Assessment of Embodied Water Impacts for Landscape Architecture Strategies: A Life Cycle Assessment Approach

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ABSTRACT

Addressing the pressing issue of water scarcity and environmental impact, this research investigates the embodied water impacts of landscape architecture strategies. Employing life cycle assessment (LCA) and water footprint methodologies, the study explores hardscape, vegetation, and building elements within urban landscapes. Through a case study of the Bauer Wurster Hall East Courtyard at UC Berkeley, various landscape design scenarios are analyzed for their embodied water impacts. The findings reveal large differentials in embodied water between scenarios. The original site design showcases an embodied water total of 1440 kL, while the remodeled version amplifies to 5820 kL. Notably, concrete and steel emerge as primary contributors to embodied water, despite their relatively low mass proportions on-site. Concrete paving, in particular, demonstrates a significant impact, outweighing other paving materials like asphalt and brick. The findings emphasize the need for informed decision-making in landscape architecture, considering both operational and embodied water impacts. The observed increase in embodied water post-remodeling highlights the necessity for sustainable design choices, especially concerning material selection. Future research directions could focus on refining embodied water analyses, including vegetation impacts, and validating regional data sources. By integrating these insights into practice, landscape architects can steer towards more sustainable and water-efficient design paradigms, crucial for mitigating water scarcity and bolstering environmental resilience in urban landscapes.

KEYWORDS

Embodied water, landscape architecture, life cycle assessment, sustainable design, water footprint

INTRODUCTION

The escalating and uncontrolled utilization of Earth's natural resources, including raw materials, water, and energy, is actively diminishing the planet's natural capital (Giljum et al. 2009, Aziz et al. 2021). Simultaneously, the utilization of these resources for various processes is accompanied by emissions and environmental impacts, exacerbating climate change and further intensifying environmental challenges in our ever-growing urban environments. Energy, water, and carbon dioxide (CO_2) influence urban sustainability. Building construction activities use 16% of global water, 33% of raw materials, and nearly half of energy (Horvath et al. 2004, Dixit et al. 2017). Significant research has been carried out to minimize building environmental impacts, focusing on energy use and more recently greenhouse gas emissions (Zeng and Chini 2017). As we shift towards more sustainable developments, operational impacts have decreased with new technologies and innovations, increasing the share and significance of building embodied impacts (Martin et al, 2020).

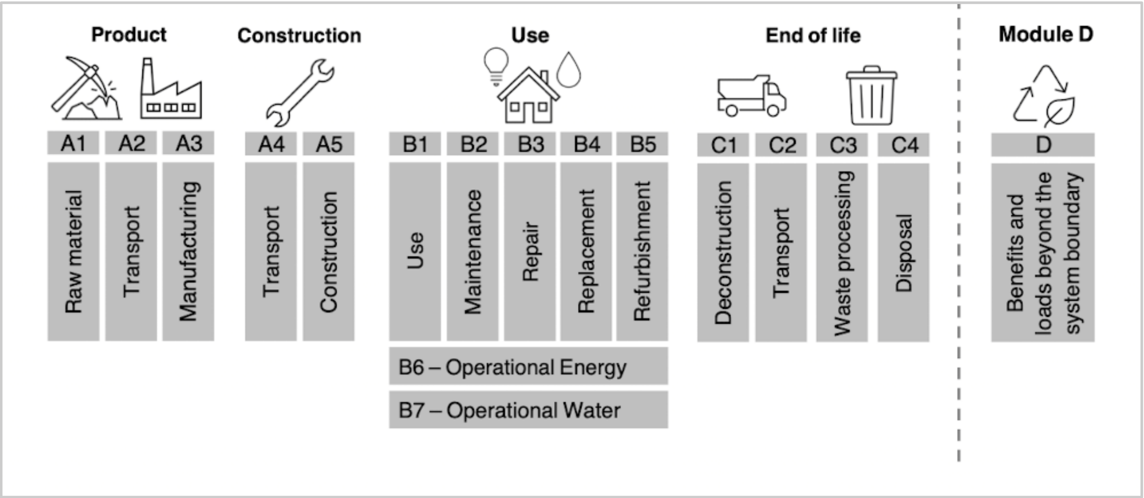
At both global and regional scales, water resources have changed due to climate change and increased water consumption. The total amount of water on earth is approximately 1,400 million km^3, of which only 200,000 km^3 (less than 1%) is available for human consumption (Amado and Baroso 2013). It is projected that half of the world's population could be living in areas faced with water scarcity as early as 2025 (UNICEF). These concerns are exacerbated by increased water consumption for industrial use, including manufacturing and construction within the building sector. As the building construction sector propels economic and social development, its substantial demand for freshwater results in significant environmental consequences, driven by the energy-intensive processes involved in water management (Mannan and Al-Ghamdi, 2020).

