Performance and Feasibility of Tidal-Flow Constructed Wetlands for Decentralized Wastewater Treatment

D e e p t a n i l P a l & E v a n B r o e r

1. Introduction
2. Overview of Tidal Flow Constructed Wetlands
3. Comparison to Other Onsite Treatments
4. Comparison to Municipal Wastewater Treatment
5. Case study: Georgia Tech Feasibility Study
6. Conclusion

* the views in this presentation are the presenters and are not reflective of NOWRA

Guiding Questions

- How do Tidal-Flow Constructed Wetlands compare to other onsite wastewater treatment systems?

- Can this technology be feasibly implemented within the urban fabric in order to create greater interdependence between human systems and ecological systems?



[StGeorge Rainway Project | Photo by Max Baars (flickr)]

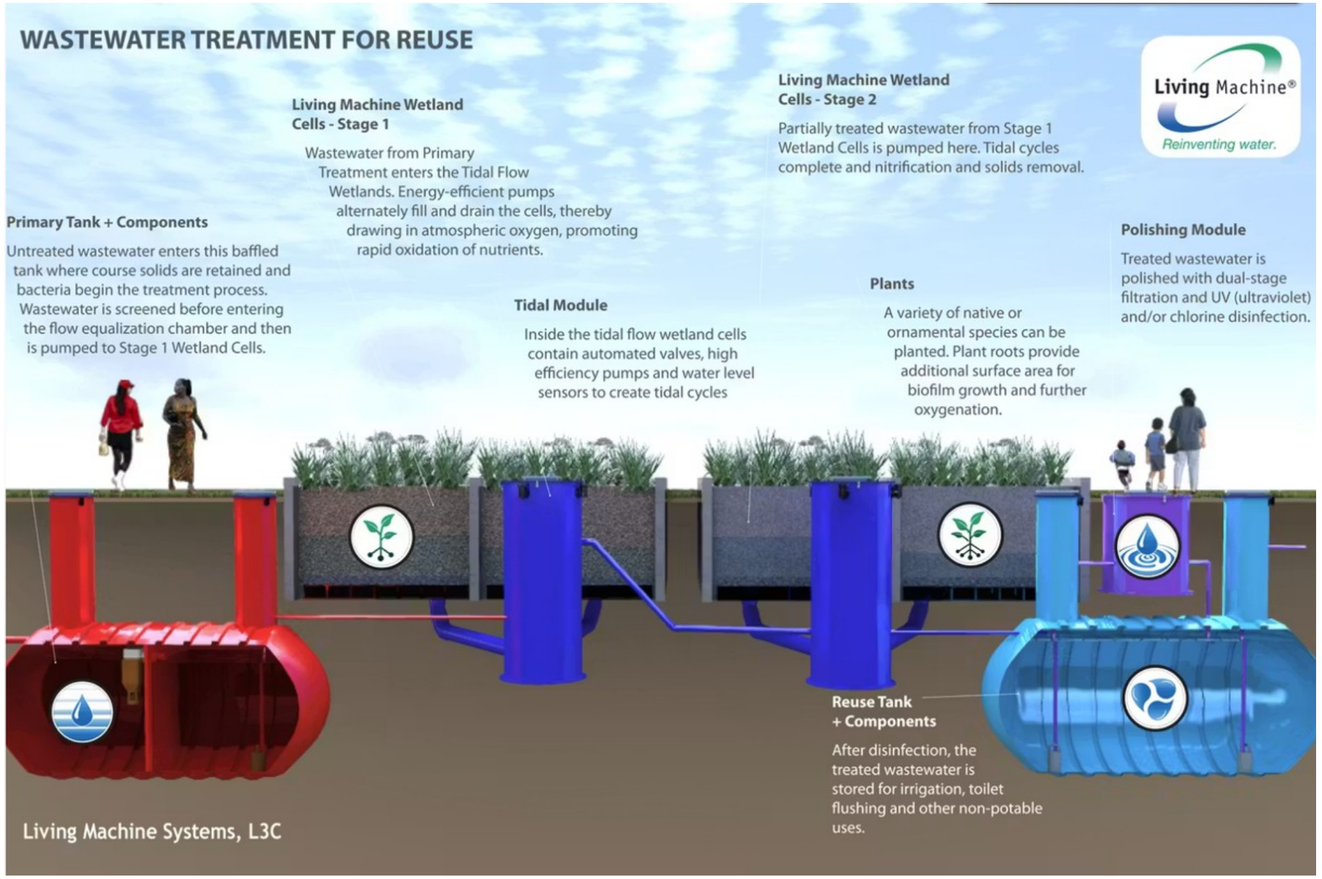
Tidal Flow Wetlands

Tidal-Flow Wetlands (TFW) is **modular wetlandbased decentralized wastewater treatment technology** that utilizes **plants and microbial fixed-film ecosystems** to break down waste in water

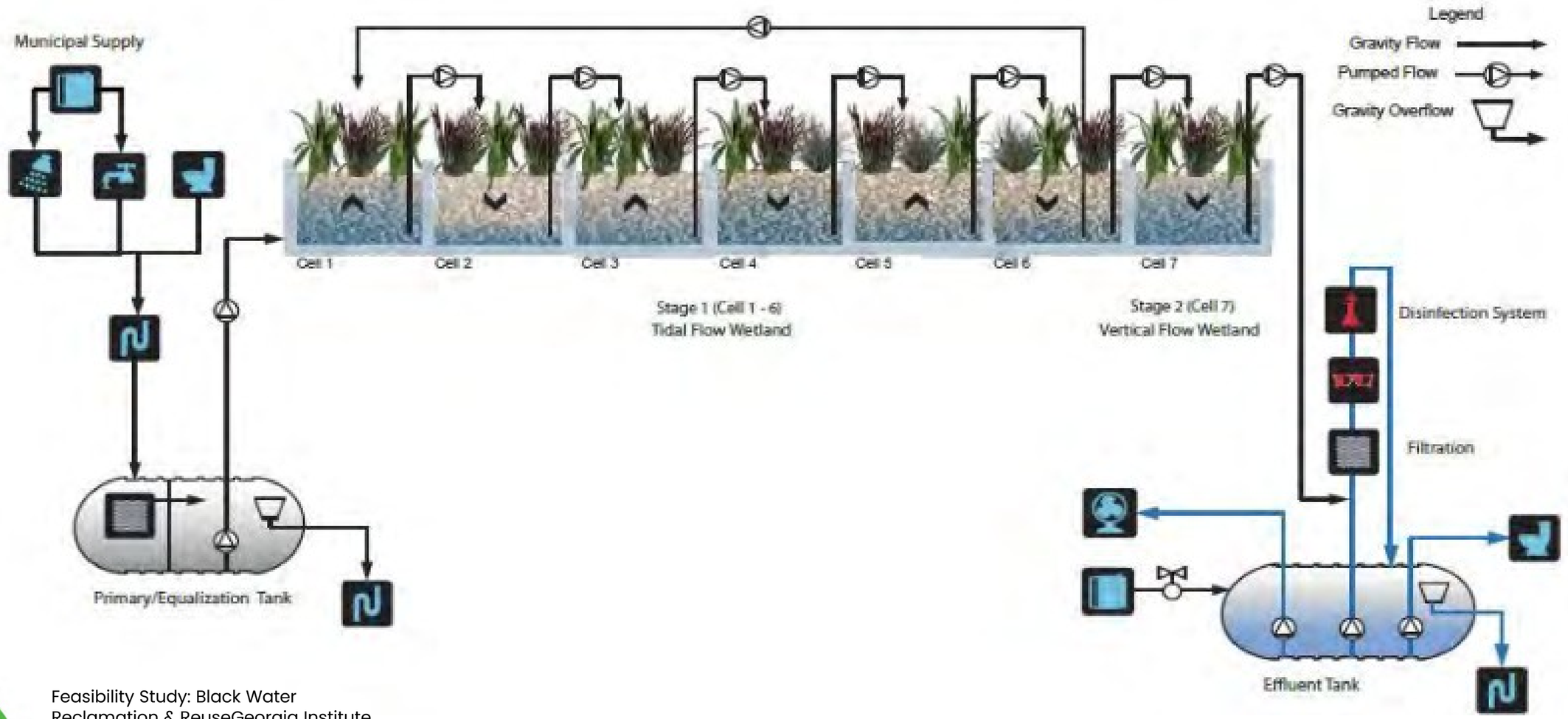
Living Machine®

Living Machine Systems is a **pioneer** of ecological water treatment systems and offers a tidal-flow treatment system. These systems use the principle of **“tidal cycling,”** which involves **repeated filling and draining of an artificial wetland area to mimic tidal events.**

