Urban Green Spaces as Green Infrastructure: A Landscape Life Cycle Analysis Approach

Resource-Positive Landscapes for the 21st Century

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Urban landscapes are often discussed in terms of aesthetics or recreational value, yet they play a much broader role in the functioning of cities, communities, and the environment. Urban landscapes influence how water moves through neighborhoods, how heat accumulates and dissipates across the urban environment, and how communities experience increasingly variable climate conditions. As cities confront rising temperatures, more intense precipitation events, and long-term water constraints, there is growing interest in understanding how urban landscapes can enhance existing infrastructure rather than serve only as aesthetic features.

This case study applies a life cycle assessment framework to amenity landscapes—designed green spaces such as residential yards, parks, institutional grounds, and other maintained landscapes that provide aesthetic, recreational, environmental, and community benefits. Rather than evaluating these landscapes only by their initial cost or irrigation demand, the approach considers the resources the landscapes require and the benefits they provide over time. By accounting for financial costs, water use, energy, labor, management inputs, and carbon outcomes, the model provides a more comprehensive basis for comparing landscape designs and understanding the tradeoffs among them.

Case Study Introduction

This case study applies of the Landscape Life Cycle Analysis (LLCA) Tool to experimental landscapes. Six types of landscape test plots[1] were managed and studied at Utah State University to inform the LLCA Tool's model. The financial costs, water needs, energy used, labor, and hydrocarbon balance of the test plots were scaled up in two ways to test the application of the LLCA Tool:

1. Residential landscape test plot data from the first two years of monitoring, 2024 – 2025, were applied and scaled to Salt Lake City residential landscapes to model resource use;
2. Landscape test plot data were used to model a 30-year life cycle of these landscapes scaled to Salt Lake City residential plots.

In this case study, five categories were measured and modeled: **(1)** financial cost, **(2)** water needs, **(3)** energy used, **(4)** labor, and **(5)** hydrocarbon balance.

[1] Each type of landscape had 4 test plots. For six landscape types there were 24 total test plots.

This case study provides water and landscape professionals with a more complete decision-making framework for evaluating the costs, environmental impacts, and water savings associated with landscape rebate and incentive programs.

This case study will walk through:

1. Project Context and Experimental Design
2. Landscape Monitoring and Data Collection
3. Landscape Life Cycle Analysis and Analytical Framework
4. Two-Year Data Application and Preliminary Findings
5. 30-year Life Cycle Analysis Results

1. Project Context and Experimental Design

Located in northern Utah, the study site includes landscape designs that are commonly used in residential, institutional, and public settings across the United States. The research team selected six distinct landscape designs and plant material compositions to represent a range of design approaches, plant palettes, and anticipated resource demands. These included:

1. Localscapes™ -high: A combination of turfgrass and ornamental plants at high water-use levels
2. Localscapes™ -low: A combination of turfgrass and ornamental plants with low water-use levels
3. Ornamental Plants: Shrubs, perennials, and a tree
4. Thyme Lawn: Thyme groundcover
5. Standard Turfgrass: Cool season turfgrass
6. Low Water Turfgrass: Certified lower water use turfgrass[2]

To ensure meaningful comparisons, each landscape design was replicated four times, resulting in a total of twenty-four experimental plots. The landscapes were installed in phases, beginning with irrigation infrastructure in 2022, followed by turfgrass and tree establishment in 2023 and ornamental plant installation in 2024. All landscapes are managed using best practices to minimize confounding effects associated with poor maintenance practices. Importantly, the project was designed as a long-term study, with data collection planned for at least ten years. This allows delayed benefits, such as tree canopy development and soil and plant carbon accumulation, to be captured.

2. Landscape Monitoring and Data Collection

A central feature of this study is the breadth of data collected across physical, biological, and climatic dimensions. Over the first two years of the project, weather conditions and irrigation water volumes were continuously monitored to contextualize landscape water demand. Soil moisture measurements provided insight into water availability and retention,

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[2] Certified bythe Turfgrass Water Conservation Alliance (TWCA)

while soil health indicators helped track changes in soil function over time. Plant growth and morphology were recorded alongside physiological measurements such as stomatal conductance[3], allowing for evaluation of plant water status and stress responses.

In addition to these measurements, the project incorporated soil gas flux monitoring and carbon accounting to assess how different landscape designs contribute to carbon sequestration or emissions. Thermal imagery was also used to quantify surface and canopy temperatures, providing direct evidence of how landscapes influence urban microclimates under growing season conditions. As of August 2026, these measurements are ongoing and will continue throughout the project lifetime. Collectively, these measurements allow the landscapes to be evaluated as integrated systems, rather than as collections of individual components, and inform the LLCA Tool.

