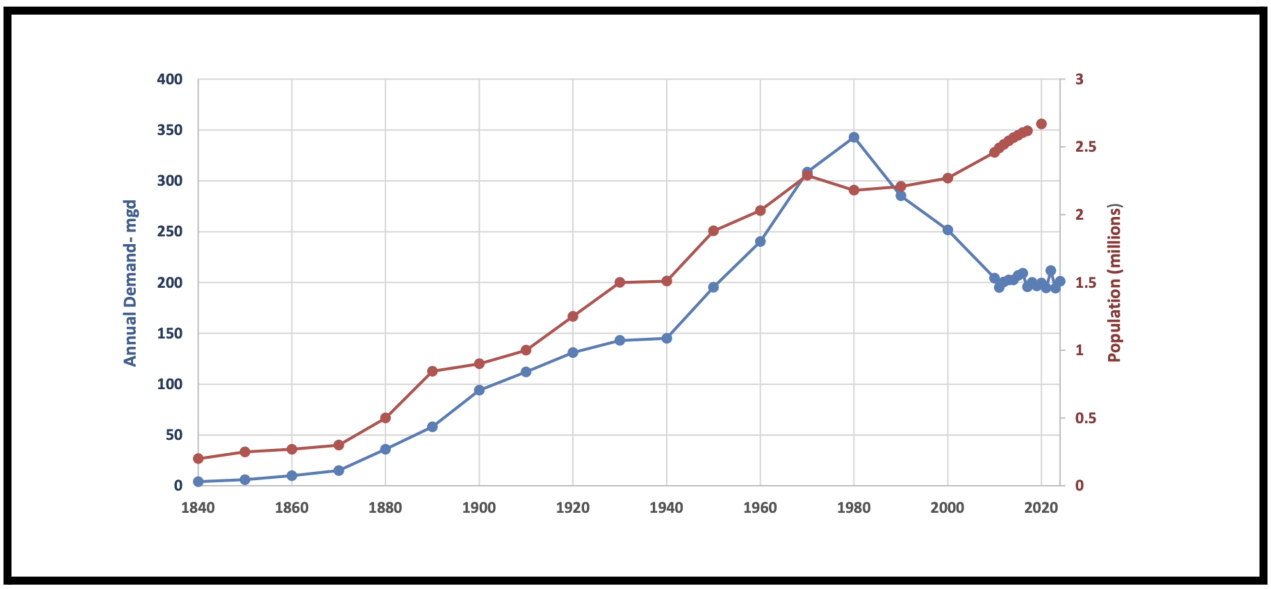
Oftentimes, due to population increases being coupled with environmental factors, cities' water sources are strained, presenting a need for new infrastructure. A prominent example of this occurred in the early 1980s in Boston, when the city water demand exceeded the deliverable quantity from their current source, the Quabbin Reservoir. Water recharge rates had remained relatively constant, but the sheer quantity of water extracted led to steep and continuous drops in water level. The urgent water shortage presented the Massachusetts Water Resource Authority (MWRA) with two possible solutions: get more water, or use less water.

Initially, Boston looked to address their water constraints through getting more water. The city worked to find a new water source to help relieve the strain on the natural recharge rates of the Quabbin. This came in the form of a plan to divert a section of the Connecticut River in western Massachusetts to increase reservoir water levels (MWRA, 2000). This plan was highly controversial on multiple levels. Residents of Western Massachusetts did not want to endure a large-scale infrastructure project with potential flooding and displacements. The state of Connecticut threatened legal action against the state of Massachusetts if they were to divert the river, therefore reducing Connecticut's access to water downstream (Estes-Smargiassi, 2025).

Apart from being a massive inconvenience and potential multistate legal battle, the Connecticut river diversion project would also have been extremely expensive. The proposed cost of the project in 1972 was 72 Million dollars, which is equivalent to over 520 Million dollars today when adjusted for inflation. Importantly, projects like these, involving water diversions consistently run significantly over budget. Massachusetts tax payers would have been stuck paying for this project (MWRA, 2000).

With a highly controversial, costly and potentially legally challenging plan to get more water, the city began to examine alternatives for the latter: Use less water. Boston, being one of the oldest cities in the United States, was filled with aging infrastructure and inefficient fixtures. To reduce consumption, the city unleashed a comprehensive plan to improve water usage efficiency. This consisted of three key components: Residential Efficiency, Industrial Efficiency, and stopping leakages. Stopping leakages required an audit of the city's 6,085 miles of pipes. The audit found an approximate daily loss of 30 million gallons per day, which were subsequently stopped (Estes-Smargiassi, 2025). Residential and industrial efficiency took the form of operation Water Sense. A program that distributed 1.3 million water saving fixtures to 350,000 buildings. Toilets, some of which were using up to 7 gallons of water per flush were replaced with 1.6 GPF models (Estes-Smargiassi, 2025). Reduced flow showerheads with projected efficiencies of 1.5-2.0 were distributed to households for replacement (Estes-Smargiassi, 2025). Additionally, MWRA launched campaigns to educate residents on water efficiency and present the rationale behind the changes.

The MWRA Boston retrofit project ended up being extremely successful, removing the need for the costly Connecticut River diversion purely through updating infrastructure and retrofitting fixtures. The following graph depicts water usage, and population of the course of the implementation. A clear downward trend in average annual demand begins with the projects commencement in 1980.



(Estes-Smargiassi, 2025)

Figure 2: Population of the city of Boston in millions (Red), and the average annual demand of water in Millions of gallons per day (Blue).

The Boston and MWRA demand management solution proves that even relatively simple, non-behavioral fixes like fixture retrofits can have massive impact at scale. Rather than enduring a costly river diversion, Boston lowered its daily withdrawals below safe yield and eliminated the need for new supply infrastructure altogether. This mirrors the core principle of this thesis: small, distributed, performance-based upgrades produce savings that compound across a community.