- Technology mimics the natural processes of tidal wetlands
- Remotely controlled, energy-efficient, aesthetically pleasing
- Modular and scalable design provides flexibility
- Can treat from thousands to hundreds of thousands of gallons of wastewater per day



Disclaimer: Living Machine® is commercial/engineered implementation



Feasibility Study: Black Water Reclamation & ReuseGeorgia Institute of TechnologyAtlanta, GA

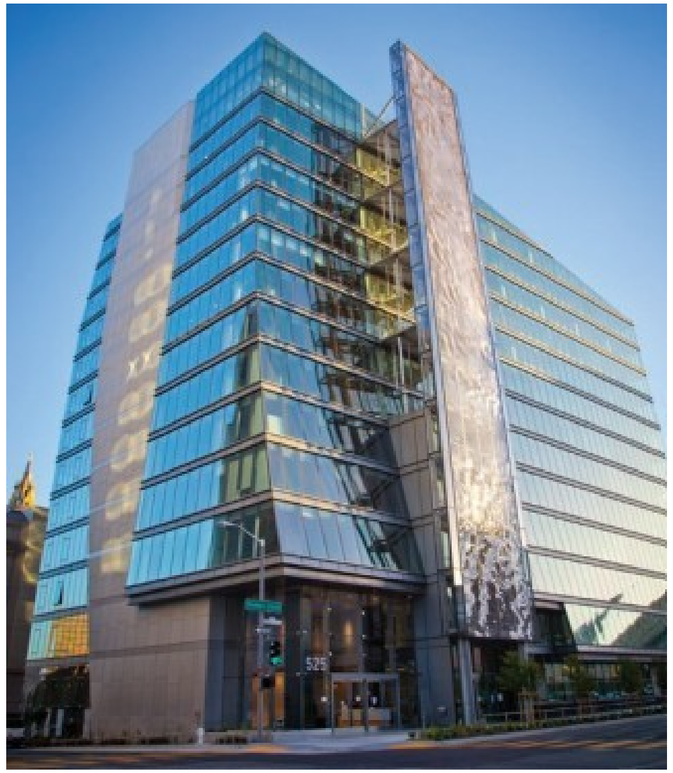
Tidal-Flow Wetland (Living Machine) Process Diagram





[Ethel M. Chocolate Factory & Botanical Cactus Garden]

- Ethel M Chocolate Factory, Henderson, Nevada
- Treats up to **32,000 gallons** of wastewater each day, high quality effluent is safe to be stored and recycle on site
- The recycled water is used to **irrigate the largest botanical cactus garden in Nevada** with over 300 different species





- San Francisco Public Utilities Commission Headquarters. San Francisco, California.
- Treats up to **5,000 gallons** of wastewater each day, high quality effluent is safe to be stored and recycle on site
- The system reduces the building's potable water consumption by approximately **65% and provides an annual potable offset of approximately 1,500,000 gallons.**





[Port of Portland Headquarters]

- Port of Portland Headquarters. Portland, Oregon.
- The building has seen a **75% reduction of water use ,** reusing employees wasterwater for flushing toilets and use in cooling towers
- The system provides **interior and exterior foliage,** and safely integrates into public spaces





[Findhorn Ecovillage]

- Findhorn Ecovillage. Findhorn, Scotland.
- This ecologically engineered sewage treatment plant is **designed to treat sewage from the population of up to 500 people** living at the Findhorn Ecovillage and is providing a research and educational facility to promote ecological water treatment technology throughout the world.
- Treatment can be taken to advanced standards in cost effective projects, which are reliable, robust and aesthetically pleasing. The approach represents **a shift from high energy, chemically intensive treatment, to the adoption of the principles of ecological engineering.**

Study Methodology

Select Systems

Tidal-Flow Wetland
Membrane Bioreactor
Activated Sludge
Textile Trickling Filter
Aerated Constructed Wetland

→

Collecting Reported Performance Data

Capital Cost • O&M Cost • Energy Use • Effluent Quality • Water Reuse
from

technical reports, peer-reviewed literature, EPA documents, and built-project case studies

→

Standardization

Onsite systems: projects at approximately 40,000–50,000 GPD where comparable data are available.

Municipal comparisons: values are compared/projected at 1 MGD where indicated in the source calculations

→

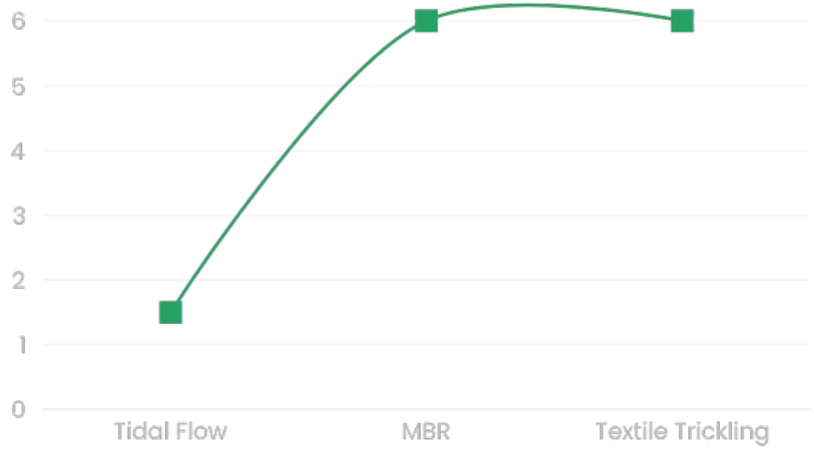
Calculate & Compare

COST (for approx. 40000-50000gpd)

Tidal Flow Living Machines: $1M-$1.5M
(EPA 2001)

MBR: $6M
(Ft. Flagler State Park Utilities," 2010)

Textile Trickling Filter: $6M
(Riviera Utilities, 2018)



ENERGY USE

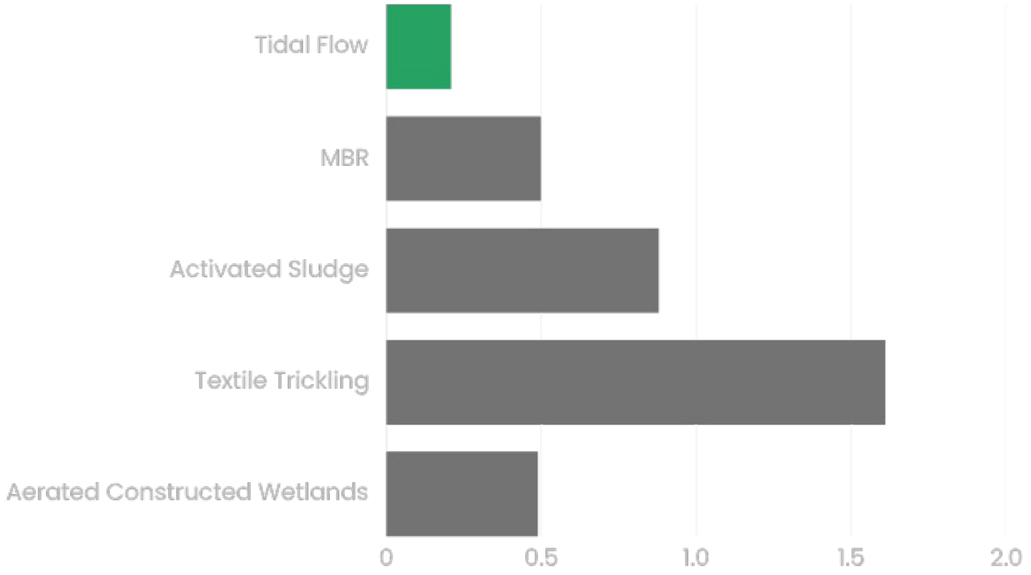
Tidal Flow Living Machines: 0.21 kW-hr per cu.m /d
(Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities, 2010)

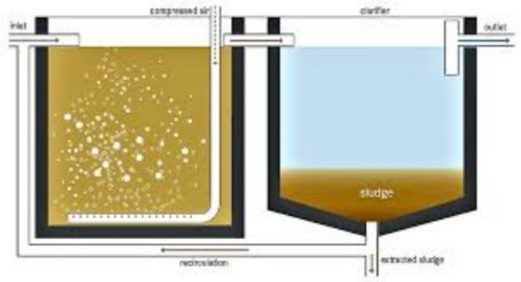
MBR: 1 kW-hr per cu.m /d flow.
(Judd, 2022)

Activated Sludge: 0.88 kW-hr per cu.m /d
(Austin & Nivala, 2009)

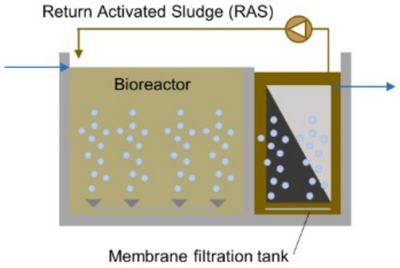
Textile Trickling: 1.61 kW-hr per cu.m /d
(Tomarken, n.d.)