3. Life Cycle Analysis and Analytical Framework

To interpret this complex dataset, the research team used a life cycle analysis framework that tracks inputs and impacts annually and throughout the lifespan of a landscape. The life cycle analysis data collected were used to update the Value Landscape Engineering Model (Rosenberg et al. 2011), a comparative model originally developed to quantify tradeoffs among landscape approaches.

This model approach accounts not only for irrigation water use, but also for the cost of materials required for installation, energy consumed for maintenance, labor inputs, fuel use, and long-term environmental outcomes. It incorporates regional climate conditions, and measures field performance to reflect current conditions more accurately. By considering how these factors interact, the analysis moves beyond short-term performance metrics toward a more realistic, nuanced understanding of landscape sustainability. This approach supports decision-making by illustrating how different landscape choices perform across multiple dimensions simultaneously.

[3] Stomatal conductance the measure of the rate of carbon dioxide entering and water vapor leaving the tiny pores, called stomata, on the surface of plant leaves.

4. Two-Year Data Applications and Preliminary Findings

To demonstrate application of the LLCA Tool, the research team used data collected from the study site plots during the first two years of the project and applied the data to Salt Lake City, UT with a series of assumptions based on city metrics. The preliminary findings for landscape cost, water use, energy use, labor and hydrocarbon balance are represented for 2024 and 2025.

Assumptions

- Each landscape covered 9,000 square feet (average landscape size in Salt Lake City)
- 2024 and 2025 evapotranspiration rates local to Salt Lake City
- 2024 and 2025 water, fuel, and power rates for Salt Lake City
- 2024 and 2025 summer and winter household energy use averages for Salt Lake City
- All labor is owner-supplied labor
- Conventional landscape maintenance levels

4.1 Total Cost by Year

The research team kept records of all costs related to the installation, management, and maintenance of the experimental landscapes (i.e. materials, plants, labor, transportation). Tree and turfgrass landscape installations began in 2023 and were completed in 2024. Shrubs and perennials were installed in 2024. The first year of complete monitoring was 2024, and the second year was 2025.

In 2024, the costliest landscape was the standard turfgrass landscape ($863) followed by the ornamental plant landscape ($802), the Localscapes high landscape ($765), the low water turfgrass landscape ($725), the Localscapes low landscape ($677), and the thyme lawn landscape ($250). In 2025, the costliest landscape was the standard turfgrass landscape ($1116) followed by the Localscapes high landscape ($962), the low water turfgrass landscape ($884), the ornamental plant landscape ($835), the Localscapes low landscape ($753), and the thyme lawn landscape ($354) (**Fig. 1**).

Purchasing water for irrigation was the highest cost in both years. While the total amount of irrigation water used in the first and second year for each landscape was similar (Section 4.2), the rising costs can be attributed to a water rate increase implemented by Salt Lake City in 2025 and higher vegetation water requirements due to increased evapotranspiration rates.[4]

[4] Utah State University. 2026. "Utah Climate Center." Accessed July 30, 2026. https://climate.usu.edu/

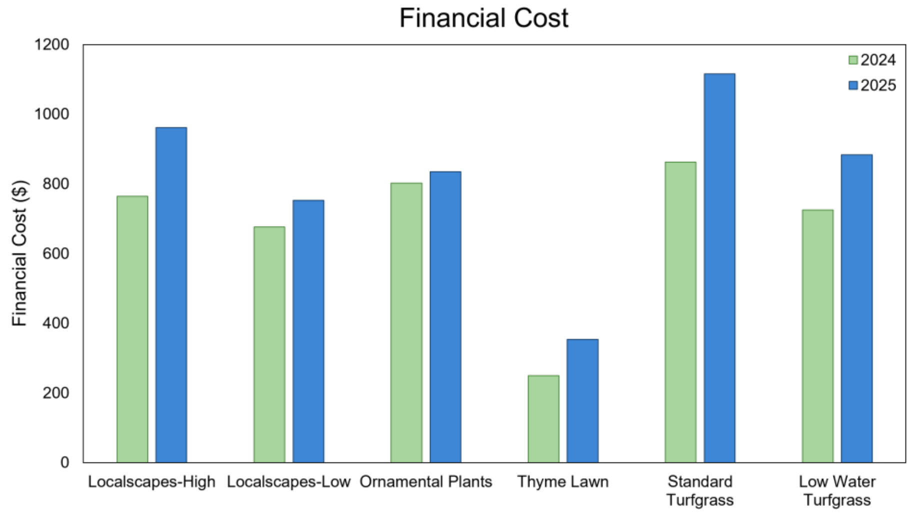

Figure 1. Total costs ($) related to the installation, management, and maintenance of the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes in 2024 and 2025. Trees and turfgrass were installed in 2023.