In recent years, global water security, increase in annual per capita water consumption, and increasing costs for water supply and sewerage treatment have created an imbalance between the supply and demand of water (Mannan and Al-Ghamdi 2020). Additionally, increased drought in urban areas such as California has incentivized consumers to reduce their water impacts (Petek 2024). These concerns highlight the need for sustainable water management. Several solutions have been implemented to reduce water consumption at the operational stage. Water-efficient appliances and services such as low-flush toilets, grey-water recycling, and drought-resistant landscaping are common solutions that occur during the operation of the building (US Department of Energy, 2010). However, it is important to consider the entire life cycle of the building. A viable strategy is drawing attention to the embodied water impacts of building construction and finding strategies to reduce its impacts.

Water use in the built environment

Due to the depletion of freshwater resources, there has been shifting attention to water use in the built environment in recent years. Efforts to reduce water demand and improve water efficiency have been made through the operational stage of the water consumed directly by a building's occupants (Crawford and Pullen 2011). These measures have significantly reduced water usage, though building construction activities continue to consume significant amounts of freshwater (Stephan and Crawford 2014). Building construction requires two types of water: embodied and operational. Embodied water is the freshwater used to produce raw materials for the building throughout the supply chain. It can be either direct (e.g., aluminum manufacture) or indirect (e.g., water for administration staff that manages the manufacturing process) (Stephan and Crawford 2014). Embodied water can be further classified into initial and recurrent embodied water. Initial embodied water is the sum of all embodied water during the first stage of construction, and recurring embodied water is the water required for maintenance materials during the use stage (Stephan and Crawford 2014). Operational water is the water consumed during the operation of buildings (Stephan and Crawford 2014). (Figure 1)

Figure 1. Life Cycle Stages adapted from EN 15978 (2011).



Embodied water accounts for 46% of total housing water demand (Crawford and Pullen 2011). Therefore, reducing the water footprint of buildings at all life cycle stages is an important objective for future research (Assadiki et al. 2022). Most research efforts have focused on water consumption during the operational stage of the building. Despite this, it is imperative to investigate the water impacts during the manufacturing and construction stages of the products to gain a holistic view of the total water usage. Generally, embodied water having any practical water policy value has been dismissed or ignored (Hannan 2011). Though operational water impacts have decreased due to improved efficiency and reduced consumption, it does not obviate the large water volume used during production. The physical water content of a product is typically a minute fraction compared to the embodied water content. For example, concrete is an integral material for building construction. Miller (2018) found that concrete production was responsible for 9% of global industrial water withdrawals in 2012. To put embodied water into this perspective, one cubic meter of 32 MPa concrete, commonly used for paving, has an embodied energy content of 5.81 GJ and embodied water of 13.1 kL (Treloar and Crawford 2010). As seen in Figure 2, materials with high embodied carbon content, such as concrete, also have high embodied water.

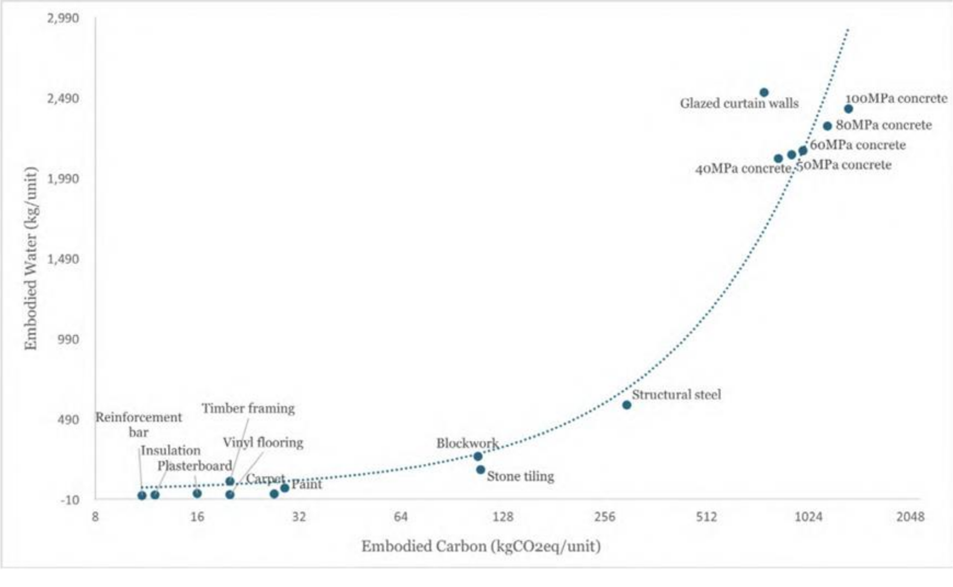


Figure 2. Embodied water and carbon of common building materials (Slattery 2023)