Aerated Constructed Wetlands: 0.49 kW-hr per cu.m /d flow.
(Austin & Nivala, 2009)

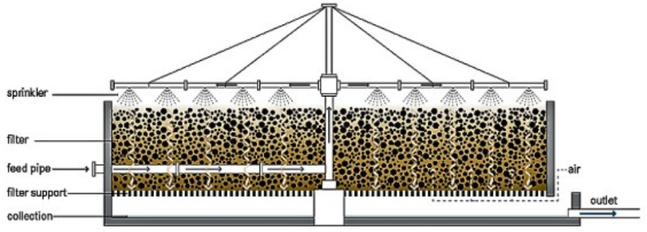




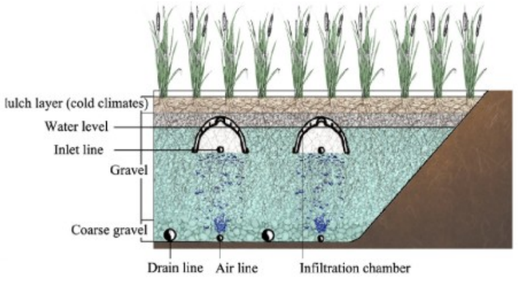
Activated Sludge



Membrane Bioreactor



Textile Trickling



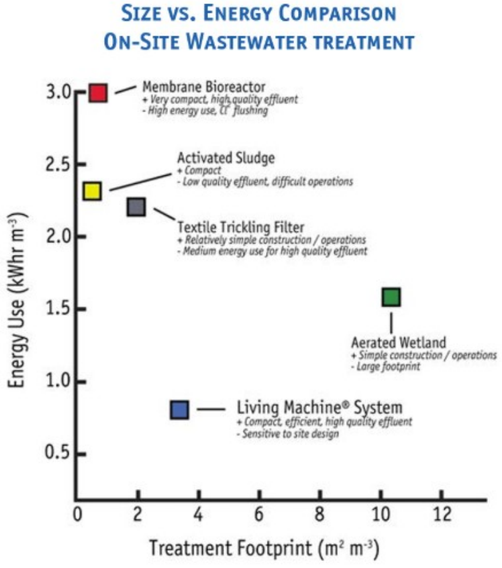
Aerated Wetland

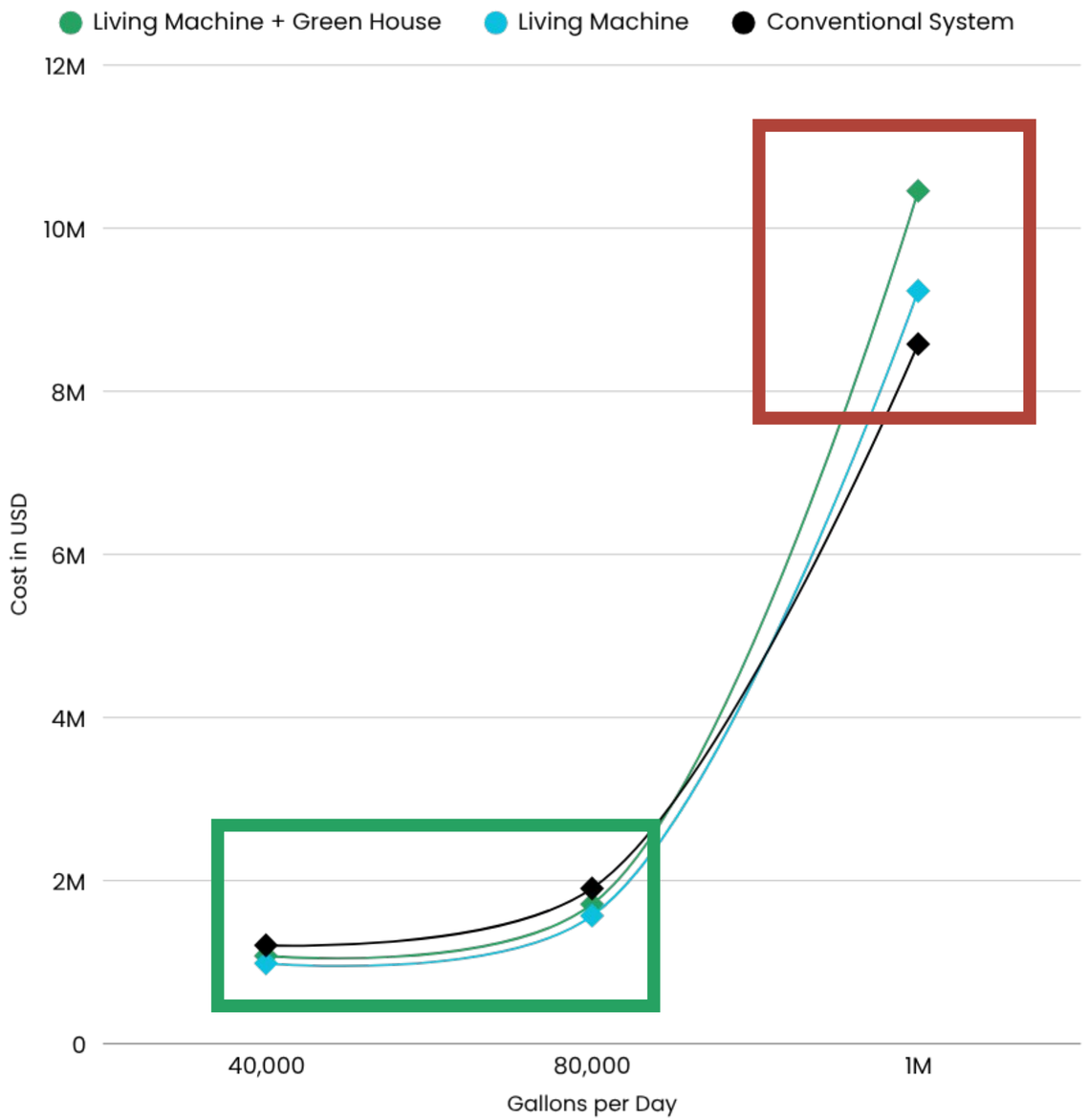
TABLE 2 PRESENT WORTH COMPARISON OF "LIVING MACHINES®" AND CONVENTIONAL SYSTEMS

Process	40,000 gpd	80,000 gpd	1 million gpd
"Living Machine" with greenhouse	$1,077,777[1]	$1,710,280[1]	$10,457,542[2]
"Living Machine" without greenhouse	$985,391	$1,570,246	$9,232,257
Conventional System	$1,207,036[1]	$1,903,751[1]	$8,579,978[2]

(1) Cost difference is less than 20 percent
(2) Cost difference is greater than 20 percent

Source: U.S. EPA, 2001.




Living Machine + Green House
Living Machine
Conventional System
12M
10M
8M
6M
4M
2M
0
Cost in USD
40,000
80,000
1M
Gallons per Day

Can we reap the benefits of Living Machines by scaling to at the municipal level?