Barrie Ontario

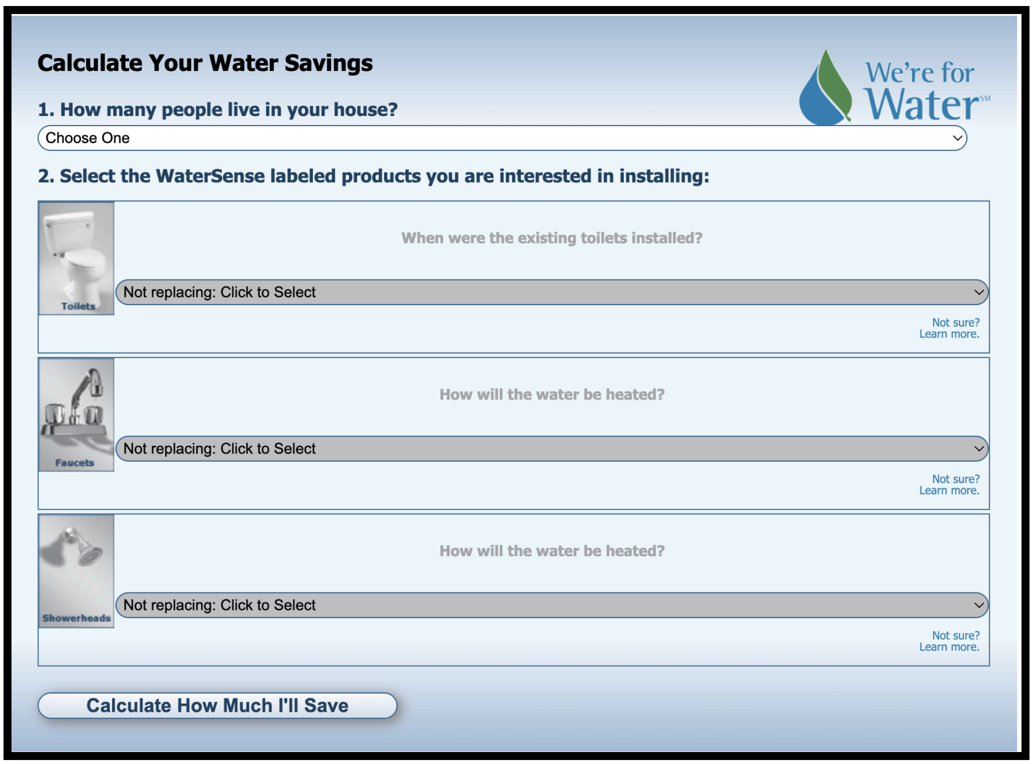
While the Boston city wide retrofit of the 80s is one of largest examples, it is far from the only example of replacing the need for a new water source through retrofit. Barrie Ontario was experiencing extreme pressure on its waste water treatment plant, as well as insufficient freshwater for their growing population. Barrie planned a new surface-water supply project costing about 27 million Canadian dollars, while wastewater flows were also pushing the city toward a major treatment plant expansion. Instead, the city partnered on a conservation program centered on high-efficiency toilet and showerhead replacements. EPA reports that the retrofit effort reduced flows enough to produce a 5-year deferral of the wastewater capital expansion, reduce the upgrade cost from C$41.0 million to C$19.2 million, and delay construction of a lake-based water filtration plant beyond 2020. This example shows that even if population growth continues, retrofit at scale can reduce the scale and price of the expansion needed (U.S EPA, 2002)

Ashland Oregon

In the early two-thousands Ashland Oregon was facing water uncertainty due to rising population and expiring water rights. In order to meet demand, Ashland officials were considering either creating a dam on Ashland creek and flooding a larger area which would cost 11 million dollars, or building a water pipeline, estimated to cost 13 million. Instead, the city created an incentivized conservation plan, which provided funding for retrofits of showerheads, toilets, faucets and pipes. The incentivization program cost the city 834,000 dollars, meaning millions in cost savings compared to a new source, through saving an estimated 500,000 gallons per day. While 834,000 dollars is a substantially lower price then the proposed 11 million for a new source, if residents could clearly see the cost savings they would receive from these retrofits, government incentives may not have been needed. This further highlights the need for an outward facing tool, clearly displaying the cost savings available to building owners from fixture retrofit (U.S EPA, 2002).

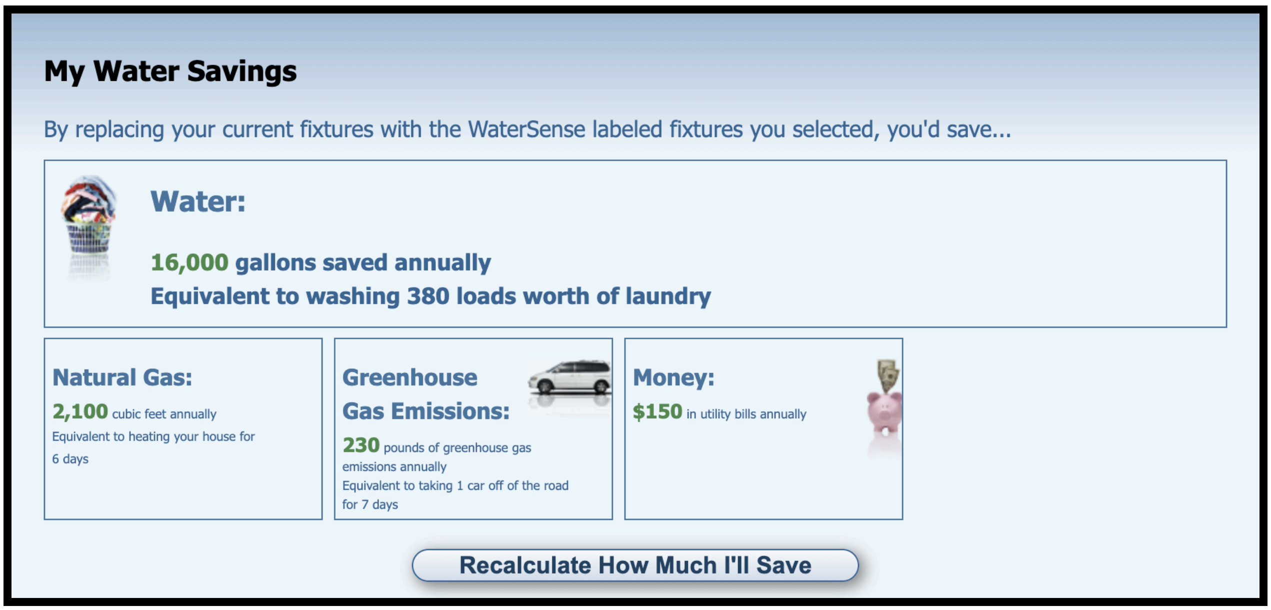
1.5. Current State of Outward Facing Savings Calculators:

Currently, there are a variety of water savings calculators publicly available. Sites very from contracting tools, to government websites. The first search result on Google, when you type in “Water Savings Calculator”, or “Water Cost Savings Calculator” is a website from the EPA titled “WaterSense Calculator”. Users are prompted to put in basic inputs, from a dropdown menu. The website offers little customization, doesn’t isolate specific fixtures, and does not direct the user clearly on next steps. Additionally, the site uses a proxy of installation date of the toilet, and no direct input for the showerheads or faucets, making calculations vague.



(EPA WaterSense Calculator, 2026)

Once the user has put in the three basic inputs, the site generates a brief overview, shown below, focused on savings, mainly in terms of environmental impact. The overview also includes a generic number, showing "cost savings" with little explanation to the breakdown of where these come from. The site offers a breakdown of the cost savings in a different document that can only be viewed when downloaded, and lacks the ability to change any of the assumptions for their model. Most importantly, cost savings are not framed in the terms of this being an investment.



(EPA WaterSense Calculator, 2026)

2. FreeFixtures.com: an Improved Savings Calculator

2.1. Measurements:

How to Measure the Flow Rate of a Showerhead

To provide more accurate measurements, users should measure flow rates of their existing fixture, as well as the low-flow model. In order to better understand how measurements are taken, I consulted Union College's plumber, Mark Moreau, who has over a decade of experience in plumbing. He reinforced what my preliminary research on measurement had found: industry standard fixture measurement is relatively easy and quick. The following section describes the processes.

Step by Step Process

1) Find a container that is at least 1 gallon in volume. Use a graduated beaker to measure exactly one gallon of water. Pour it into the container, and make a line at the water level.

2) Unscrew the existing showerhead, and screw on the new fixture.

3) Secure an impermeable tarp (garbage bags work too) around the fixture using string, wiring, or a rubber band.

4) Turn the shower on to ensure that water is not collecting in the tarp, all water is going into the bucket, and there is no leakage from the fixture pipe. Then turn the shower off again.

5) Turn the shower on to the temperature level you usually use it at. Simaultenously, start a stopwatch.

6) Once the water level gets to the line you made earlier, stop the stopwatch.