Embodied water of landscape architecture

As the field of embodied water expands within the built environment, the focus has been primarily on buildings. The embodied water of our urban landscapes is severely understudied. To have a comprehensive understanding of sustainability within the built environment, we must consider the intricate relationship between the Whole Building Life Cycle Assessment (WBLCA) and embodied water for all aspects of the built environment. Through the lens of landscape architecture, embodied water accounts for the water to produce the raw materials, including hardscapes such as brick and concrete, vegetation and organic material, irrigation systems including piping, and electrical systems, etc. The embodied water of vegetation refers to the total amount of water used throughout the entire life cycle of the plant, including its growth, maintenance, and associated processes such as planting and transplanting. This differs from the operational water of vegetation, which is the day-to-day water requirements for the maintenance and growth of plants, such as watering the lawn.

Urban green spaces and landscapes weave the urban fabric between buildings. On a daily basis, people are exposed to the landscape architecture attached to buildings more than the inside of the building itself. Therefore, we must draw attention to the landscapes when assessing the environmental impacts of the whole building. With increasing efforts to increase open space in our built environment, we can begin to assess the energy and water impacts of them, similar to the building. Urban greening has significant water footprints, largely attributed to operational use through maintenance (Nouri et al. 2019). However, little is known about how the green space’s embodied water contributes to its total water footprint. As there are efforts for low-drought landscapes, we have to assess if the water savings through the intervention outweigh the embodied water of the renovation. Despite its importance, there is no existing standard to quantify embodied water of the landscape architecture strategies within our built environment.

Aim and scope

The main goal of this study is to create a methodology to quantify the embodied water impacts of landscape architecture elements. This goal will be reached by pursuing the following three objectives: (1) Understand the existing resources to measure embodied water for the built environment, focusing on landscape architecture and green infrastructure. (2) Using LCA and water footprint methods, develop a methodology to quantify embodied water impacts of landscape architecture elements. (3) Analyze and compare the embodied water impacts of retrofitting an existing landscape design through a case study. Through these methods, I expect to have a better assessment of the impacts landscape retrofits have on embodied water.

LITERATURE REVIEW

Existing landscape architecture LCA tools and methods

Though research has focused on buildings, there are new studies that begin to investigate other aspects of the built environment, namely landscape architecture. Recent studies have provided methodologies for LCA within the landscape architecture field following EN 15978 and ISO 14040 (Lin 2021). The role of landscape in the climate crisis is becoming a wider debate. It is imperative to consider the integrated landscapes within the infrastructure of our cities (Nikologianni and Albans 2023). There have been emerging tools in the last decade that begin to quantify environmental impacts such as embodied carbon and LCA of landscape systems. These include Pathfinder, Landscape Carbon Calculator, Carbon Conscience App, i-Tree, Precinct Carbon Assessment (PCA), and Embodied Carbon in Construction Calculator (EC3) (Nikologianni and Albans 2023). The methods used for the tools can be transferred to the quantification of the embodied water impacts as well. Since embodied impacts are calculated within similar frameworks (i.e. process-based, input-output, hybrid), there is significant potential to apply the same principles of these tools to measure embodied water. It is important to note that the application of LCA within landscape architecture is a continually growing field. With further research, the tools will become more robust and comprehensive. This study would contribute embodied water impacts to a similar framework.

Embodied water-energy relationship

Embodied energy is defined as the direct use of energy in onsite and offsite construction and installation activities and indirect energy use that comes with the embodied energy of each material used in the facility (Dixit and Singth 2018). The definitions of embodied energy and embodied water have similarities as they discuss similar topics within adjacent fields of energy and water. Within our current infrastructure, water and energy are inextricably linked. Power generation requires water, both directly (e.g., cooling water) and indirectly (e.g., embodied water involved in the life cycle of fuel). Meanwhile, water supply requires power for treatment, delivery, sewage disposal, and other infrastructure (Fisher and Flanagan 2017). Figure 2 depicts the correlation between embodied carbon and water at a logarithmic scale.

A comprehensive sustainability assessment of our built environment necessitates a thorough understanding of both embodied energy and water and their interdependencies. For landscape architects, the imperative lies in reducing all embodied impacts to mitigate water and energy consumption. By addressing the interdependencies of these impacts, we can develop strategies that not only enhance the efficiency and resilience of our landscapes but also contribute to a more sustainable and interconnected built environment. This holistic approach acknowledges the intricate relationship between energy, water, and infrastructure, paving the way for informed decision-making for environmental design and construction practices.