Drawbacks to current municipal systems:

- High transportation costs
- Low percent of treated water recycled
- Low effluent quality
- Not aesthetically pleasing or visible
- Seperated from / Damaging to, local ecologies



Austin’s Purple Pipe

Source: Austin Water Conservation Plan (https://services.austintexas.gov/edims/document.cfm?id=440216)

Data from Walnut Creek + South Austin Regional only

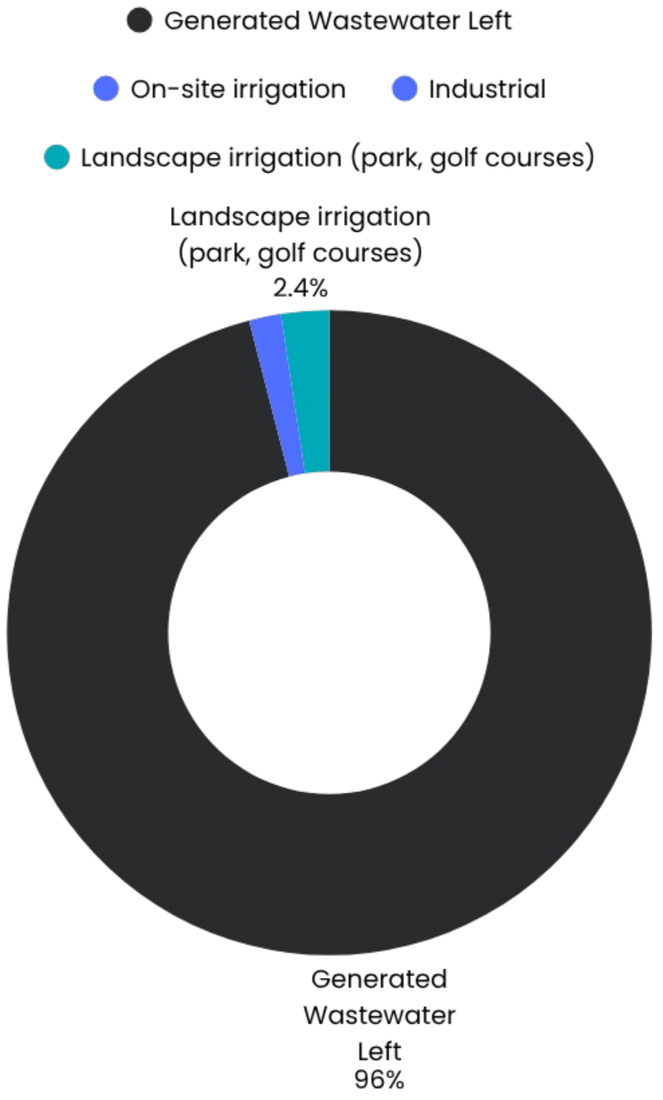
Every gallon of reclaimed water is one gallon saved from Austin's lakes.



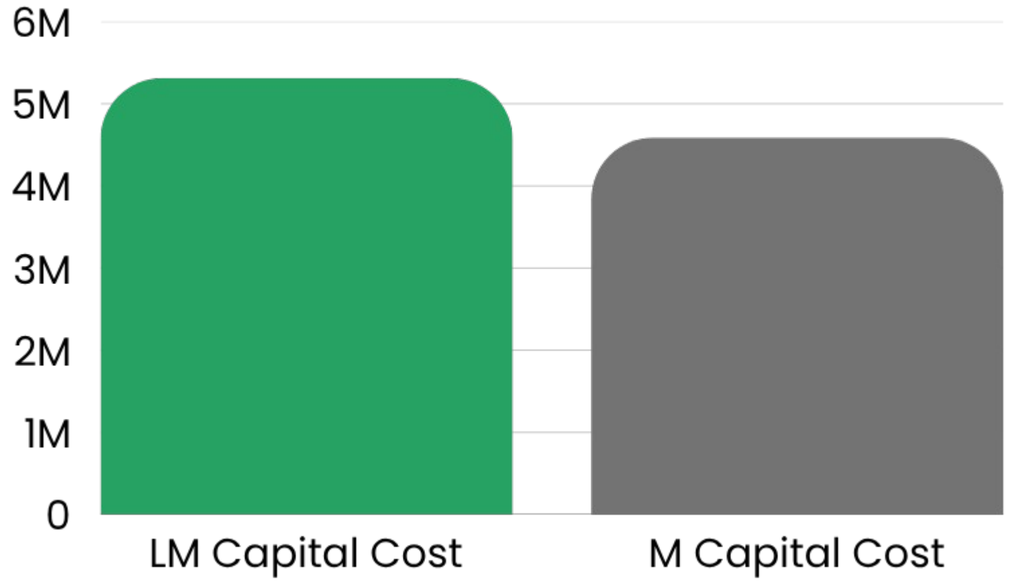
MONTHLY VOLUME OF WASTEWATER TREATED (IN THOUSAND GALLONS)

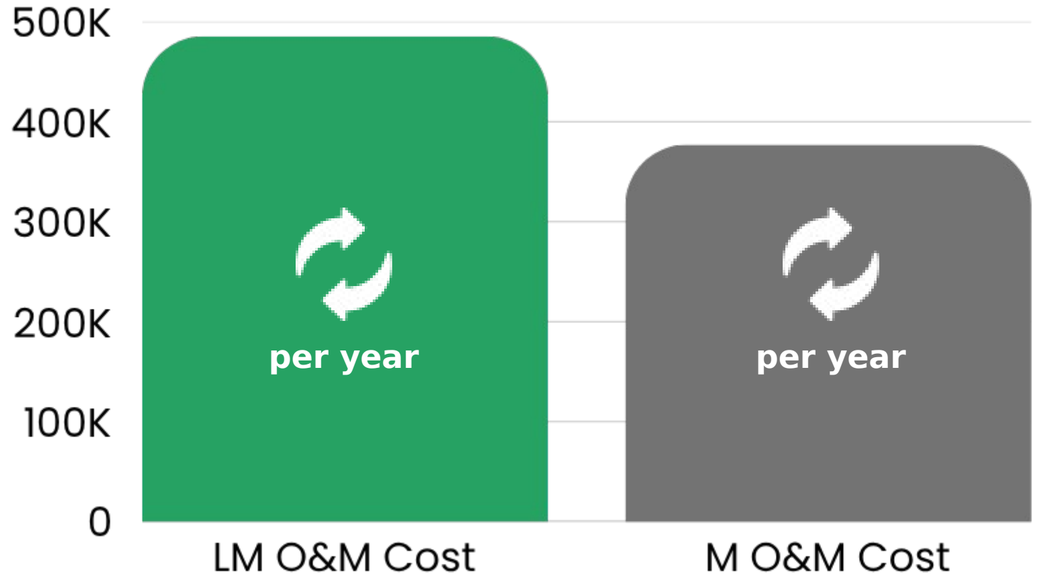
	2019	2020	2021	2022	2023
January	3,708,765	2,800,844	3,044,414	2,899,674	2,999,137
February	2,680,303	2,861,340	2,836,168	3,240,818	2,997,903
March	2,965,722	3,058,785	3,155,101	3,051,613	3,014,295
April	3,323,406	2,974,798	3,020,344	3,055,210	3,353,414
May	4,032,151	3,260,018	3,871,683	3,177,750	3,619,955
June	3,116,667	2,832,939	3,827,024	2,919,609	3,137,860
July	2,997,113	2,726,402	3,283,108	2,953,290	2,932,356
August	2,791,708	2,829,107	3,195,987	3,100,582	2,934,889
September	2,689,971	3,128,329	2,858,197	2,969,567	2,970,899
October	2,811,429	2,638,340	3,286,881	2,860,915	3,274,428
November	2,554,556	2,593,189	3,035,373	3,082,337	3,162,091
December	2,739,583	2,751,468	3,016,548	3,181,447	3,208,378
Total	**36,411,374**	**34,455,558**	**38,430,828**	**36,492,812**	**37,605,605**

Type of reuse activity	Total annual volume (in thousand gallons)
On-site irrigation	666.2
Plant wash down	0
Chlorination/de-chlorination	0
Industrial	601,593.8
Landscape irrigation (park, golf courses)	903,159.7
Agriculture	0
Discharge to surface water	359.2
Evaporation Pond	0
Other	46,897.3
Total	1,552,676.2



				Remarks
Cost (projected to 1MGD)	$4,586,351 (NEPIS | US EPA, 2016) Table 7.4	$5,315,458 (NEPIS | US EPA, 2016) Table 7.4	Capital Costs	**Living Machines ® higher by 16%**
	$376,964/yr (NEPIS | US EPA, 2016) Table 7.4	$485,377/yr (NEPIS | US EPA, 2016) Table 7.4	O&M costs	**Living Machines ® higher by 29%**

