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WEST HOUSTON
ASSOCIATION
Leadership in Quality Growth

Final Project Report: Analyzing Sustainable Solutions for Houston

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I. Executive Summary

As one of the most spacious and fastest-growing American cities in recent years, Houston has become a major attraction for various real estate and infrastructure developments due to its profitability and the feasibility of implementation.

The purpose of this report is to identify the financial benefits of sustainable initiatives to garner the support of Houston developers and incentivize them to prioritize sustainability efforts into their urban designs. As one of the West Houston Association's goals, overcoming this challenge faces the difficulty of involving not just environmental, but also economic, political and social factors that pose a myriad of obstacles along the way.

With this goal in mind, our team set out to determine the returns on investment (ROI) for various sustainable projects in and around Houston. Through our initial discussions with the West Houston Association, we narrowed down our investigation to focus on two or three specific initiatives, namely water treatment or reuse, energy conservation, and adaptive reuse or repurposing—which was directly inspired from our interest in the downtown POST Houston structure.

Our approach involved interviewing experts in various fields who were directly involved in the development of sustainable projects and could therefore speak to its benefits, impacts, as well as share any financial data such as capital investments and other costs. Through the data we collected in our semester-long investigation from various interviews, we determined that there were several potential developments that may interest the West Houston Association in starting future discussions with developers.

While the long term financial benefits are perhaps ambiguous at the start, energy can be significantly conserved by using geothermal exchange heating, ventilation and air-conditioning

(HVAC) systems in single or multi-family homes, generating a payback in roughly 7 years. Similarly, implementing underground water detention systems rather than the current overground system most of Houston's buildings implement may seem costly up front, but yields a payback within 7-8 years as well. A common feature among our investigated projects, therefore, is that they tend to have a higher capital investment, but generate greater profits than their conventional counterparts in the long term. Our hope is that the West Houston Association can utilize this narrative to market such sustainable developments as more profitable and ultimately more beneficial for our community and our future environment. Our research into adaptive reuse, however, provided less positive results. Our investigation showed that while potentially beneficial, this type of development is often risky and faces numerous challenges that are hard to quantify or measure.

II. Background and Project Approach

Sustainable solutions have clear environmental and social benefits on society. However, the financial benefits are not always evident, making it difficult to incentivize local developers to invest in sustainable infrastructure. The goal of our project is to determine the Return on Investment (ROI) for various sustainable infrastructure projects. Our team defined ROI as the number of years required to break even on the capital investment—the payback period. We wanted to simplify our ROI calculation using this method since the data we collected across the different projects varied in units and measurement. This allowed us to standardize the data across projects to create a clearer and more effective side-by-side financial comparison. In addition, we determined that this method of calculating ROI was straightforward enough to present to developers and create a compelling narrative, without the unnecessary confusions related to complicated financial data analysis.

To begin, we first reached out to professionals in different sectors of the sustainable industry. We learned about Houston’s Municipal Utility Districts (MUD) from Mr. Harry Thompson, senior attorney at ABHR LLP. He taught us about the utility system within MUDs and what they are (MUD 101). Our other contacts—Ms. Kathleen English, Ms. Noelle George, and Mr. Kirby Liu—were able to provide us with data and background information on their own unique experiences within sustainable infrastructure.

We first spoke with Ms. Kathleen English, a lead architect at English + Associates Architects, who introduced us to her infrastructure project, CoHousing Houston. We learned about integrated design and various components CoHousing Houston implements specifically. Ms. English shared architecture design layouts and financial data for geothermal energy and stormwater drainage that she envisioned to be implemented within the single or multi-family homes in this project. We then communicated with Ms. Noelle George, managing director of the WateReuse Association, a non-profit that aims to advocate, educate, and research water reuse. We learned from MUD 101 about the high costs of buying water from the city and recalled the solution of purple pipes, water that has been used and treated (Texas Rivers Protection Association, 2016). Finally, we interviewed Mr. Kirby Liu, the director of Lovett Commercial. Lovett Commercial developed POST Houston, an old US Post Office building redeveloped into a public space with many arts, entertainment, and foods for the Houston community to enjoy. Mr. Liu shared the benefits and challenges of adaptive reuse-repurposing an existing building.

From these interviews, we focused on sustainable infrastructure solutions that could be implemented at the individual level. We defined sustainable infrastructure as organizational structures that balance social, environmental, and economic elements and needs that are maintained over time.

III. Case Studies

a. CoHousing Houston

Cohousing is a collaborative and intentional living arrangement where individuals or families come together to form a close-knit community. In cohousing, residents actively participate in the design, development, and ongoing management of their shared living space. The community typically consists of private homes or apartments, complemented by shared spaces such as a communal kitchen, dining area, and common recreational areas. The goal of cohousing is to foster a sense of community, mutual support, and shared responsibilities among its residents. Decision-making within the community is often done through consensus, encouraging open communication and cooperation. Cohousing promotes a sense of belonging, encourages social interaction, and allows for the pooling of resources to create a more sustainable and interconnected way of living. It represents a modern approach to community living, emphasizing collaboration and the building of meaningful relationships among residents.