4.2 Total Water Application by Year

The total volume of irrigation water applied to the experimental landscapes was measured on an annual basis. In 2024, the ornamental plant landscape had the lowest water use (41 kgal), followed by the Localscapes-low landscapes (77 kgal) and thyme lawn (89 kgal), the Localscapes-high landscape (107 kgal), the low water turfgrass landscape (141 kgal), and the standard turfgrass landscape (189 kgal). In 2025, the ornamental plant landscapes had the lowest water use (44 kgal), followed by Localscapes-low landscape (78 kgal), the thyme lawn landscape (94 kgal), the Localscapes-high landscape (134 kgal), the low water turfgrass landscape (141 kgal) and the standard turfgrass landscape (202 kgal) (**Fig. 2**). All landscapes excite the low water turfgrass landscape required more water in 2025 compared to 2024. This is attributed to a higher evapotranspiration during the growing period in 2025.[5]

[5] Utah State University. 2026. "Utah Climate Center." Accessed July 30, 2026. https://climate.usu.edu/

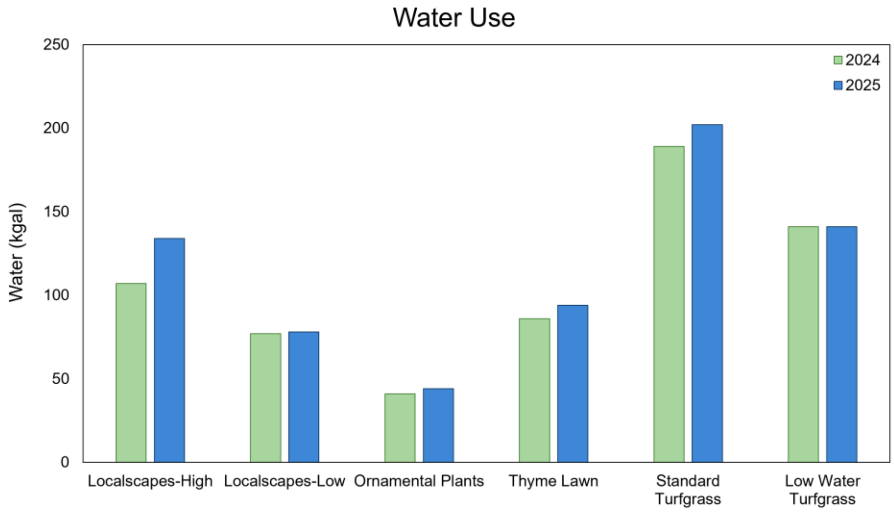

Figure 2. Total irrigation water volumes applied to the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes in 2024 and 2025.

4.3 Total Energy Use by Year

The total amount of energy used to maintain the landscapes was recorded and was solely associated with mowing the landscapes that included turfgrass. In this case study, a battery-powered mower was used to mow all landscapes. Unlike total costs and water application, energy use remained consistent during 2024 and 2025 for each landscape. Energy use ranged from highs of 299 and 303 kilowatt-hours for the standard and low water turfgrass landscapes, respectively, to a low of 109 kilowatt-hours for the Localscapes™-high and -low landscapes in both 2024 and 2025 (**Fig. 3**). Mowing was not needed for the ornamental plant and thyme lawn landscapes, and no electrical energy was used for maintenance during either year.

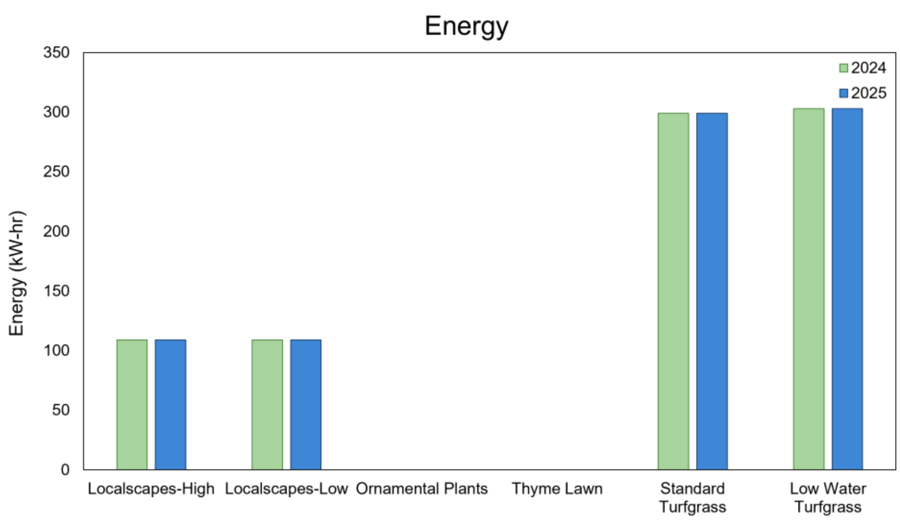

Figure 3. Total kilowatt-hours of energy required to maintain the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes in 2024 and 2025.