METHODS

Study site

The site used for the case study was the East Courtyard at Bauer Wurster Hall at UC Berkeley. Situated in Berkeley, California, the site is located in a temperate Mediterranean climate. As California has experienced severe water drought, it is insightful to examine the embodied water impacts of a landscape design. Originally constructed in 1962, the East Courtyard underwent a redesign and remodeling in 2003, following a design competition won by Patricia O’Brien (O’Brien 2003). The site is an exemplary site for landscape architecture strategies, including hardscape with brick paving, concrete steps, and vegetation including a grass lawn, shrubs, and trees. Additionally, the site has several design elements contextual to landscape architecture. The materials on site can be categorized into the following: hardscape, vegetation and organic material, irrigation, and electric systems.

Embodied water information was gathered for two scenarios: 1) the original design from 1962, and 2) the present-day courtyard design adapted from O'Brien's winning design. These two scenarios provided a real-life comparison of embodied water for each retrofit, assessing the impact of redesigns on embodied water.

The study examined the embodied water impacts of each material within the courtyard for each scenario, as well as the total embodied water of the courtyard. Material quantity and information were acquired from as-built construction documents for the two scenarios that were accessed through the Environmental Design Archives at the College of Environmental Design at UC Berkeley. From the findings in the literature review and method development, the case study validated the method framework, verifying its ability to measure embodied water for landscape architecture.

Figure 3 indicates the study site boundaries. Since the site has undergone a renovation, we did not consider pre-existing conditions for each scenario. For example, the northwest stairway was only considered for the initial construction scenario (Scenario 1) of the study site. The study site bounds were identical for each scenario for accurate comparison.

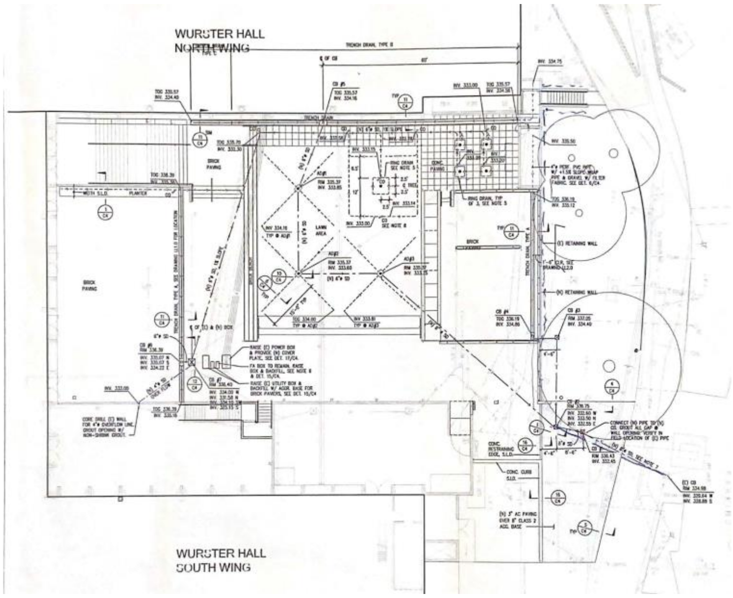


Figure 3. Study site boundaries of Bauer Wurster Hall East Courtyard (Environmental Design Archives)

Embodied water

Embodied water quantification methods can vary by specificity, standards, and frameworks. LCA methods were used to calculate embodied water and other water consumption impacts (Dixit and Kumar 2022). Within the field of LCA, there exist three main approaches: Process-based, Input-output-based, and hybrid-based methods. In a process-based method, specific data (i.e. energy or water use) is collected to compute the embodied impacts at each life cycle stage. Process-based utilizes bottom-up methods that require comprehensive databases for each stage, making it tedious and resource-intensive. Input-output (IO) based methods use national macroeconomic data. Utilizing a top-down approach, the IO-based method is faster and more efficient, but it is also a broader approach (Dixit and Kumar 2022). Lastly, the hybrid approach combines elements of the process-based and IO-based methods. Hybrid methods have been developed to provide a more reliable assessment. Dhingra and Choudhuri (2018) found that an input-output hybrid (IOH) analysis method increases the reliability and completeness of an embodied water analysis of a typical commercial building by 40-50% over traditional analysis methods.

The methodology illustrated by Stephan and Crawford (2014) was used for this study. Figure 4 depicts the research framework used for this study. First, a life cycle inventory was developed to represent the materials and processes included within the system boundary for this study. The LCI was developed using archive as-built drawing sets of the study site.