7) Calculate the flow rate by dividing 60 by the amount of time it took to reach 1 gallon in seconds, and you have your flow rate in gallons per minute (GPM)

Image 1: Mark Moreau measuring the flow rate of a showerhead using the method described above in Raymond House, Union College.

Comparing the Flow Rates of Low Flow Fixtures:

Measurements were taken across the days of February 6, 18, 20, and March 2, 2026. Data was collected using the methodology described above, using a 5 gallon bucket from Lowes, and a 1 gallon container. To ensure accuracy, water was measured with a 1000 ml beaker, and added to each container, with a line being designated for the 1 and 5 gallon marks exactly in each container. Four different low flow fixtures purchased from Amazon were tested, as well as two types of existing fixtures previously installed in the building. The four fixtures purchased for testing are listed below, along with their purchase price, along with their listed flow rate and measured flow rate.

The site of measurement was Raymond House, located on Union College in Schenectady, New York. The building contains two centralized, gas powered, tank water heaters. The pressure of the plumbing system, as measured by the gauge, was 80 PSI. Each fixture was measured a total of ten times, 5 times with the 1 gallon bucket, and 5 times with the 5 gallon bucket. Measured flow rates represent the mean of the ten measurements taken.

Each fixture measured a lower flow rate than the advertised maximum flow rate. On average, measured flow rates were 13.4 percent lower than the advertised maximum, representing a large enough difference to suggest the need for measurement. The following table shows a photo of each fixture, along with advertised flow rate, measured flow rate and price.

Image	Fixture Name	Price	Advertised Flow Rate	Measured Flow Rate
	Niagara Conservation Adjustable	15.94	0.5-1.5	0.89 (Set at 1 GPM)
	Delta Faucet Modern	32.98	1.75 GPM	1.68 GPM
	Niagara Cone	19.49	1.5 GPM	1.39 GPM
	High Sierra Classic	44.95	1.2GPM	1.19 GPM

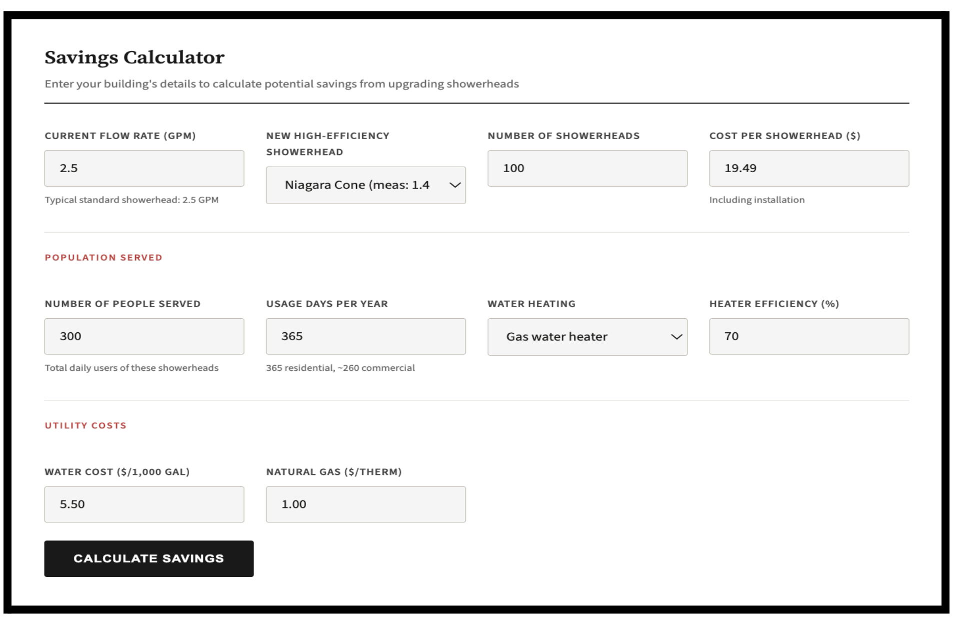
Table 1: A comparison of flow rates for the four fixtures measured.

2.2 A Breakdown of the Website

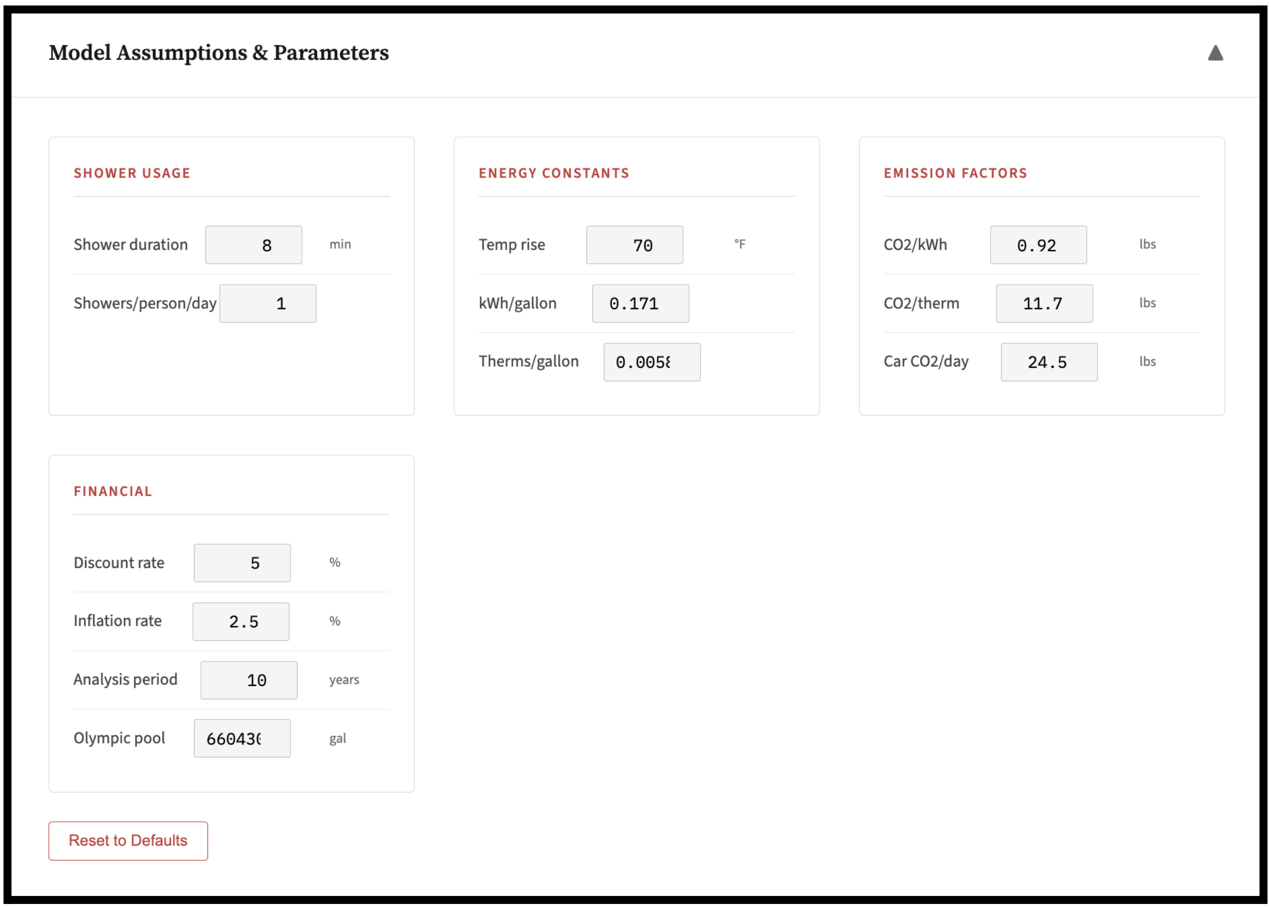
The website Freefixtures.com, uses measured flow rates of current, and upgraded efficiency fixtures along with additional inputs to calculate financial and environmental benefits. The objective of Freefixtures is to create a clear display of key investment evaluation metrics with transparent methodology and customizable inputs.