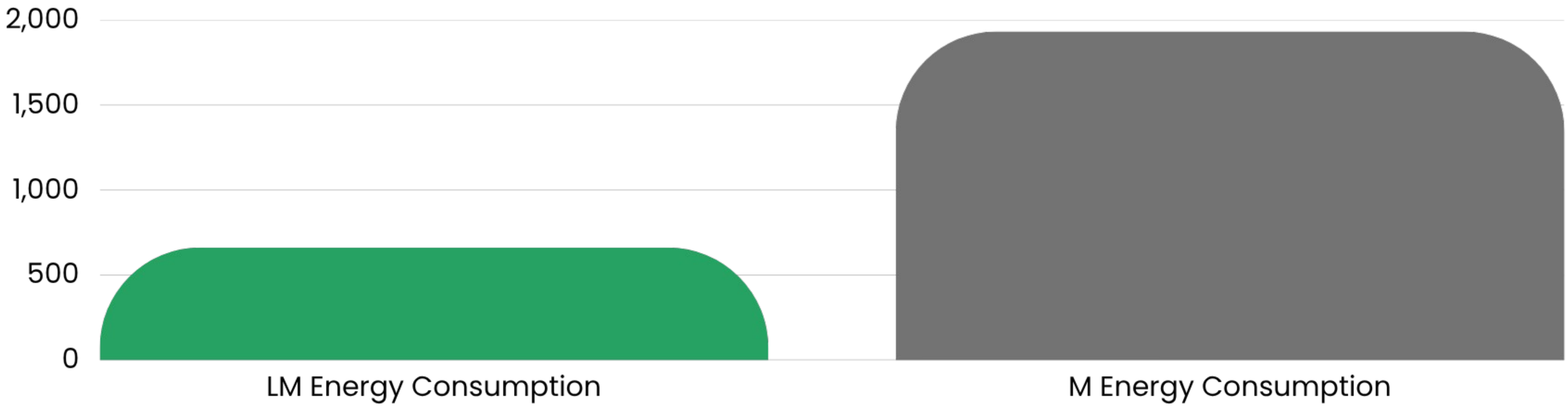


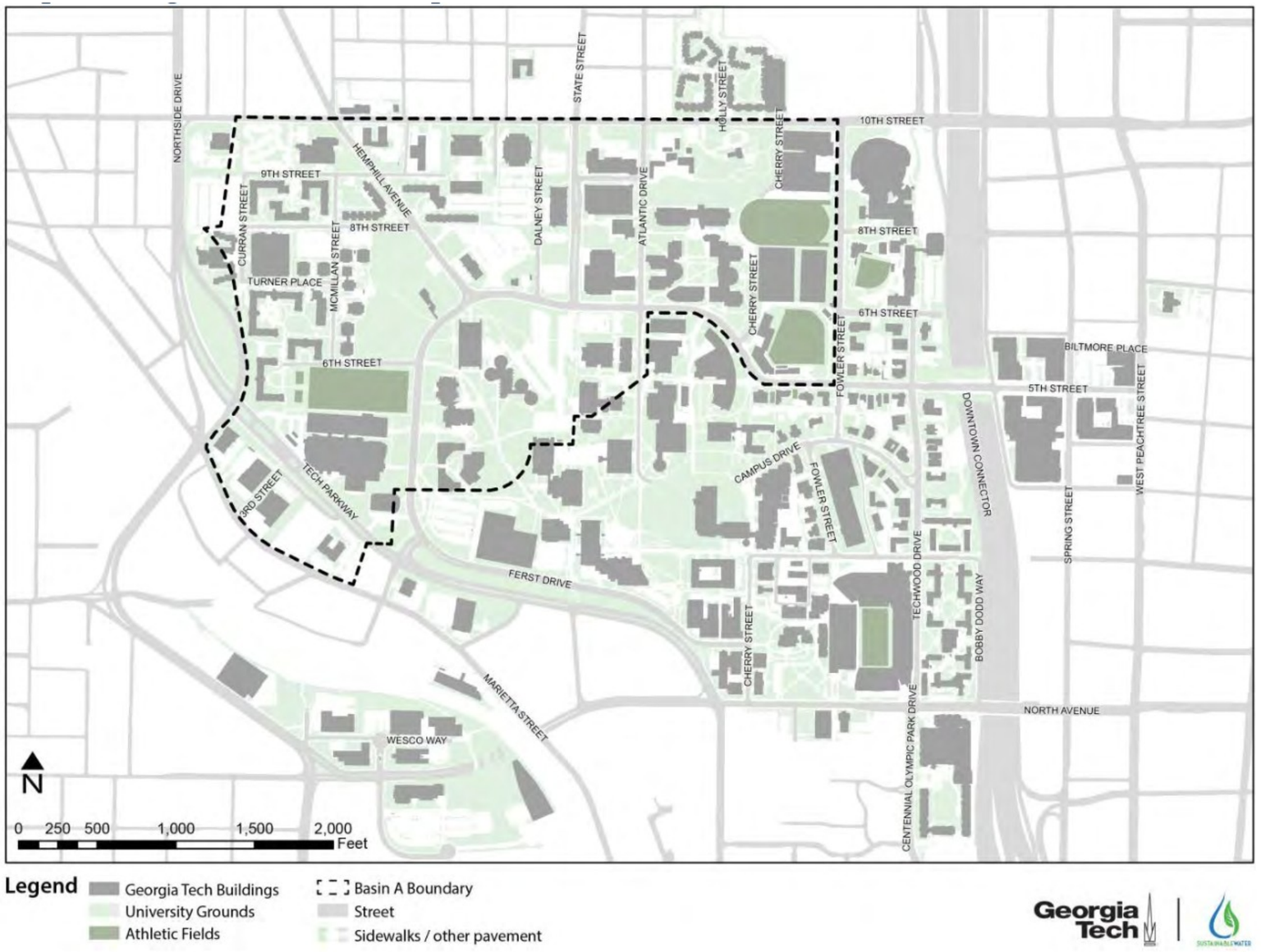


		Municipal	Living Machines ®	Remarks
Water Reusability	Reuse Documented	calculated to be around 4.5% - 7% (using https://data.austintexas.gov/Utilities-and-City-Services/Austin-Water-Gallons-of-Wastewater-Treated/vuwy-s6qv/data_preview)	100% as mentioned by Ethel M Chocolate Factory (Stated by Ethel M Chocolate Factory)	**Living Machines® have the potential to reuse 100% of the wastewater**
	Reuse Potential	Already established and sturbborn system	Greater Opportunity for localized on site reuse	**If Living Machines® are implemented in a localized scales, it is possible to reuse 100% of wastewater**

	Parameter	Municipal, Austin	Living Machines ® - South Burlington	Remarks
Effluent Quality	$CBOD_5$	≤10 mg/L	5.9 mg/L	**Living Machines ® is well below**
	TSS	≤15 mg/L	5.3 mg/L	**Living Machines ® is well below**
	NH_3-N	≤2 mg/L	0.4 mg/L	**Living Machines ® is well below**
	TN, TP, COD, TKN, TN, TP	**Living Machines ® performs better**		

		Municipal	Living Machines ®	Remarks
Energy (projected to 1MGD)	Energy Consumption Costs	≈1,932 kWh/day (Document Display | NEPIS | US EPA, 2016)	Calculated and projected to be ≈662 kWh/day ("Municipal Wastewater Treatment Projects by TAYA - WFI" 2023)	**Living Machines ® lower by ≈66%**