4.4 Total Labor by Year

Labor was tracked and recorded separately, including the amount of labor hours required for all installation, management, and maintenance practices for the landscapes. Owner-supplied labor, rather than contracted labor, was assumed for these landscapes.[6]

In 2024, the ornamental plant landscape required the most labor (170 hours), followed by the Localscapes-high (148 hours), Localscapes-low (134 hours), thyme lawn (115 hours), low water turfgrass (104 hours), and standard turfgrass landscapes (102 hours). In 2025, the Localscapes-high landscape required the most labor (188 hours), followed by the Localscapes-low landscape (171 hours), the ornamental plant landscape (170 hours), the thyme lawn (115 hours), and the low water and standard turfgrass landscapes (104 hours each) (**Fig. 4**).

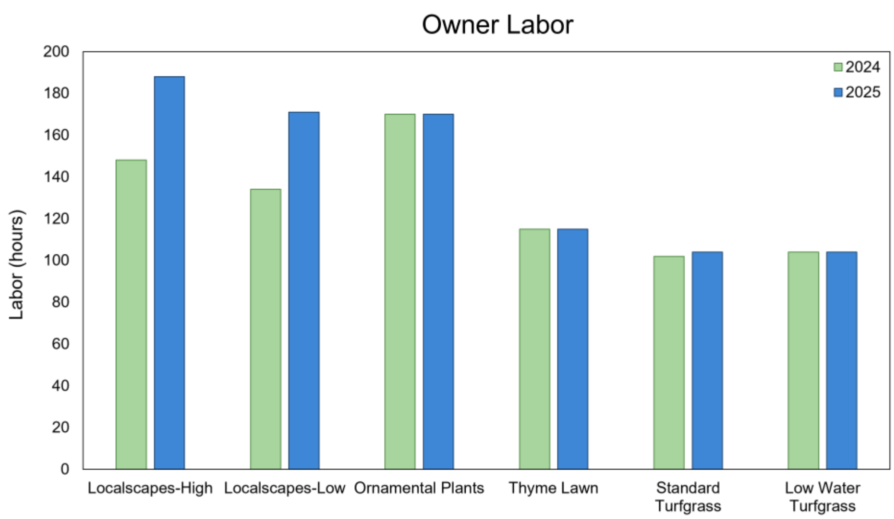

Figure 4. Total labor (hours) required to maintain the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes in 2024 and 2025.

4.5 Hydrocarbon Balance by Year

The hydrocarbon balance for each landscape represents the amount of carbon sequestered in the landscape in relation to the amount of carbon emitted due to management practices. It is measured as the weight of the amount of carbon required for landscape installation, management, and maintenance against the amount of carbon sequestered in the plants and soils of the landscapes. Currently, the LLCA Tool only considers carbon sequestered in the plant material. As more data is collected from testing plots, carbon sequestered in the soil of the landscapes will also be incorporated into the model. All hydrocarbon measurements were made in carbon dioxide (CO_2) equivalents.

In all cases, the landscapes sequestered more carbon than was released to the atmosphere due to management practices like mowing and trimming. In both years, the greatest amount of carbon sequestered was 3,468 pounds of CO_2 by the ornamental plant landscape,

[6] Contracted labor increases the cost per landscape.

followed by LocalScapes (3050 pound CO_2) and the thyme, standard turfgrass and low water (**Fig. 5**). All landscapes provide an environmental benefit by drawing down CO_2 from the atmosphere.

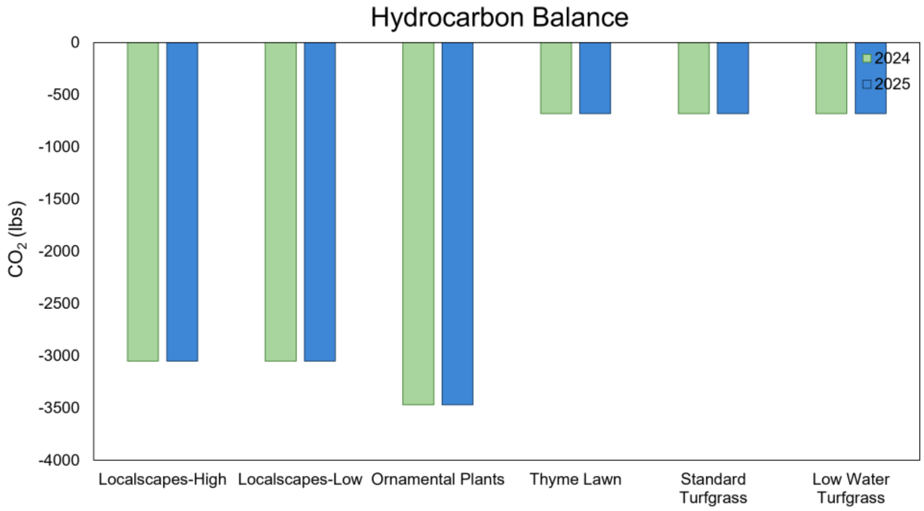

Figure 5. Hydrocarbon balances of the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes in 2024 and 2025. Negative hydrocarbon balance indicates a CO_2 sink, meaning carbon is being sequestered by the landscape.