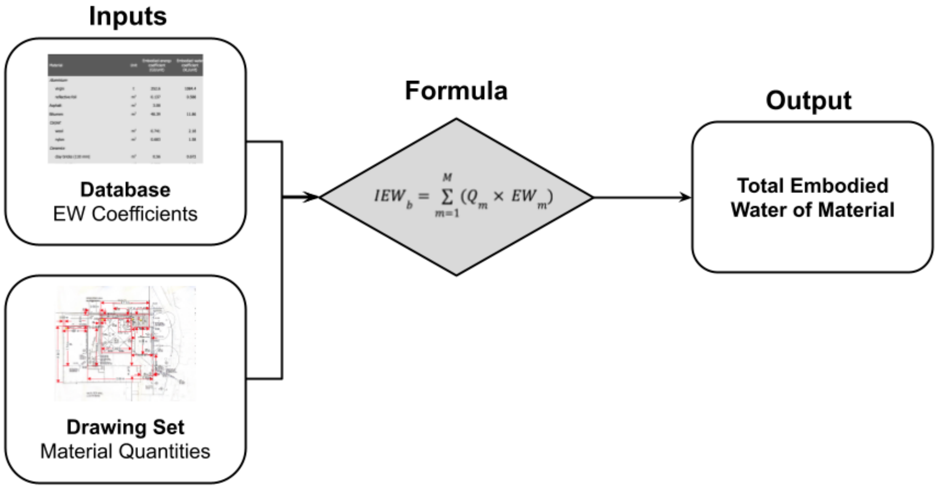


Figure 4. Methodology framework for embodied water quantification. Adapted from Stephan and Crawford 2014.

The study primarily employed an embodied water of construction database by Treloar and Crawford (2010). While the library of embodied water coefficients has expanded for the buildings sector, there were no existing libraries for vegetation and landscape elements at the time of this study. For materials lacking embodied water coefficients, I consulted Environmental Product Declarations (EPDs). ISO standard 14025 defines EPDs as declarations that quantify environmental information on the life cycle of a product, enabling comparisons between products fulfilling the same function. Although EPDs provided total freshwater content for each life cycle stage, they did not constitute the "water footprint" of the product due to the absence of water use information from different geographical locations (EPD International, n.d.). Given the scarcity of existing databases and information, the study utilized a combination of embodied water coefficient databases and EPDs.

The life cycle inventory material quantities and embodied water coefficients were input into our framework:

$$IEW_b = \sum_{m=1}^{M} \square \, (Q_m \times EW_m)$$

IEW_b is the initial embodied water of the building in kL; Q_m is the quantity of material m in functional units (e.g. ton, m^3); and EW_m is the hybrid embodied water coefficient of material m in kL per functional unit.

The output, IEW_b, is the total initial embodied water of each material. With these embodied water quantities, I calculated the embodied water of product categories of hardscape, irrigation, and vegetation. Total site embodied water was also documented for the multi-scenario case study comparison.

System Boundary

This study utilized a life cycle approach to quantify the embodied water of our study site. The developed framework followed a cradle-to-gate system boundary, including water requirements for raw material extraction, material processing, transport and manufacture, and construction. The operation and end-of-life stages were out of the scope of this study.

RESULTS

The embodied water requirements of the case study included those associated with the production and construction stages for building materials. The total embodied water of the original site design, Scenario 1, was 1440 kL. The embodied water normalized by area was 1130 kL/m^2. The total embodied water of the site was disaggregated into embodied water by material (Figure 5a) and embodied water by landscape element (Figure 6).