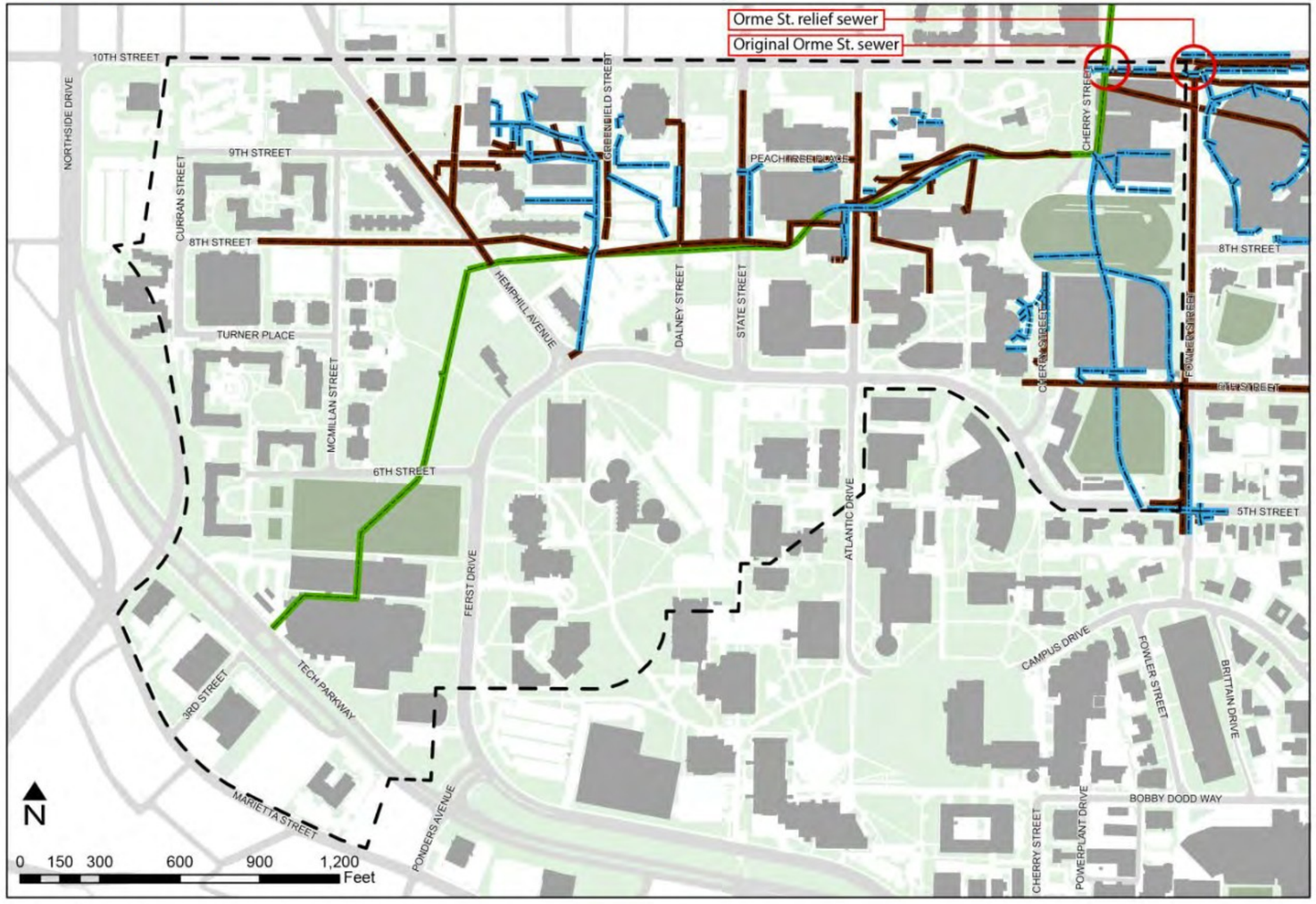
Source

Feasibility Study: Black Water Reclamation & ReuseGeorgia Institute of TechnologyAtlanta, GA

Prepared for:Capital Planning & Space ManagementGeorgia Institute of Technology, Atlanta, Georgia

Prepared by:Sustainable Water23 W. Broad StreetRichmond, VA 23220804.545.5485
www.sustainablewater.com

Map 3: Sanitary and Stormwater Sewer Infrastructure, Basin A



Source

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Map 8: Non-potable Demand Location and Usage (2012), Basin A

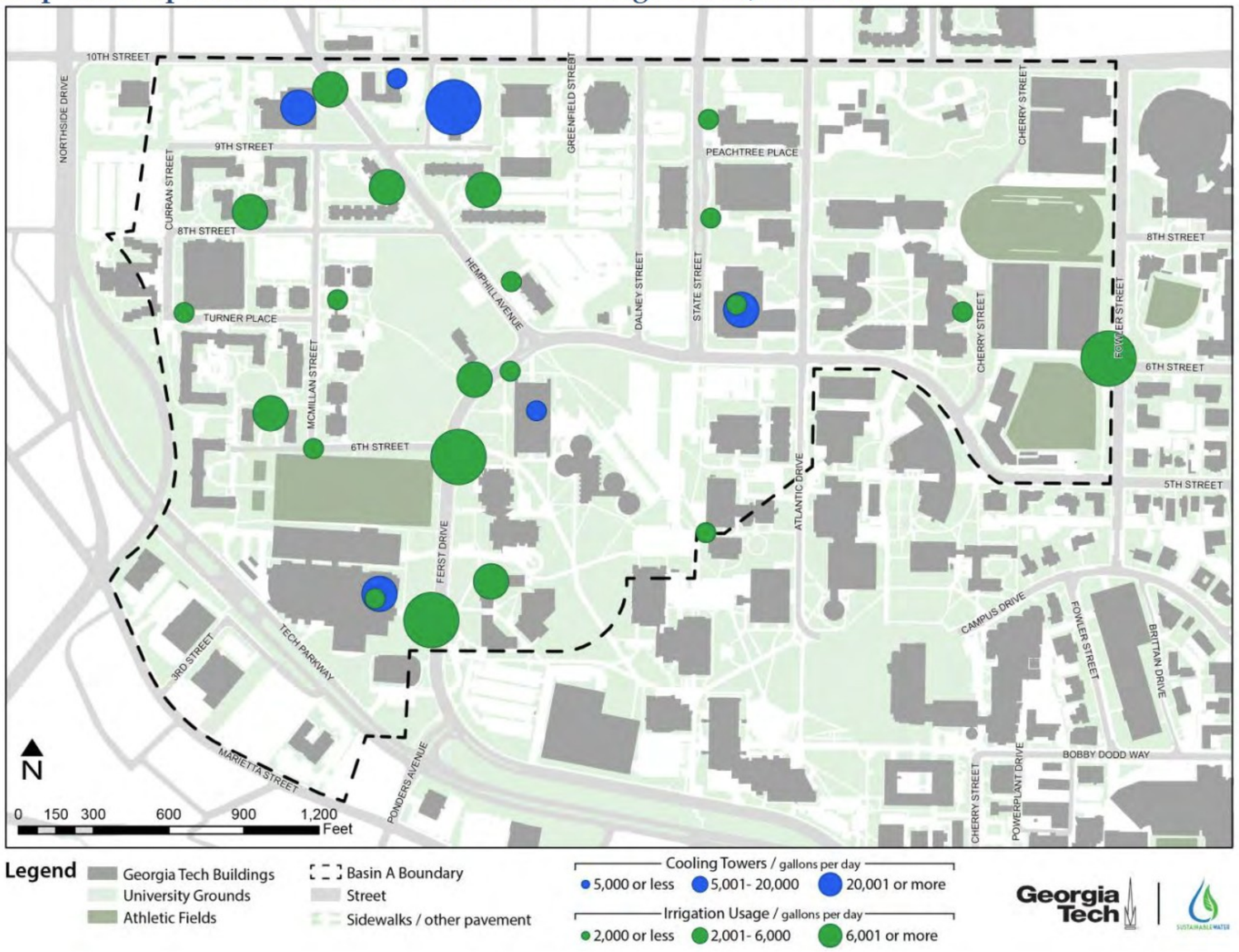




Figure 13: Students conducting research in a Living Machine Treatment System

Figure 14: Phase I Facility Adjacent to Eco-Commons Lawn



Source

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Figure 20: Conceptual Rendering of Inside Hydroponic Treatment System



Figure 19: Conceptual Rendering Looking Toward Eco-Commons from Hydroponic System