5. 30-Year Life Cycle Analysis

In addition to annual life cycle analyses conducted for 2024 and 2025, the research team applied the LLCA Tool to model a 30-year life cycle analysis for the six test landscapes (**Fig. 6**). The long-term, 30-year life cycle analysis of the experimental landscapes illustrates that each of the six landscape design approaches perform differently across economic and environmental dimensions.

The following Assumptions were used for model landscape comparisons.

Table 1. Initial assumptions for the LLCA Tool comparisons over a 30-year lifecycle.

Variable	Value	Unit
Interest Rate	2.0	Percent
Economic Life of Landscape	30	Years
Owner Supplied Labor	100	Percent
Hired Labor Rate	40.00	$/hour
Water Price	1.50	$/1000 gal
Utility Power/Electricity Price	0.08	$/kW-hour
Fertilizer Price	0.30	$/pounds N
Herbicide Price	147.62	$/pounds active ingredient
Insecticide Price	1,278.56	$/pounds active ingredient
Fungicide Price	2.38	$/pounds active ingredient
Carbon Offset Price	2.80	$/gallon
Summer Household Energy Use	5.00	$/1000 pounds CO_2
Winter Household Energy Use	870	kW-hour/month
Growing Season Length	760	kW-hour/month
Local Evapotranspiration	135	Days

There is no single landscape design that emerges as universally superior under all life cycle metrics. Rather, the results highlight meaningful tradeoffs that should be considered when landscapes are planned, evaluated, or incentivized at municipal or household scales.

The ornamental plant and thyme landscapes had the highest 30-year life cycle financial costs followed by the Localscapes™ -low and -high landscapes. The standard and low water turfgrass landscapes had the lowest life cycle financial costs (Fig. 6, Fig. 7). The ornamental plant and thyme lawn landscapes required the most labor over their life cycles followed by the Localscapes™ -low and -high landscapes. The standard and low water turfgrass landscapes required the least labor over their life cycles (Fig. 6, Fig. 8). While the ornamental plant landscape had the highest overall financial cost and labor requirements, these landscapes also sequestered the most carbon and required no energy for maintenance over their life cycles. This finding demonstrates the complexity inherent to the decision-making process around landscape choice.

Further demonstrating the complexity of landscape evaluation, standard and low water turfgrass landscapes had lower financial costs and required less labor hours but needed more water and energy input for maintenance compared to other landscapes. Compared to the standard turfgrass landscape, low water turfgrass landscape had the same low financial costs and labor hours as a standard turfgrass landscape but required less water (Fig. 6, Fig. 7, Fig 8.). Both turfgrass landscapes sequester carbon, despite higher energy needs.[7]

The hydrocarbon balance results reinforce the importance of accounting for carbon sequestration alongside emissions related to landscape management (Fig. 6, Fig. 9). Landscapes that include persistent plant materials and managed vegetation can be important sources of carbon sequestration, even when they require recurring energy inputs. Landscape designs that minimize vegetation may reduce some operational demands, but they also may forgo carbon sequestration and additional environmental benefits[8]. These distinctions further demonstrate that the six landscapes reflect a spectrum shaped by species selection and management strategies.

In general, water and landscape professionals should consider the purpose of a landscape (i.e. functional and aesthetic quality) in addition to the maintenance resource requirements when choosing a type of landscape to install. In certain situations, such as public parks or gardens, a landscape's functional or aesthetic components may be more important than considering the landscape's life cycle financial or labor requirements.

The following figure shows the relative 30-year lifecycle resource requirements of each landscape type. The figure allows you to compare resource requirements across all the landscapes, but it does not provide actual values.

[7] Energy needs for turfgrass landscapes were for mowing via a battery-powered mower.
[8] Environmental benefits may be cooling, stormwater runoff management, water quality management, and aesthetics.