Inputs on FreeFixtures

The following images show calculations from a hypothetical building with the following inputs: A current showerhead flow rate of 2.5 GPM (standard flow rate), with a proposed retrofit to a Niagara Conservation fixture with a measured flow rate of 1.43 GPM. A cost of water of $5.50 per 1000 gallons. Gas water heaters with 70% efficiency and a gas price of $1.00 per therm. The building contains 100 total showerheads, serving 300 residents for 365 days per year. The input tab where users can add their own information is shown below.

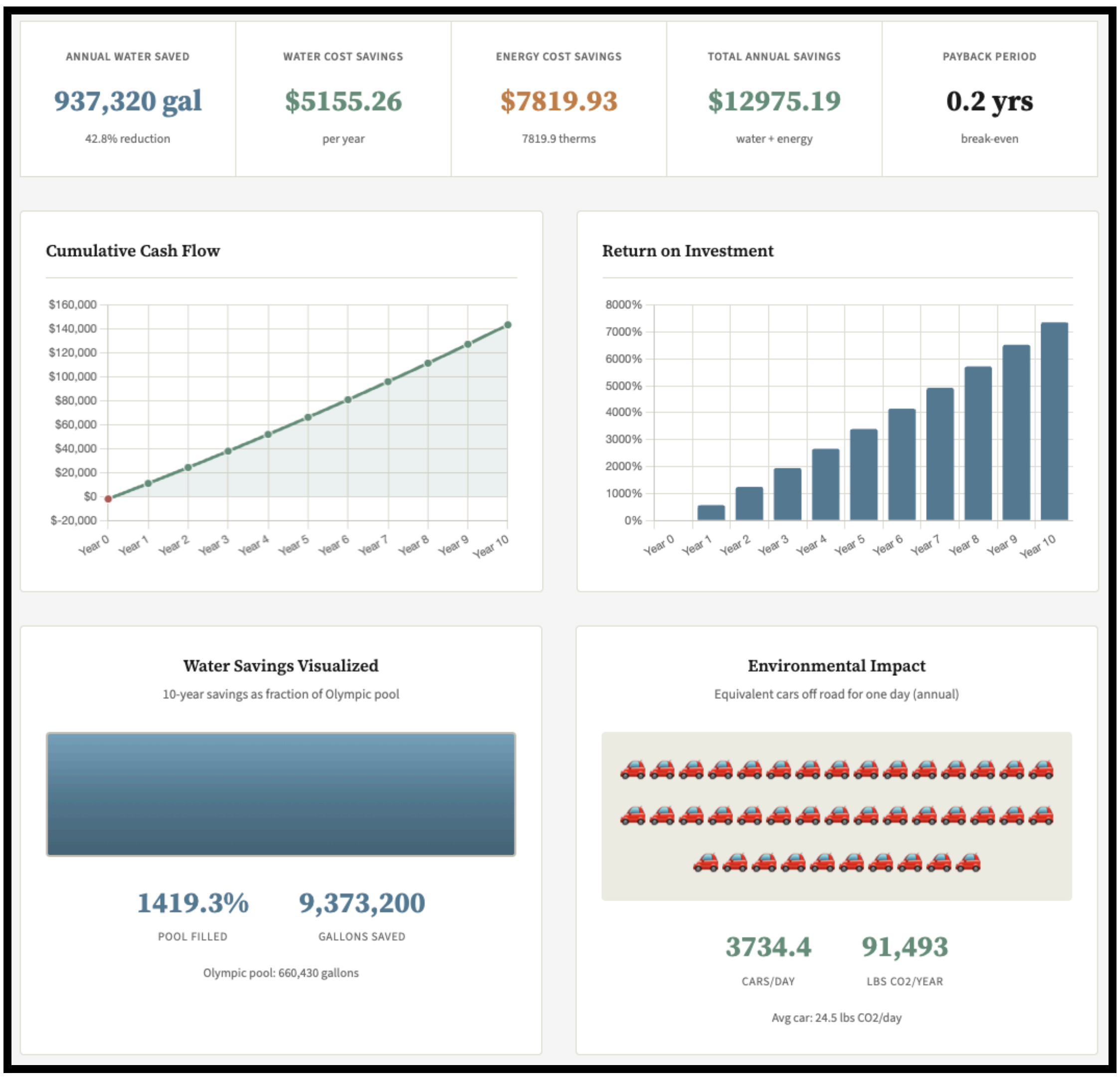


In addition to the user inputs, the calculation of savings requires several assumptions. The assumptions are grouped into the following categories: shower usage, energy, emissions, and financial. These assumptions are displayed below, and are able to be changed for improved accuracy by the building owner.

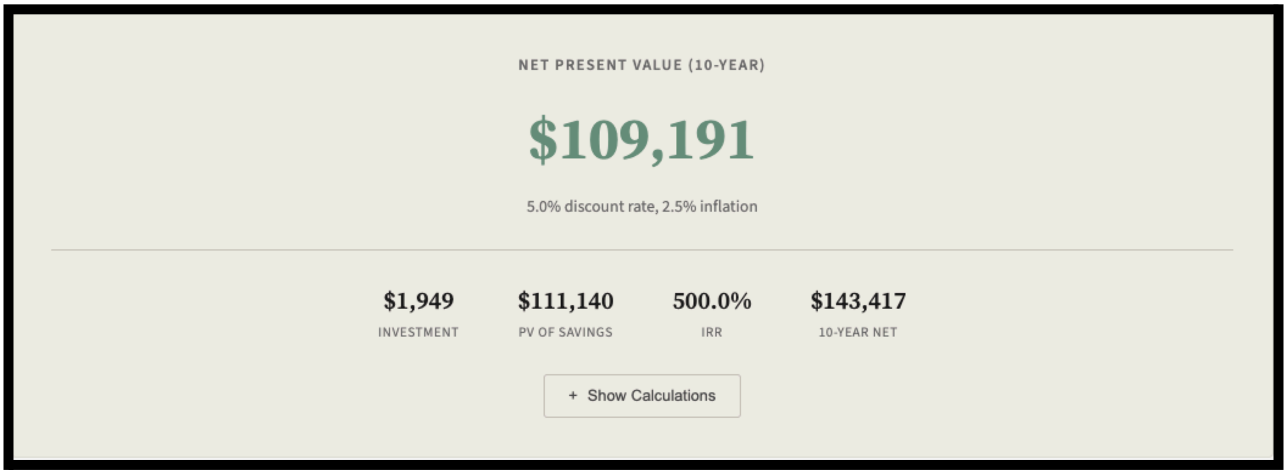


A Breakdown of the Cost Savings Dashboard:

Upon entering the necessary calculations in the input tab, and clicking the "Calculate Savings" button, the user is given the following dashboard. At the top, annual water savings, water cost savings, energy savings, total savings, and payback period are shown. Further down the page, are two graphs, the first shows inflation adjusted cash flow, and the second, return on investment over time. Additionally, two visualizations of environmental savings are shown. On the left, annual water savings is visualized as a portion of an olympic swimming pool, and on the right, CO2 savings displayed as the quantity of cars taken off the road for a day.