Figure 16: Conceptual Rendering of Greenhouse Lamination for Phase II



Figure 15: Conceptual Rendering of Phase I Tidal Flow Wetland System



Figure 17: Conceptual Rendering inside Hydroponic Facility



Source

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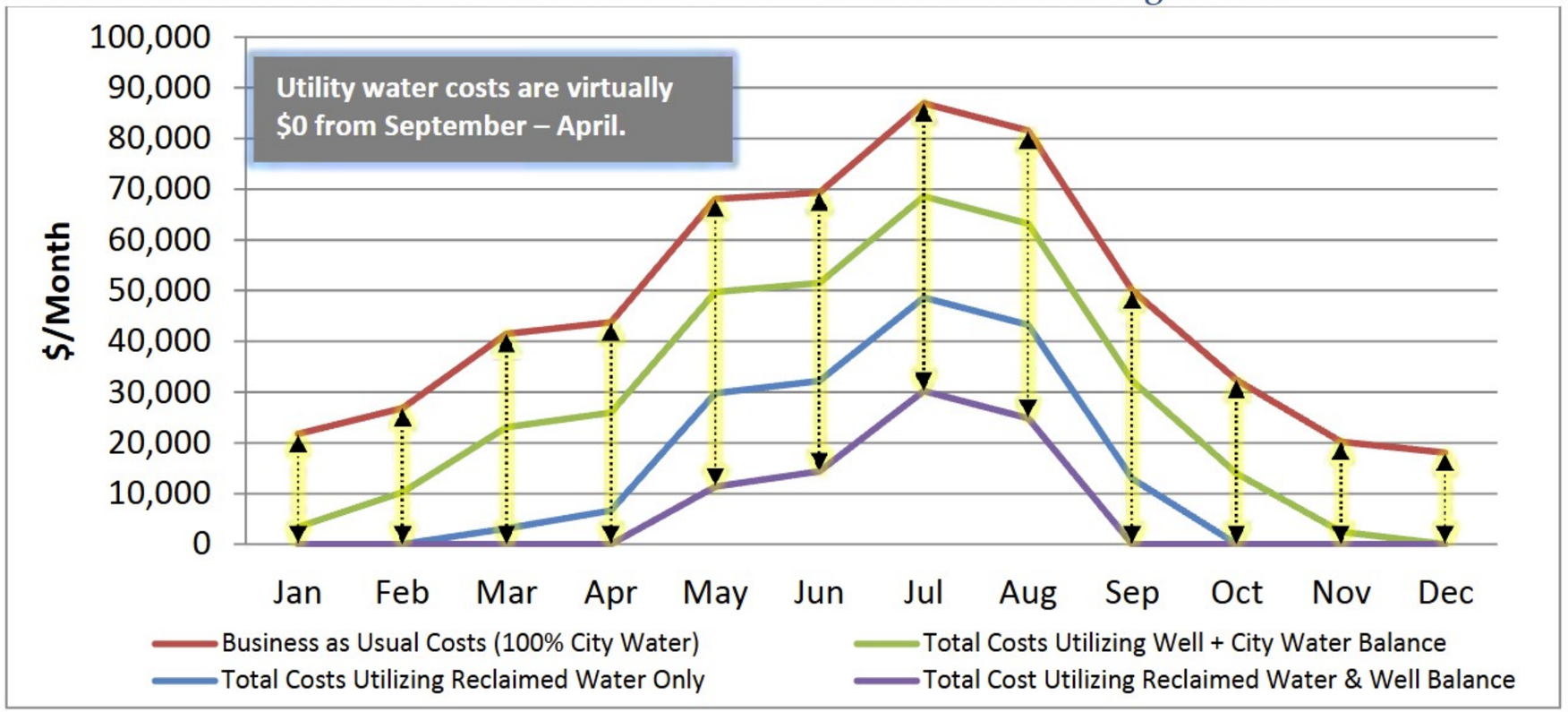
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Chart 21: Business-as-Usual Water Costs vs. Phase I Reclaimed Water Program Costs



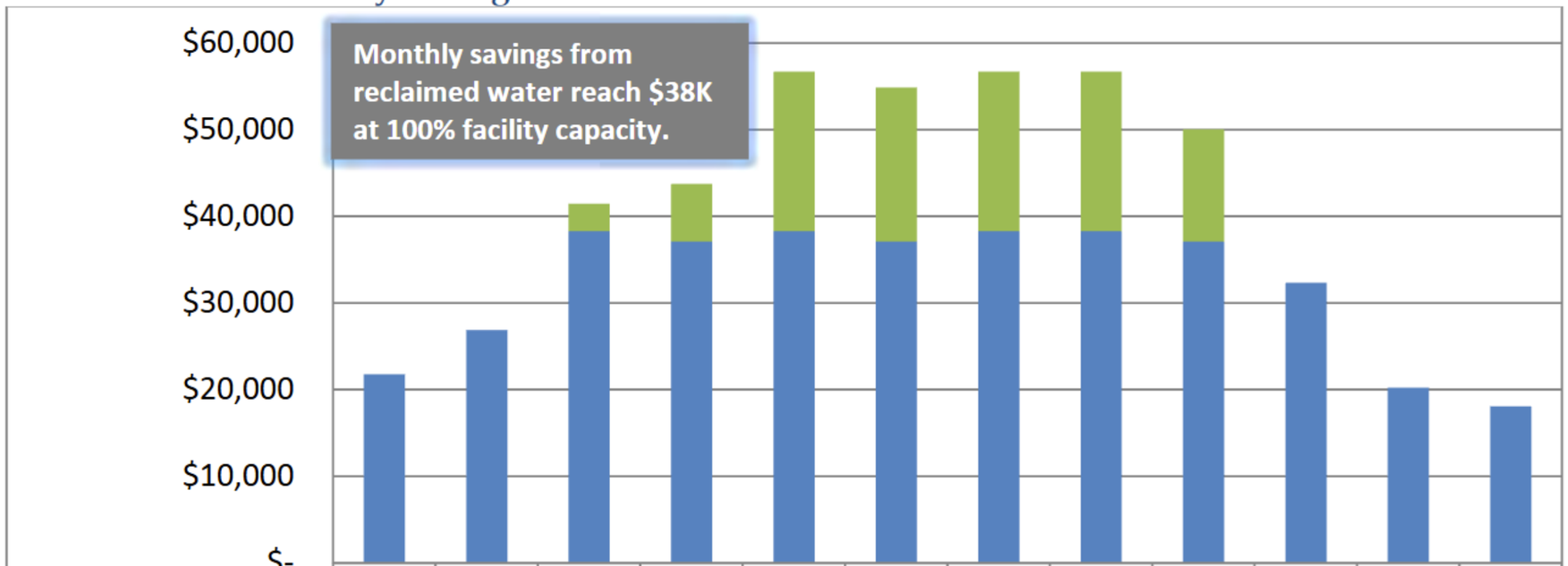
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Chart 22: Year 1 Monthly Savings under Phase I WPA



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Well Savings	$-	$-	$3,153	$6,671	$18,392	$17,798	$18,392	$18,392	$12,937	$-	$-	$-
Reclaimed Water Savings	$21,776	$26,871	$38,316	$37,080	$38,316	$37,080	$38,316	$38,316	$37,080	$32,350	$20,229	$18,107

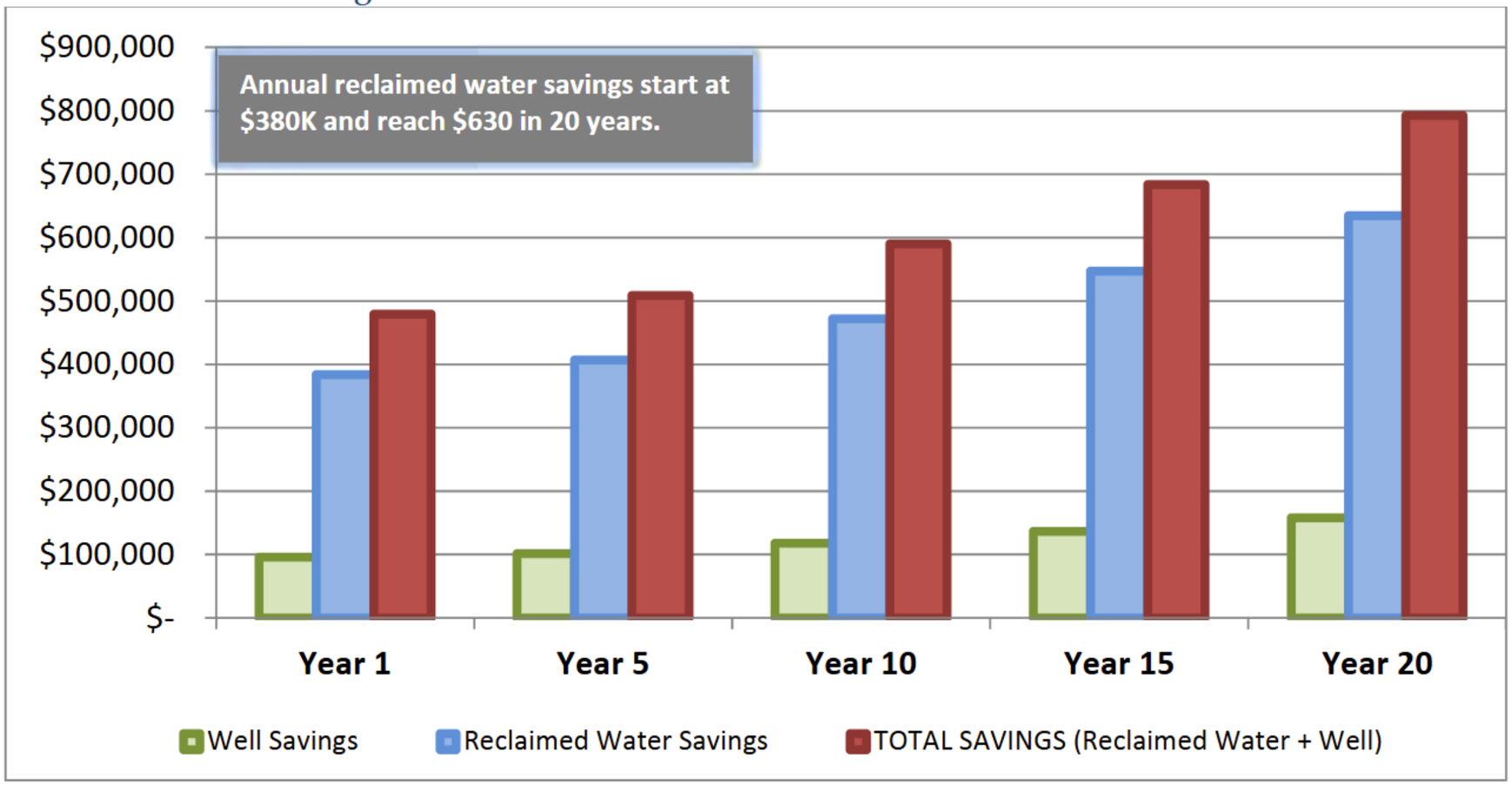
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Chart 23: Annual Savings over 20 Years under Phase I WPA