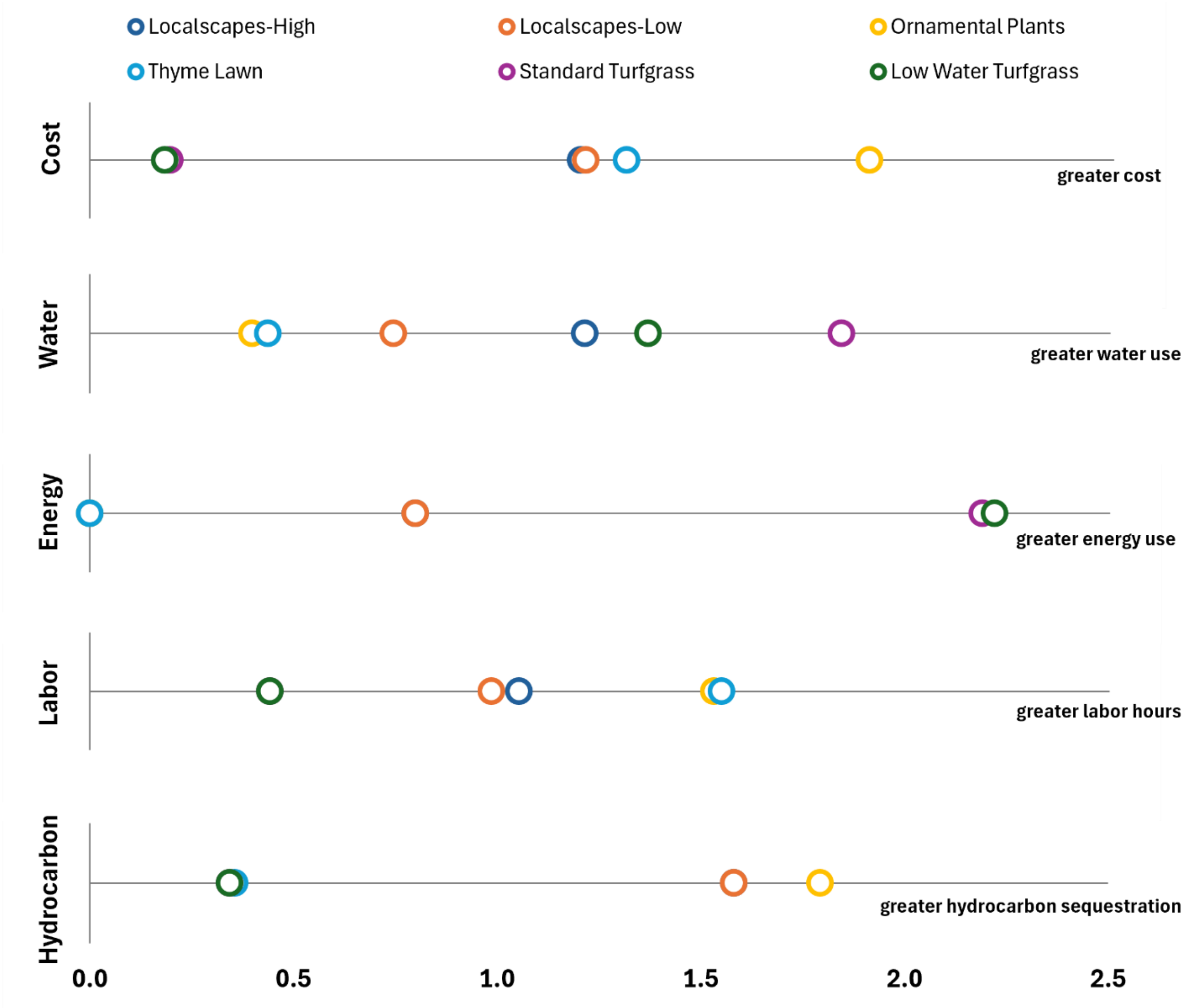

Figure 6. The relative lifecycle resource requirements of all six landscapes across five variables. Each landscape is represented as a point and plotted along the seven resource lines. All landscape data represented on this figure are relative to the other landscapes. Values were calculated by taking the average resource requirement across all six landscapes and dividing the resource requirement of each landscapes by the average. A value of 1.0 is equal to the average resource requirement across all landscapes for a 30-year lifecycle. If a landscape has a value less than 1.0, then it is less than the average and if has a value greater than 1.0 it is greater than the average.