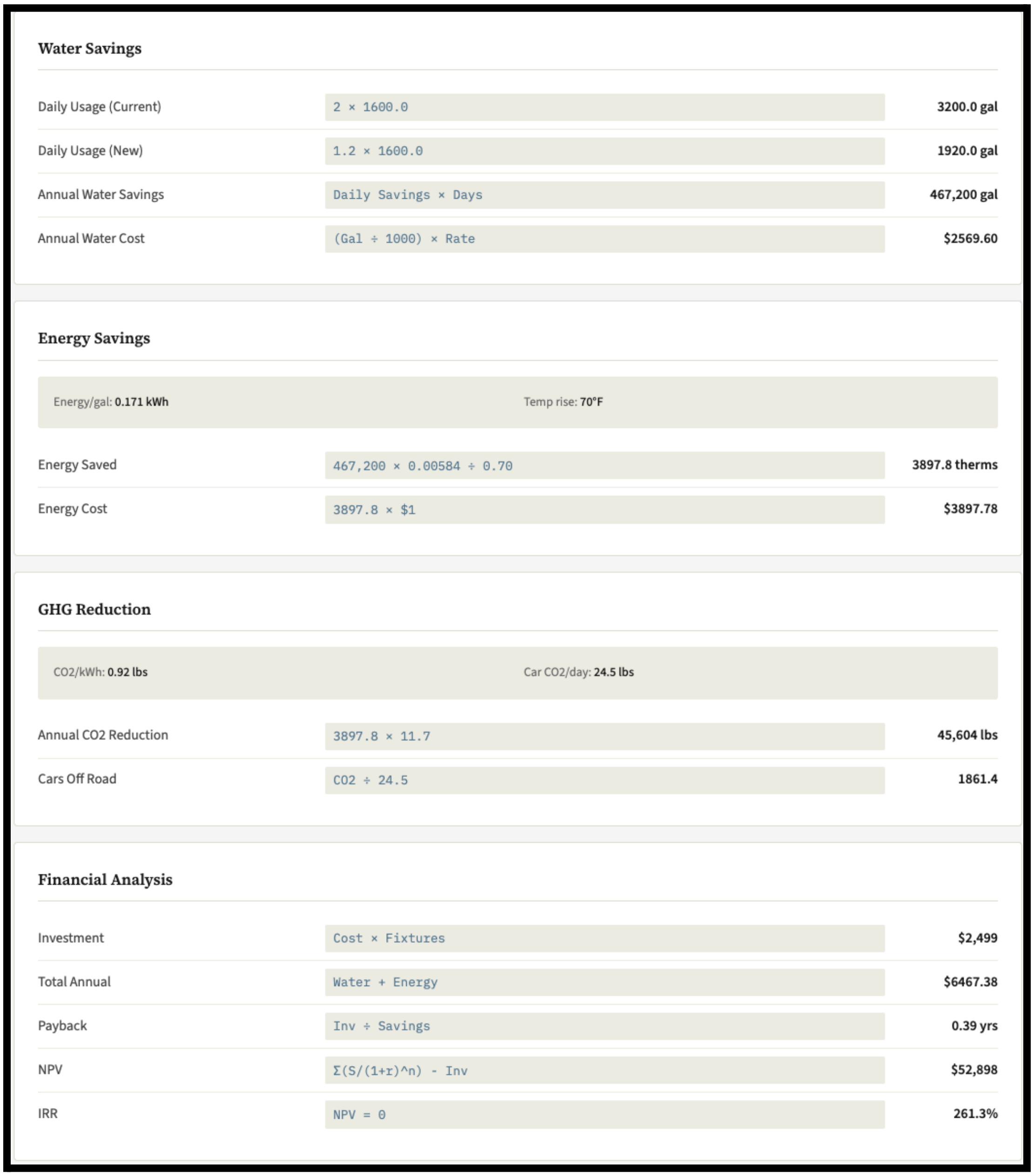


The dashboard aims to provide a visually appealing, first glimpse at the estimated cost savings and environmental impacts of the inputted retrofit. The following section clearly displays a financial overview of the project, with Net Present Value (NPV), investment cost, present value of savings, internal rate of return (IRR) and the 10 year net cash flow.



Behind the Calculations:

The show calculations button, seen in the bottom middle of the image above, provides the equations used to calculate each of the metrics in the table. This aims to provide transparency to the calculations.



Water Savings

Daily Usage (Current)	2 × 1600.0	3200.0 gal
Daily Usage (New)	1.2 × 1600.0	1920.0 gal
Annual Water Savings	Daily Savings × Days	467,200 gal
Annual Water Cost	(Gal ÷ 1000) × Rate	$2569.60

Energy Savings

Energy/gal: **0.171 kWh** Temp rise: **70°F**

Energy Saved	467,200 × 0.00584 ÷ 0.70	3897.8 therms
Energy Cost	3897.8 × $1	$3897.78

GHG Reduction

CO2/kWh: **0.92 lbs** Car CO2/day: **24.5 lbs**

Annual CO2 Reduction	3897.8 × 11.7	45,604 lbs
Cars Off Road	CO2 ÷ 24.5	1861.4

Financial Analysis

Investment	Cost × Fixtures	$2,499
Total Annual	Water + Energy	$6467.38
Payback	Inv ÷ Savings	0.39 yrs
NPV	Σ(S/(1+r)^n) - Inv	$52,898
IRR	NPV = 0	261.3%

In addition to the equations provided under "Show Calculations" an additional section was created to display the intermediate equations leading into Net Present Value. First, a glossary was provided, matching each variable used in the equations, with the user input or assumption. The intermediates, which are used in the NPV equation and are calculated from these variables, are also provided.

Variable Glossary

INPUTS — USER-DEFINED											
F_c	Current flow rate	2 GPM	F_n	New flow rate	1.2 GPM	d	Shower duration	8 min	s	Showers/person/day	1
P	People served	200	D	Usage days/year	365 days	q	Num. fixtures	100	c_f	Cost/fixture	$24.99
c_w	Water cost/1k gal	$5.5	c_e	Energy cost	$1/therm	k	Energy/gallon	0.00584 th/gal	η	Heater efficiency	70%
r	Discount rate	5.0%	g	Inflation rate	2.5%	n	Analysis period	10 yrs	C_0	Initial investment	$2,499
INTERMEDIATES — DERIVED VALUES											
W_c	Current daily water use (gal/day)	3200.0 gal/day	W_n	New daily water use (gal/day)	1920.0 gal/day	ΔW	Annual water saved (gal/yr)	467,200 gal/yr	S_w	Annual water cost savings ($)	$2569.60
ΔE	Annual energy saved (kWh or therms)	3897.8 therms	S_e	Annual energy cost savings ($)	$3897.78	S_1	Year 1 total savings ($S_w + S_e$)	$6,467.38			

After the variable glossary, a six step process is laid out, to show how the initial difference in fixture flows is used to calculate the intermediates, and later the NPV.