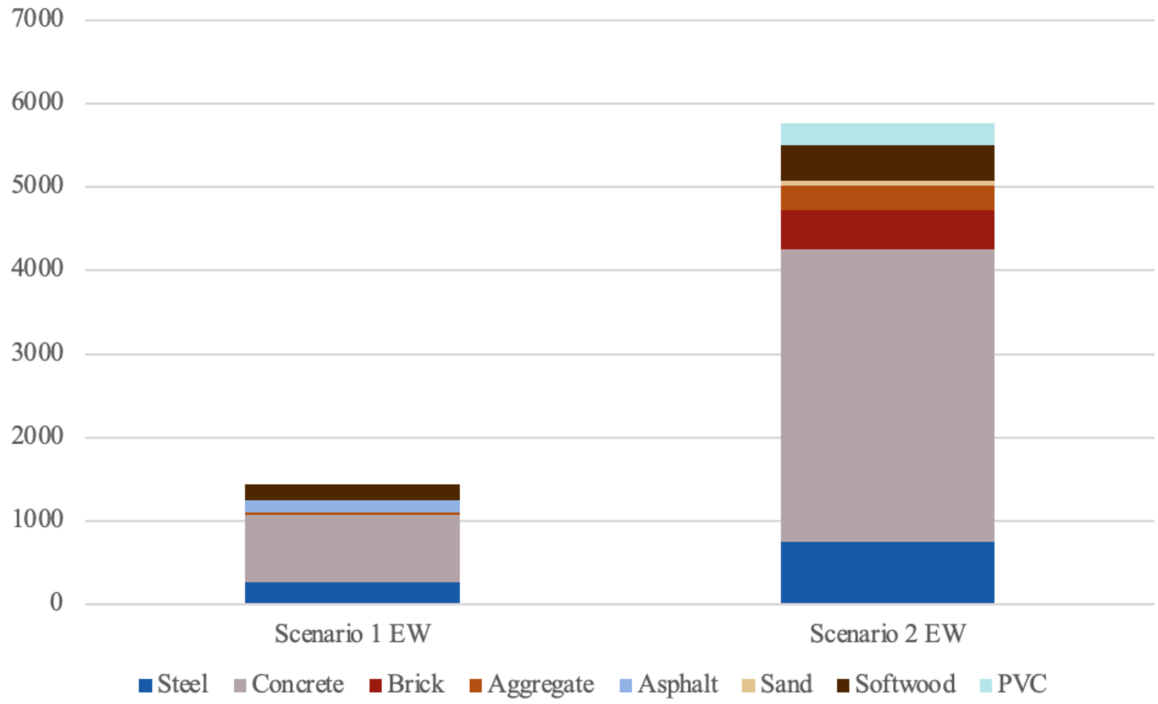


Figure 5. Embodied water of materials for the site. (A) Scenario 1 Original Site from 1962, (B) Scenario 2 Remodeled Site from 2003 by Patricia O'Brien.

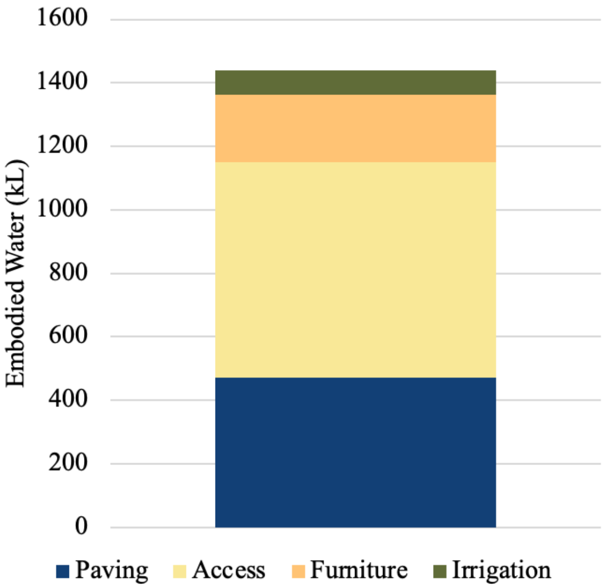


Figure 6. Scenario 1 Embodied Water of Landscape Elements

Table 1 displays the total embodied water by elements for Scenario 1. The largest contributors to EW were the stairs, followed by concrete paving, furniture, and asphalt paving. The embodied water of materials was compared to their respective mass of material in Table 2.

Table 1. Embodied water by landscape architecture element for Scenario 1

Landscape Element	**EW (kL)**	**% Total EW**
Asphalt Paving	146	10%
Stairs	681	47%
Bench	212	15%
Concrete Paving	324	23%
Irrigation	76	5%

Table 2. Embodied water and mass comparison for Scenario 1

Material	**EW (kL)**	**Mass (tonnes)**
Steel	264	2.7
Concrete	803	141.1
Aggregate	37	79.9
Asphalt	146	114.1
Softwood	189	4.7
Total	**1440**	**342.4**

The total embodied water of the remodeled site design, Scenario 2, was 5820 kL. The embodied water normalized by area was 4575 kL/m^2. The total embodied water of the site was disaggregated into embodied water by material (Figure 5b) and embodied water by element (Figure 7). The embodied water of materials was compared to their respective mass of material in Table 1. (Table 3, 4)

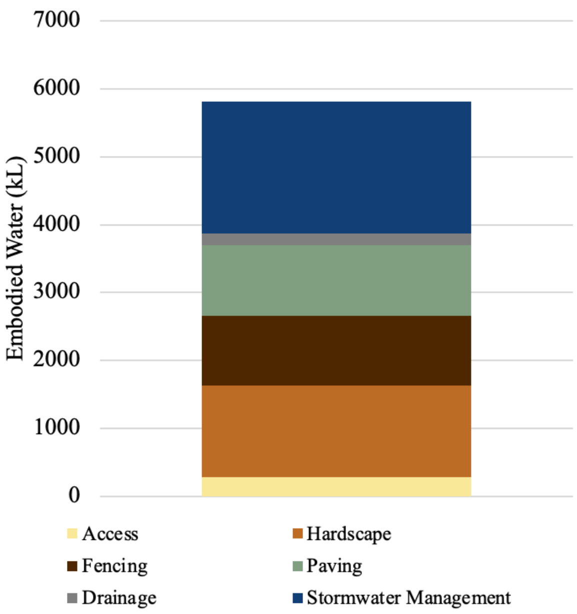


Figure 7. Scenario 2 Embodied Water of Landscape Elements

Table 3. Embodied water and mass comparison for Scenario 2

	Scenario 2 EW	**Scenario 2 Mass**
Steel	747	8
Concrete	3505	642.2
Brick	478	137.3
Aggregate	284	483.3
Sand	65	30.4
Softwood	426	8.5
PVC	253	0.7
Total	**5758**	**1310.4**