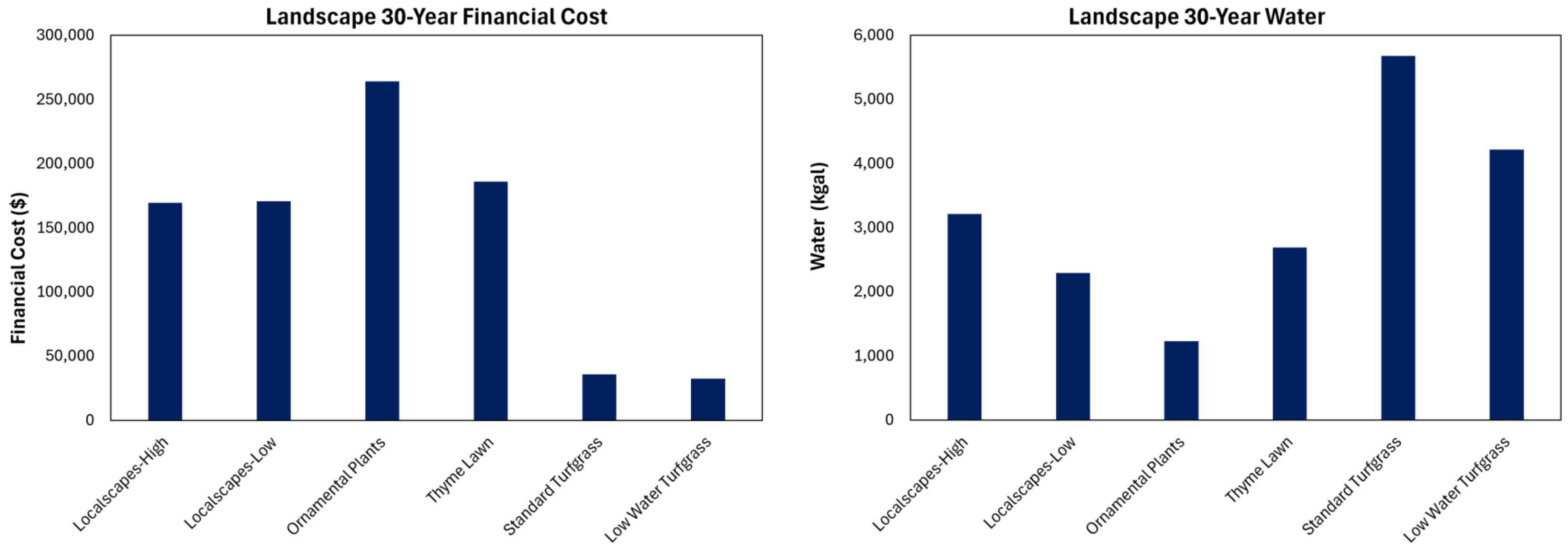

Figure 7. Total financial costs and water use related to the installation, management, and maintenance of the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes over a 30-year life cycle.

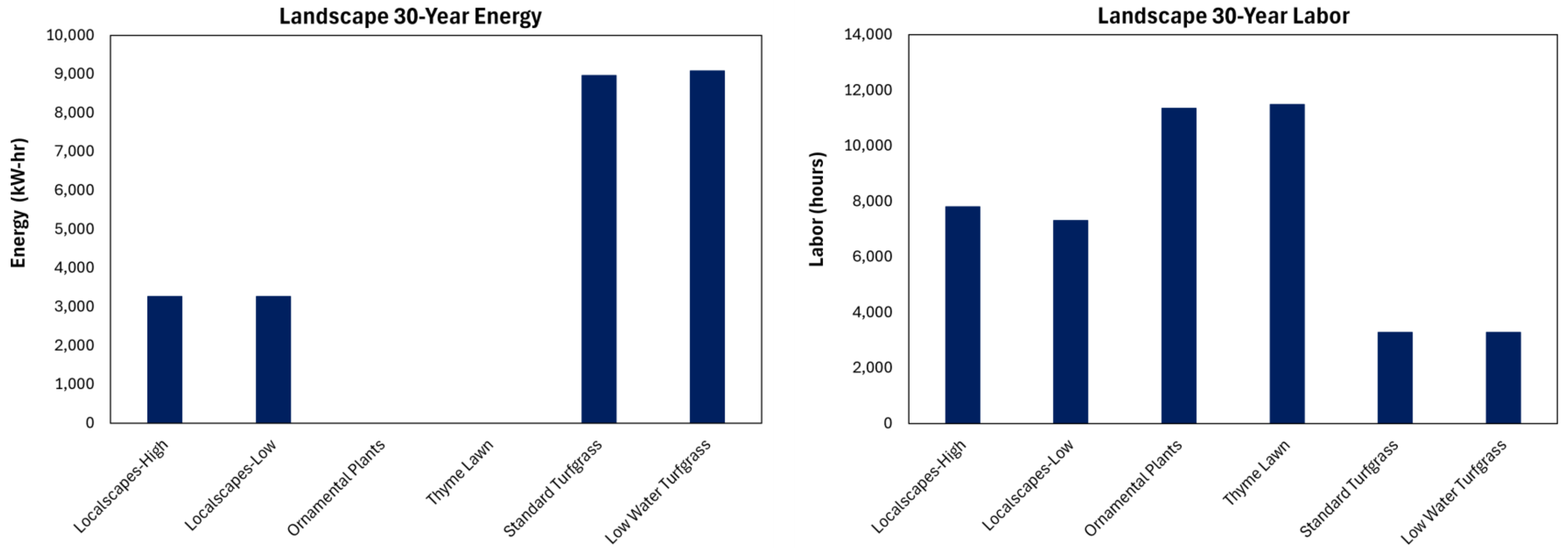

Figure 8. Total energy use and labor hours related to the installation, management, and maintenance of the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes over a 30-year life cycle.