1 Daily Water Usage

$$W_c = F_c \times d \times s \times P$$

`2.5 × 8.0 × 300 = 6000.0 gal/day`

$$W_n = F_n \times d \times s \times P$$

`1.43 × 8.0 × 300 = 3432.0 gal/day`

W_c = current daily water usage (gal/day), W_n = new daily water usage

2 Annual Water Savings

$$\Delta W = (W_c - W_n) \times D$$

`(6000.0 − 3432.0) × 365 = 937,320`

RESULT: **937,320** GAL/YEAR

3 Annual Water Cost Savings

$$S_w = (\Delta W \div 1000) \times c_w$$

`(937,320 ÷ 1000) × $5.5 = $5155.26`

RESULT: **$5155.26**

4 Annual Energy Cost Savings

$$\Delta E = \Delta W \times k \div \eta$$

$$S_e = \Delta E \times c_e$$

`937,320 × 0.00584 ÷ 0.70 = 7819.9 therms → × $1 = $7819.93`

RESULT: **$7819.93**

5 Total Savings & Initial Investment

$$S_1 = S_w + S_e$$

`$5155.26 + $7819.93 = $12975.19`

$$C_0 = c_f \times q$$

`$19.49 × 100 = $1,949`

6 Net Present Value (NPV)

$$NPV = -C_0 + \sum_{t=1}^{n} S_1(1+g)^{t-1} \;/\; (1+r)^t$$

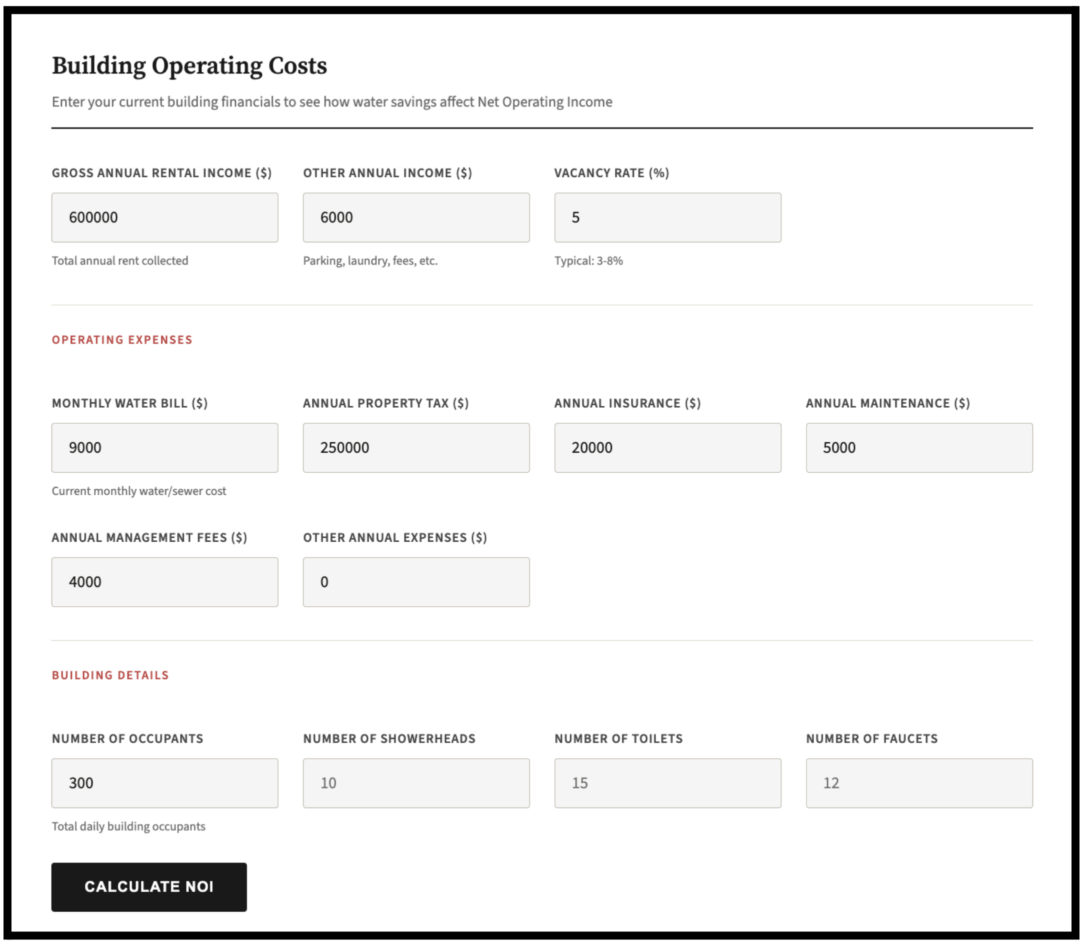
`−$1,949 + Σ[$12975.19×(1+2.5%)^(t-1) / (1+5.0%)^t] for t=1..10`

NPV = **$109,191**

PV of Savings = $111,140 | Initial Investment = $1,949 | IRR = 500.0%

Extrapolating Savings to Key Financial Metrics for Building Owners.

To deliver maximum impact of cost savings display, additional sections were added to the website to show how the savings translate to net operating income (NOI). The user is prompted to add key inputs for NOI, including gross rent income, taxes, maintenance, and average vacancy rates. Projections, based on the size of the building are shown in light grey, but the user is required to input key information. While further inputs could be necessary, the calculator aims to be relatively simplistic, and use easily accessible information. Additional expenses or income can be aggregated and put in the "Other" category. The following image shows the input page for the NOI calculator.



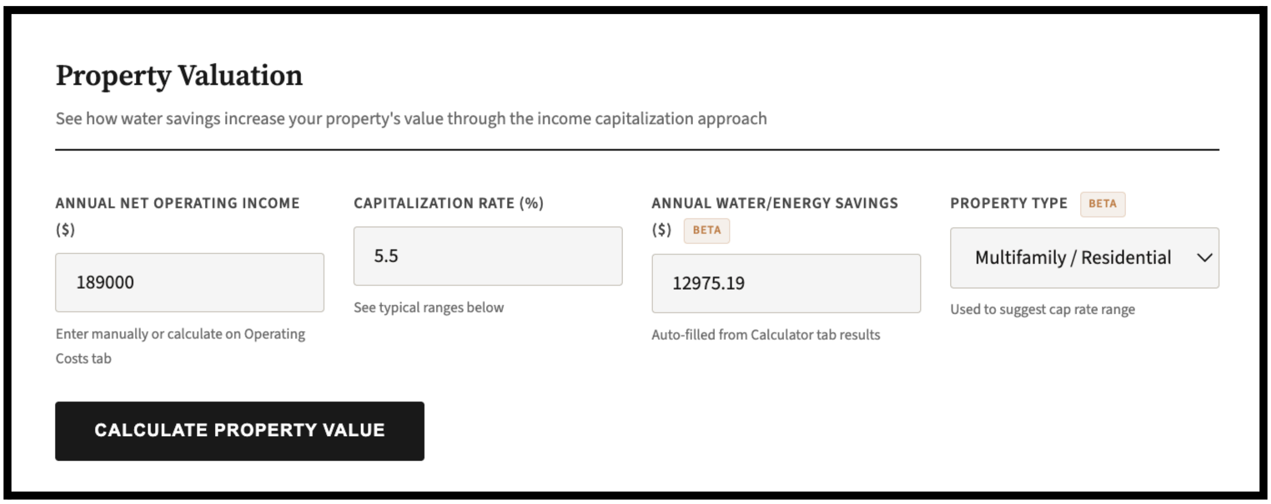
After filling out the NOI input section, the user, upon clicking the calculate savings button, is given a brief financial breakdown of their NOI, and projected subsequent increase or decrease from showerhead retrofit. Key metrics are displayed clearly at the top of the page, with a further breakdown available below.