Table 4. Embodied Water by landscape architecture element for Scenario 2

Landscape Element	**EW (kL)**	**% Total EW**
Trench Drain	1661	28.6%
Wood Fencing	895	15.4%
Brick Paving	643	11.1%
Planter at Terrace	425	7.3%
Concrete Paving	400	6.9%

Step Wall	315	5.4%
Curb Wall	302	5.2%
Brick Wall	297	5.1%
Piping	188	3.2%
Egress Steps	150	2.6%
Guardrail	129	2.2%
Brick Steps	117	2.0%
Area Drain	105	1.8%
Catch Basin	97	1.7%
Subdrain	44	0.8%
Piping	21	0.4%
Retaining Wall	19	0.3%
Handrail	11	0.2%
Vegetation and Organics	Out of Scope	Out of Scope

Generalized Embodied Water Findings

The embodied water totals of the main elements are listed in this section. The embodied water values were normalized by their respective functional units in Table 5. These values can be used as a generalized embodied water for specific building elements for future designs.

Table 5. Embodied Water Generalizations for Landscaping Elements

Landscaping Element	Embodied Water	Functional Unit
Brick Paving	0.34	kL/m2
Asphalt Paving	0.2	kL/m2
Concrete Paving	4.41	kL/m2
Guardrail Fencing	4.19	kL/m
Trench Drain	55.95	kL/m

DISCUSSION

The remodeling of the study site contributed significantly to the total embodied water of the site. The addition of new elements, such as brick paving, fencing, and irrigation contributed largely to the increase of embodied water. The embodied water from Scenario 1 to Scenario 2 has an increase of 4380 kL, or 282%, as seen in Figure 4. Additionally, the material breakdown differs from Scenario 1 to 2. Though material masses have increased, concrete and steel continued to be the largest contributors to embodied water of both scenarios.

The elements with the largest embodied water impact was the concrete steps for Scenario 1 and the trench drain for Scenario 2. Both of these elements are comprised almost entirely of steel and concrete. Paving materials such as brick and asphalt followed in embodied water quantity, largely attributed to their quantities. As highlighted in Table 2 and 4, the mass of material does not directly translate to the embodied water of a material. Though materials such as aggregate and brick contributed to majority site mass, their embodied water impacts were significantly smaller than concrete and steel. Steel had the smaller mass of material for both Scenario 1 and 2 with 2.7 tonnes and 8.0 tonnes—its embodied water impacts were 18.3% and 13.0% of the total embodied water impact, respectively.

DISCUSSION

The total embodied water associated with the site for Scenario 1 and Scenario 2 were estimated at 1440 kL and 5820 kL, respectively. These values are compared with household water consumption to provide context and perspective. The average California household's annual water consumption is approximately 202 kL (Mount et al. 2023). For Scenario 1, the embodied water quantity was approximately 7.1 California Households' yearly water consumption. The EW of Scenario 2 equates to approximately 27.2 California Households' yearly water consumption. According to the EPA WaterSense Water Budget Tool, the average operational water for a site of equal area is estimated to be 2436 kL/year. The embodied water for Scenario 1 equates to approximately 0.61 times of the operational water use, while Scenario 2 is 2.45 times the operational water.

The highest impact materials for both scenarios were concrete and steel. Concrete is used in several forms throughout both sites, including walls, paving, and drainage. The two materials appear concurrently within the site as concrete requires steel for reinforcements. Referring to Table 3, the mass of steel on-site only comprises 0.8% and 0.6% of mass for Scenario 1 and 2, respectively, though it accounted for 18.3% and 13% of the total embodied water on site. On the other hand, paving materials, such as asphalt and brick paving, though comprising a larger proportion of mass, have a smaller embodied water footprint than concrete and steel, accounting for 10% and 11.1%, respectively. The embodied water of steel and concrete is largely attributed to the A1-A3 stages of the embodied water life cycle. Concrete has an embodied water coefficient of 13.1 kL/m3 or 5.46 kL/tonnes. Steel has an embodied water coefficient of 98.64 kL/tonnes. Asphalt has an embodied water coefficient of 3.08 kL/m3 or 1.33 kL/tonnes, and brick has a coefficient of 0.672 kL/m2 or 37.33 kL/tonnes. Considering these coefficients is crucial as they play a pivotal role in determining the overall embodied water content of each material, effectively balancing the impacts of both material use and embodied water.