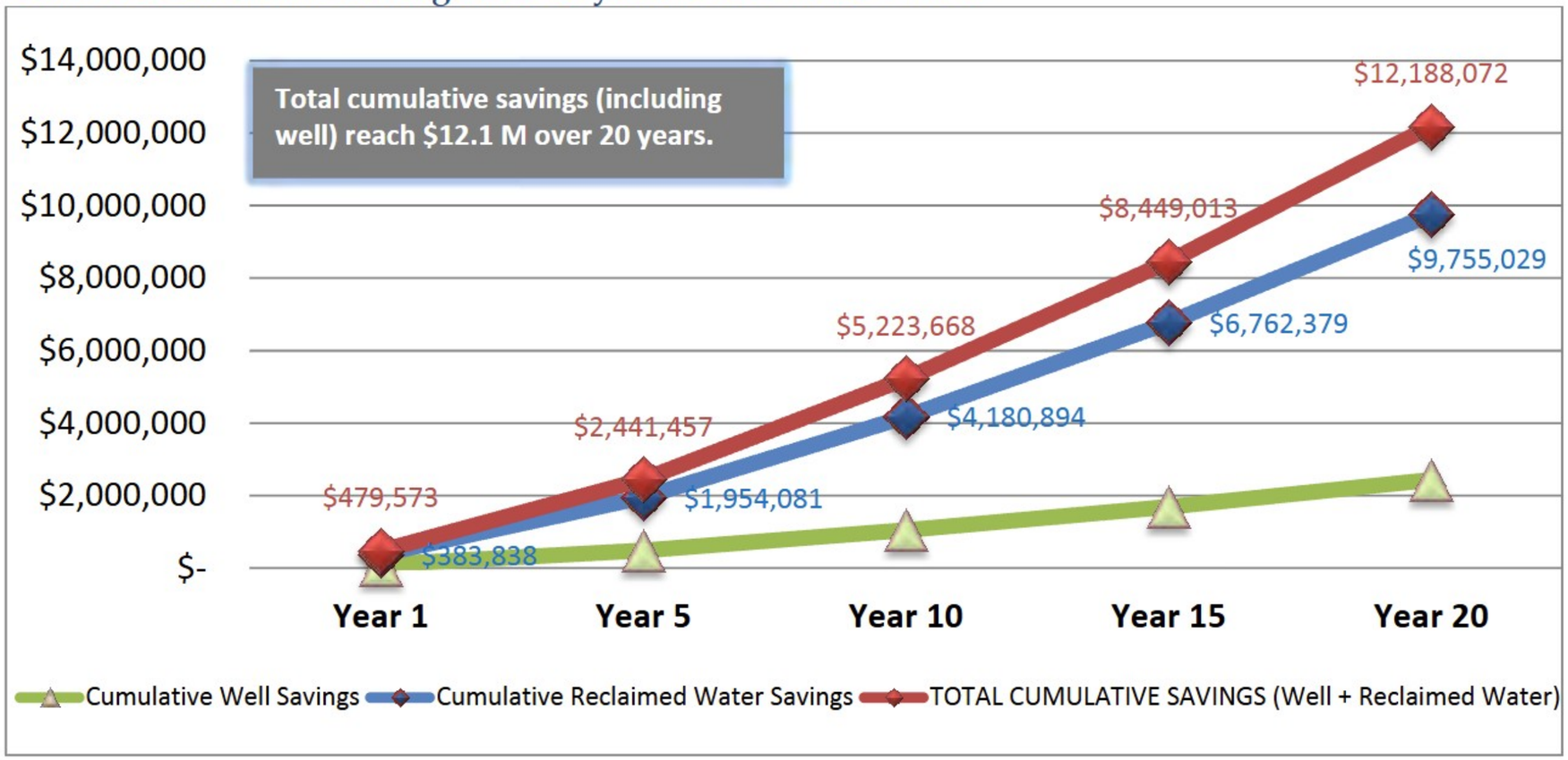
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Chart 24: Cumulative Savings over 20 years under Phase I WPA





Great Potential at Certain Scales

Increase in amount of water recycled
More water recycling means more savings on the water bill and better for the ecology.

Better Effluent Quality and Energy Efficiency
High quality effluent means safer storage of recycled water, increase recycling capacity and greater ecological health. Energy efficient treatment compared to other on-site treatment systems.

Better Annual maintenance: if automated
Scalable, modular, and remotely controlled technologies greatly decrease building and operational costs

Regenerates Ecologies & Wetlands, that is positive for the biodiversity, aesthetics & climate crisis
Closes the loop of our human water cycle while incorporating it into natural ecologies



Aerial view from the SW of Austin by Sculpin

Challenges & Discussions

Challenges in implementing
Our municipal Wastewater systems have been there for a while and have evolved over the past and there is no going back. To think of a Tidal Flow systems as a retrofit at a municipal scale is almost impossible in current times with our current infrastructures. It can possibly considered in future urban planning projects

Higher Setup Costs compared to municipal systems & higher electricity
Due to a higher amount of technological integrations like sensors and automated systems, people need to bear a more expensive setup.

Different Lifestyles or Views over Ecological Systems
As per certain surveys only very few people accepted the idea of reusing of wastewater into the systems. Constructed wetland systems are more efficient in warmer climates, with greenhouse requirements in cold climates

Chfadi, T., Gheblawi, M., & Thaha, R. (2021). Public Acceptance of Wastewater Reuse: New Evidence from Factor and Regression Analyses. *Water*, *13*(10), 1391. https://doi.org/10.3390/w13101391

“Ethel M Chocolates TM H E N D E R S O N , N E va DA.” n.d. Accessed September 23, 2025. https://www.utelite.com/wp-content/uploads/2018/06/LM_EthelCase1.pdf.

Ft. Flagler State Park Utilities Improvements & MBR Project. (2022). Wwdmag.com. https://www.wwdmag.com/top-projects/article/10919963/ft-flagler-state-park-utilities-improvements-mbr-project

Living Machine System. n.d. *Appendix F*. Fibershed. Accessed September 22, 2025. PDF file. https://fibershed.org/wp-content/uploads/2016/10/Appendix-F.pdf.

Riviera Utilities. (2018). Wwdmag.com. https://www.wwdmag.com/top-projects/article/10937289/orenco-systems-inc-riviera-utilities

Wastewater Technology Fact Sheet Free Water Surface Wetlands. (2000). https://www.epa.gov/sites/default/files/2015-06/documents/free_water_surface_wetlands.pdf

wdtalampas. (2025). *Living Machines - John Todd.pdf*. Scribd. https://www.scribd.com/document/462775138/Living-Machines-John-Todd-pdf

“FIGURE 1 the OPEN AEROBIC TANKS of the LIVING MACHINE® in SOUTH BURLINGTON, VT.” n.d.

https://facilities.gatech.edu/sites/default/files/2023-05/2013_05_20_gt_reusefeasibilityreport_final-reduce-revi.pdf

Let’s Talk

Thanks for listening