CURRENT NOI	ANNUAL WATER SAVINGS	PROJECTED NOI
$189,000	$12,975	$201,975
Before water savings	From calculator results	After water savings

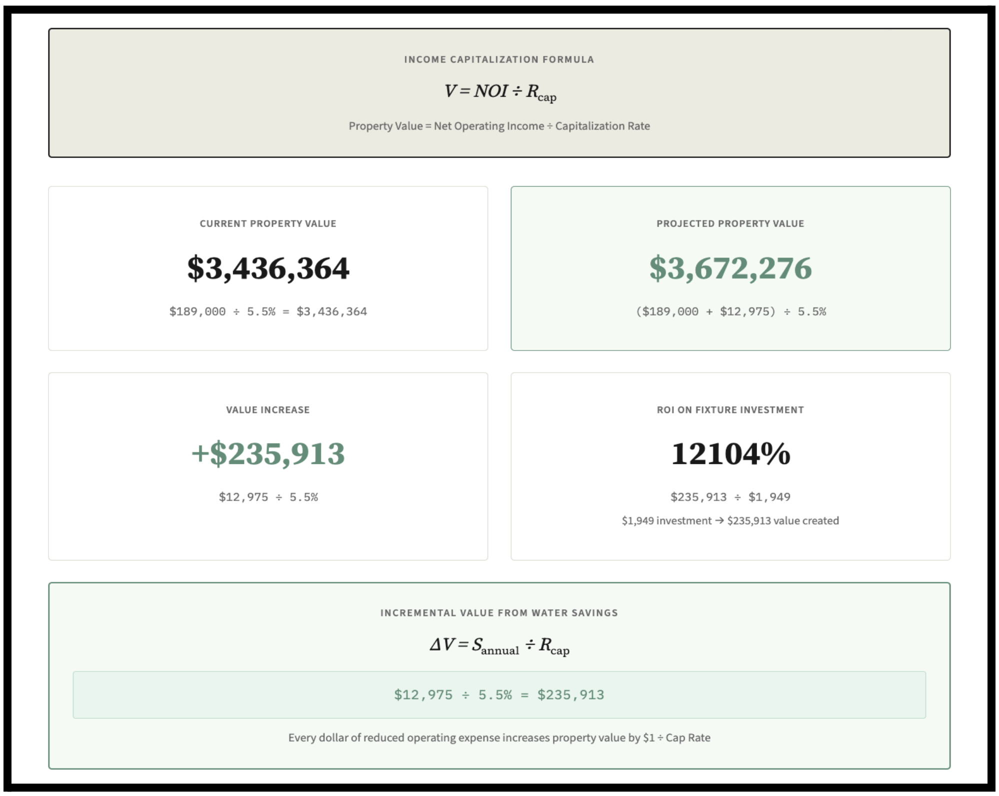
NOI Breakdown

Gross Rental Income	$600,000
+ Other Income	$6,000
− Vacancy Loss	−$30,000
= Effective Gross Income	**$576,000**
− Water/Sewer (Annual)	−$108,000
− Property Tax	−$250,000
− Insurance	−$20,000
− Maintenance	−$5,000
− Management	−$4,000
− Other Expenses	−$0
= Net Operating Income (NOI)	**$189,000**

The last core feature of the website is a calculator for property valuation. A common method of property valuation divides NOI by market capitalization rate (cap rate) to arrive at a property value. Thus, given the change in NOI, owners and investors can estimate the impact of retrofits on the property value using their cap rate. A property type drop down is available to provide an estimate for the cap rate, with users also being able to manually change this. NOI, and retrofit savings, are pulled from the previous input tabs.

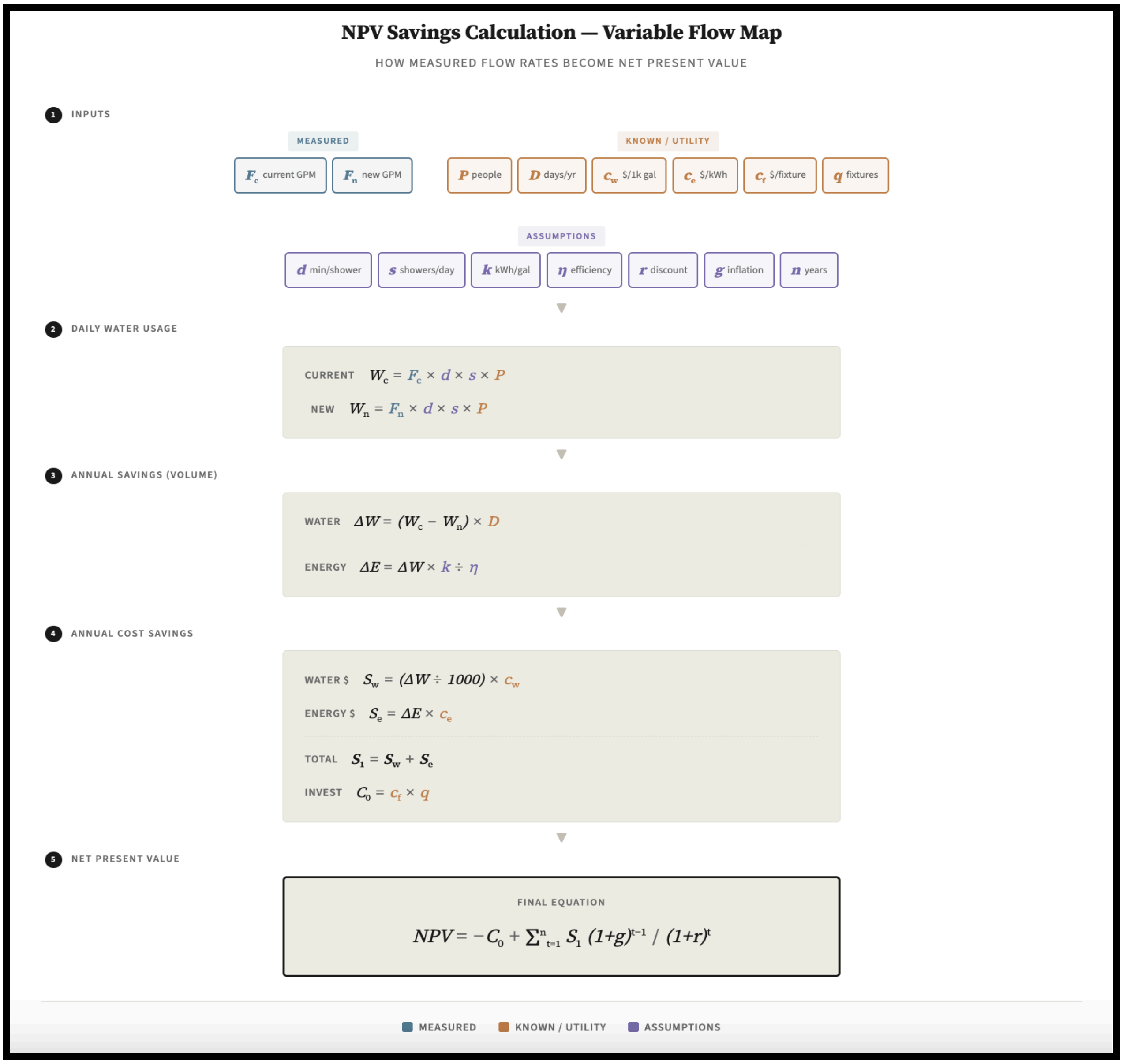


Once the user has inputted, or used the assumed cap rate, they are provided with an estimate of their property value. Clearly displayed is the increase or decrease generated from the retrofit. The return on investment, in terms of the increase in property value based on the improvement, is displayed to further show how a small, low cost, retrofit, can have substantial returns. Furthermore, efficiency improvements could allow building owners to perform a cash out refinance, essentially allowing the owner to profit directly off of the retrofit.