The types of pavings used have significant variations in total embodied water. Figure X lists the embodied water of the three pavings used in both scenarios. Concrete paving has the highest embodied water per meter square, followed by brick and asphalt paving. When selecting paving for future design, it is imperative to consider the embodied water impacts of the materials used, as they can drastically alter the total embodied water of the site. When making decisions about pavement selection for future designs, it is crucial to factor in the embodied water impacts of the materials chosen, as these considerations influence the overall embodied water of the site. Additionally, materials have varying service lives that influence the recurring embodied impacts of the site when paving materials are repaired, maintained, and replaced throughout the operation of the site. However, it is equally important to balance these environmental concerns with aesthetic design choices, ensuring that the chosen pavements not only minimize environmental impact but also contribute to the desired visual and experiential qualities of the space.

Future Work and Limitations

Future research will be carried out to improve the robustness of the embodied water analysis. Several variables will affect the results due to limitations and assumptions. First, vegetation embodied water impact was unavailable within the scope of this study due to the unavailability of existing vegetation embodied water databases. The next steps will produce embodied water coefficients for the site vegetation and organic materials.

Furthermore, the embodied water coefficients used for this study were from Crawford and Treloar 2010, which used a hybrid input-output model from Australia. The embodied water of Australia differs from our site in California, US due to several factors, including local water availability, regional differences in production practices, resource management, and compliance with local regulations. Due to the lack of available local embodied water databases, the usage of the Crawford and Treloar database was used, providing both quality and reliable data for the site. Future research and validation efforts will be conducted to compare the Australian data with local data once available.

The drawing sets used for both scenarios were sourced from the Environmental Design Archives. While these archives provided valuable information for the scenarios, there were some limitations in the data that impacted the analysis. In particular, the drawings for Scenario 1 were incomplete, missing specific details such as cross sections and certain architectural elements. To address these gaps, assumptions had to be made based on the available information from Scenario 2. For example, in the absence of clear cross-section details in Scenario 1, the design of stairs and other features was assumed to follow the patterns and dimensions indicated in the drawing sets from Scenario 2. This approach allowed for continuity and consistency in the analysis but also introduced potential inaccuracies due to the need for estimation. Further investigation or additional sources of data may be required to validate the assumptions made and provide a more comprehensive assessment of Scenario 1.

The site and system boundaries have been carefully delineated to facilitate scenario comparison. Following the methodology outlined by Stephan and Crawford (2014), a defined system boundary of cradle-to-operations (A1 to B7) was applied consistently across both scenarios. Furthermore, despite undergoing remodeling, the site maintains consistent boundaries, ensuring reliable comparison of values and impacts for thorough analysis.

CONCLUSION

This study has shown that embodied water has a significant impact on the total life cycle water of landscape architecture. Remodeling of the study site increased embodied water by 282%, largely attributed to the addition of new design elements. Concrete and steel are the highest embodied water impact materials for both scenarios. There is a large variation in embodied water impacts of different landscape elements, with stormwater management and drainage being significant contributors in the presence of green space.

The findings presented in this study carry significant implications for various stakeholders involved in urban landscape management, including landscape architects, individual households, and landscaping manufacturers. By highlighting embodied water's substantial contribution to urban landscapes' overall water demand, this research underscores the importance of prioritizing water conservation efforts beyond just operational water use, particularly in irrigation practices. As we transition to a sustainable built environment, it is imperative to look beyond buildings and towards the landscapes that weave our urban fabric. Their significant water impacts must further be investigated to create a holistic sustainability assessment for our built environment.

Future research aimed at comparing operational and embodied water impacts will enable designers to make informed and conscious decisions to reduce water consumption across the entire life cycle of a landscape. Assessing the interplay between operational and embodied water is crucial for understanding the life cycle water demand in landscapes and the potential trade-offs between minimizing operational water use and embodied water. By conducting comprehensive assessments that consider both aspects, designers can develop strategies that optimize water efficiency and sustainability while ensuring the longevity and resilience of urban landscapes.

This research provides an example to evaluate various landscape architecture components in terms of their embodied water impacts. Its findings should be integral to future landscape architecture decisions, providing essential insights into the implications of different design choices on water conservation efforts. The future of landscape architecture must add future considerations of embodied impacts, including carbon, energy, and water. By incorporating these findings into decision-making processes, landscape architects can make more informed and sustainable choices, thereby contributing to the conservation of water resources for future generations.

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