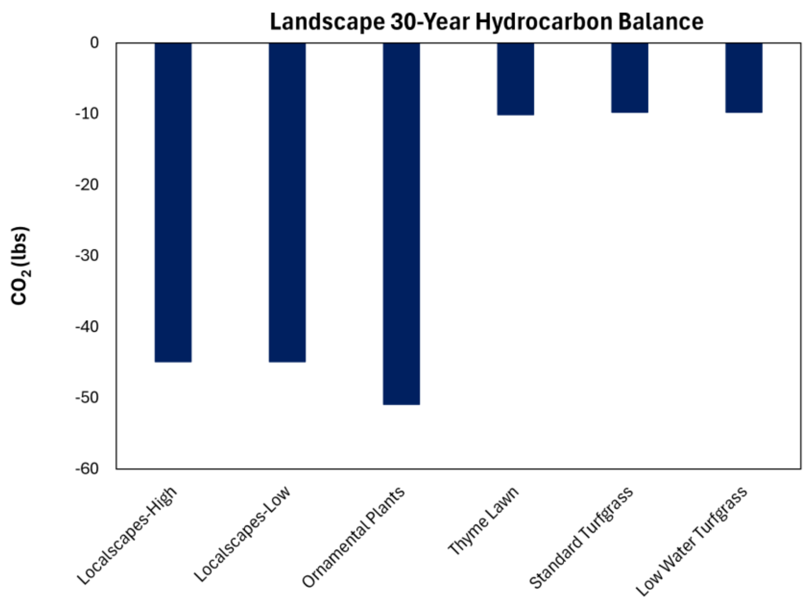

Figure 9. Total hydrocarbon balance related to the installation, management, and maintenance of the Localscapes™-high, Localscapes™-low, ornamental plant, thyme lawn, standard turfgrass, and low water turfgrass experimental landscapes over a 30-year life cycle.

Overall, the 30-year life cycle analysis demonstrates that landscape performance should not be evaluated using single-factor metrics such as cost or irrigation volume alone. The ways in which cost, water, labor, energy, and carbon outcomes interact and vary by design and site function should be considered to meet community needs and mitigate potential unintended negative consequences. Communities will achieve better long-term outcomes when landscape policies and incentives recognize these system-level tradeoffs and support site-appropriate solutions rather than prescriptive "one-size-fits-all" approaches.

5. Case Study Lessons and Implications

One important lesson from this case study is that urban landscapes can function as infrastructure systems. The test landscape designs provided real-world data to inform and validate the LLCA Tool. Of these six landscape designs, no single landscape outperformed its counterparts across all measured metrics in the model. Ultimately, the performance[9] of a landscape depends on intended use, design, materials, maintenance, and time. Evaluating urban landscapes through a life cycle lens provides a more accurate basis for long-term planning and investment decisions.

For water and landscape professionals, preliminary findings suggest that landscape policies focused exclusively on reducing irrigation demand may overlook opportunities to enhance climate resilience and deliver long-term environmental benefits. For example, vegetative landscapes reduce urban heat-related risks and this variable will be added to the model in future iterations.[10] Irrigation efficiency to support water conservation is a fundamental component of environmental resilience; however, water and landscape professionals should consider additional environmental benefits when planning and implementing outdoor water use conservation programs. Integrated evaluation tools that consider multiple resource flows can help balance water conservation goals with additional livability, environmental, and public health outcomes.

6. Conclusion

This case study shows the value of applying a life cycle analysis framework to urban landscapes. The differing resource requirements across the six landscapes demonstrate that no single landscape type is superior over a 2-year and a 30-year life cycle. The decision on optimal landscape type is dependent on intended use, available resources, and desired benefits and outcomes.

By treating green spaces as beneficial infrastructure and evaluating them comprehensively, water and landscape professionals can make more informed, defensible decisions about landscape design and management, as well as the rebate and incentive programs that drive ornamental landscape change. As natural resource pressures intensify, such approaches are increasingly important for aligning water efficiency, climate resilience, and community well-being.

[9] Performance defined as optimizing financial costs, labor, energy input, and maintenance to reduce water needs, increase hydrocarbon sequestration, and maximize environmental benefits of a landscape.
[10] Preliminary results from 2024 confirm that all vegetative landscapes reduce heat.

References

Rosenberg, David, Kelly Kopp, Heidi Kratsch, Larry Rupp, Paul Johnson, and Roger Kjelgren. 2011. Value landscape engineering: Identifying costs, water use, labor, and impacts to support landscape choice. Journal of the American Water Resources Association. 47:635-649. DOI: 10.1111/j.1752-1688.2011.00530.x.