Difference in Flow Rates, to NPV, Color Coded Breakdown

In addition to the explanatory information under variables, a "Calc Map" is provided in the main menu. The objective of the calc map is to clearly display, with color coded variables how the difference in flow rates is extrapolated into savings. Variables are color coded by type. Direct measurements are shown in teal, values that can be found are labeled as "Known/Utility, and shown in orange, and assumptions are shown in purple.

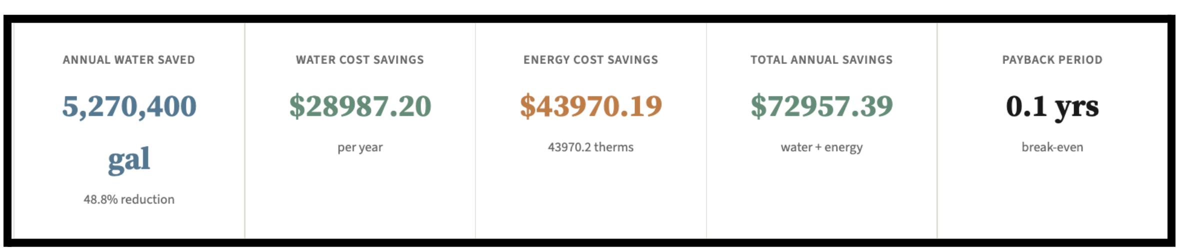


2.3. Projected Savings Case Studies

Union College

One of the initial goals of this thesis was to propose efficiency upgrades on Union College's campus. The showerhead, found in almost every building on campus is a metal cone showerhead, manufactured by Delta. These fixtures have an advertised maximum flow rate of 1.8 GPM, but contain an additional flow restrictor. The calculated flow rate of this fixture across 10 measurements was 1.28, making it already fall in the ultra low flow category. Thus, instead of looking at how low flow showerheads could save Union money, I chose instead to calculate how much money Union has saved by having efficient fixtures.

For the case of the Union College savings projections, the following assumptions were made. The number of showerheads on campus was estimated to be 250, and to serve a population of 2000 students. Union uses gas water heaters, estimated to be 70% efficient, with a cost of water, as shown on their water bill of $4.30 per 1000 gallons, and natural gas estimated at $1 per therm. Flow rate of the existing fixture uses the measured value of 1.28 GPM, and is compared to the maximum allowed flow rate of 2.5 GPM. With these assumptions, the savings calculator estimates that Union saves $72,957 annually in combined water, and water heating costs. Water savings is estimated at 5.4 million gallons annually, and CO_2 reduction at over 514,000 pounds per year. Notably, this does not include waste water savings, due to lack of available data. The following image shows the breakdown provided by the FreeFixtures website.



Impact of Fixture Change at Raymond House

In 2024, due to issues with existing fixtures, residents of Raymond house, replaced the cone showerheads with a new fixture. The make, model, and max flow rate of the fixture is unknown, but it's real flow rate was measured at 1.47 GPM. Assuming each fixture costed $15, and knowing that Raymond house has 70 residents and 12 total showerheads, here is the financial impact of the change.

ANNUAL WATER SAVED	WATER COST SAVINGS	ENERGY COST SAVINGS	TOTAL ANNUAL SAVINGS	PAYBACK PERIOD
-28,728 gal	$-158.00	$-239.67	$-397.68	N/A
-14.8% reduction	per year	-239.7 therms	water + energy	break-even

Something as simple as getting a few new showerheads for Raymond House seems like a trivial thing, but it highlights how small fixture decisions can have broader financial and environmental implications. A difference of only a few tenths of a gallon per minute can translate into hundreds of thousands of gallons of additional water consumption over the course of a year when multiplied across many residents and repeated daily use. As demonstrated in this example of Union's campus, the difference between a 1.28 GPM fixture and the federally allowed maximum of 2.5 GPM can represent millions of gallons of water annually and tens of thousands of dollars in operating costs. When considered within the broader operating budgets of universities, these types of efficiency decisions become financially meaningful rather than trivial.

More broadly, this case illustrates the importance of transparency in fixture performance and the potential value of tools that make these impacts visible. In many buildings, fixture replacement decisions are made quickly in response to maintenance issues, without consideration of long-term water or energy costs. The goal of the FreeFixtures website is to make these tradeoffs easier to understand by translating small changes in flow rate into concrete financial and environmental outcomes. By providing a simple way to visualize savings from efficient fixtures, the FreeFixtures website aims to encourage more informed purchasing decisions not only at Union College, but also across other campuses, apartment buildings, and institutional facilities where similar fixtures are used at scale. In this way, seemingly small design choices can contribute to meaningful reductions in water consumption, operating costs, and associated carbon emissions. Future research should focus on measuring the impacts of showerhead retrofit on water and electricity bills over time.

3. Final Thoughts, and Future Direction

Ultimately, the goal of this project is to make efficiency improvements easier to understand, evaluate, and implement. Many building owners are unaware of the cumulative financial impact of inefficient fixtures, particularly when these costs are spread across utility bills over many years. By clearly linking fixture performance to operating costs and environmental outcomes, tools like FreeFixtures can help shift efficiency from a niche sustainability concern into a practical financial decision. When the economic benefits are clearly visible, efficiency upgrades become not only environmentally responsible choices, but also profitable investments in building performance.

Moving forward, the FreeFixtures platform will expand beyond showerheads to include additional common household fixtures such as faucets and toilets. These fixtures represent a significant share of indoor residential water use and therefore offer similar opportunities for cost savings through efficiency improvements. According to the U.S. Environmental Protection Agency, showers account for roughly 20 percent of indoor residential water use, while toilets represent nearly 24 percent, making them the largest single source of indoor water consumption (EPA,2025). By incorporating these fixtures into the calculator, the platform will provide a more comprehensive picture of how fixture upgrades affect building-level water consumption.

Over time, the scope of the tool will extend even further to include other non-water related efficiency upgrades that are easily implemented by property owners and residents. Appliances, lighting systems, and insulation improvements all represent relatively accessible opportunities to reduce operating costs while lowering environmental impact. By integrating these categories into a unified savings calculator, FreeFixtures aims to provide a centralized platform where users can evaluate multiple efficiency improvements simultaneously. This broader approach reflects the reality that meaningful reductions in residential energy and water consumption typically occur through a series of small improvements rather than a single major intervention.

While the primary goal of FreeFixtures is to drive environmental change, the website will be monetized through affiliate links. Upon each purchase of a fixture recommended through the site, 4% of the total purchase price will go to FreeFixtures. The website is hosted through github pages for free, with the only reoccurring expense coming from the $11.99 domain fee through GoDaddy. In order for the website to be profitable, a total volume of $300 worth of fixtures will need to be purchased from the site annually.

Traffic to the website will be generated through collaboration with local governments facing water shortages, coverage from legacy media, and advertisements. For governments, FreeFixtures will be marketed as a tool to help promote resource savings initiative, by clearly demonstrating financial benefit for building owners. In these instances, local TV stations and newspapers will be contacted to help spread the word. Google, and social media ads could also be used to generate initial traction and improve search engine optimization. Analysis of water usage, price, and affordability trends, used to inform the targeting of marketing efforts is available on the website.

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