CoHousing Houston is a new housing development in the East End aimed at bringing this spirit of cohousing to the Houston area. It is being undertaken by David Kelley, the developer, and designed by Kathleen English of Kathleen English Architects. This project consists of 33 households with shared communal areas. Legally, it operates similarly to a condominium association and through institutions like a Homeowner’s Association (HOA), members can influence key design components of their living space. One of the priorities of the current members of CoHousing Houston was to incorporate sustainability into the design of the project. As such, Ms. English was brought on to use her expertise in sustainable design to make this an environmentally responsible and resilient place to live. Through an interview with her, we learned the development includes geothermal heating and cooling, solar panels, Energy-Star appliances, and a sustainable underground detention system for stormwater drainage. The way these different aspects of sustainable architecture are being used collectively in this project is referred to as integrated design.

b. ***WateReuse Association***

The WateReuse Association was first established in California in 1990. It then opened a branch in Texas in 2005 and has grown, but its missions have stayed the same: to advance United States laws and policies on water reuse and to advocate and educate about water reuse as a sustainable source of water. Through MUD 101, we were first introduced to purple pipes and reusing water for irrigation. Through Ms. George and her close contact Mr. David Batts, we understood the process of water reuse and gained access to some financial data to further decipher its sustainable impact.

Reusing water has various benefits. Financially, purchasing water from the city of Houston can become expensive. A solution to this is to recycle the water being used within a community. Water can be treated and reused for agriculture, potable, energy, etc., depending on the level of water treatment. Treated water can help water farms, be dispersed as drinking water for people, and help cool power plants. Recycling water used in a community helps prevent bayou sources from getting depleted and decreases the necessity of outsourcing water for a community. Furthermore, water reuse creates jobs as pipelines and treatment plants must be built and maintained. Ms. George shared that the value of reusing water is not limited to environmental and financial benefits, but also social benefits. It is important for water to be safe and healthy to consume for communities. Water reuse helps this as it keeps the water local and reliable as it is easy to track the source of community water.

c. POST Houston

POST Houston was reopened by Lovett Commercial in 2021 as an entertainment venue and community space. The building was first built in 1934 as a US Post Office building and redevelopment started in 2015. This building is an example of adaptive reuse. Mr. Liu taught us about some challenges he encountered during the development process of POST Houston. For instance, since Lovett Commercial was redeveloping the original building, some of the rooms and structures must stay the same to keep the history of the building. An example he provided was that certain rooms that were historically a woman's washroom or men's washroom must be used for the same purpose in the new refurbished design. Furthermore, adaptive reuse is so complex since each building is different. Therefore, financial benefits are difficult to measure depending on the building structure and historical elements. POST Houston inspired our research into adaptive reuse as a sustainable development strategy.

IV. Key Findings

a. Integrated Design

Introduction

Integrated design represents a holistic and collaborative approach that harmonizes various facets of a project to achieve sustainable and efficient outcomes. Essentially, this idea can be thought of as 1+1+1=5. This equation represents how different sustainable components can support each other, so the total monetary and environmental impact they have is greater than the sum of the individual parts. It emphasizes the interconnectivity of building components, recognizing that the collective impact of well-coordinated elements can surpass the benefits achieved individually. This methodology considers the entire life cycle of a project, promoting a comprehensive evaluation of sustainability factors from the project's inception. By involving stakeholders such as architects, engineers, environmental experts, and community members, integrated design fosters a multidisciplinary environment that encourages innovative solutions for minimizing environmental impact and optimizing resource efficiency.

One key aspect of Integrated Design Analysis involves meticulous consideration of site selection. This includes evaluating factors such as local climate, topography, and access to renewable resources to inform design decisions. Energy systems integration explores ways to synergize renewable energy sources and improve overall energy efficiency. For instance, solar panels strategically incorporated into building design not only generate clean energy but also serve as effective shading devices, reducing the reliance on traditional energy-intensive cooling systems. Water-related systems, another crucial element, encompass strategies like rainwater harvesting, stormwater management, and water-efficient landscaping. Integrating rainwater harvesting into the already mandated underground detention systems not only meets regulatory requirements but also enables cost-effective water reuse and conservation.

In addition to the examples provided, there are numerous other instances of integrated design in action. Building materials selection is a prime area where sustainability can be enhanced; choosing locally sourced, eco-friendly materials can reduce transportation costs and environmental impact. Emphasizing natural lighting not only improves indoor environmental quality but also lowers the need for artificial lighting, contributing to energy efficiency. Furthermore, the incorporation of green spaces within urban developments not only enhances aesthetics but also promotes biodiversity, mitigates heat island effects, and contributes to overall community well-being. In essence, integrated design encapsulates a comprehensive and forwardthinking strategy that transforms disparate sustainability measures into a unified and impactful project.

In this report, we will specifically focus on the ways energy and water systems can be made more efficient, citing examples from our research and investigation of the case studies CoHousing Houston and WateReuse Association.

Energy Efficiency

Energy efficiency refers to the optimal use of energy to accomplish a specific task while minimizing waste and reducing overall consumption. It involves employing technologies, practices, and systems that aim to extract the maximum output from the energy input, thereby enhancing performance and minimizing environmental impact. The importance of energy efficiency lies in its ability to address the growing concerns related to resource depletion, environmental sustainability, and economic considerations. By improving the efficiency of energy use in various sectors, such as buildings, transportation, and industrial processes, energy efficiency contributes to the reduction of greenhouse gas emissions, lowers energy costs, and enhances energy security. This strategic approach not only conserves valuable resources but also plays a crucial role in mitigating climate change, promoting sustainable development, and fostering a more resilient and responsible energy infrastructure. We focused on two sustainable and cost-saving methods of using energy that we found through our research. First, renewable energy sources have a higher upfront cost but result in greater savings over time. Second, conservation efforts can decrease the amount of energy required overall and lead to savings on the costs of energy.

For renewable energy sources, we compared solar and geothermal energy harvesting as utilized in the CoHousing Houston Project. While solar panels have gained popularity as a renewable energy source, it's important to acknowledge certain challenges associated with their implementation. One notable drawback is the initial cost of installation, which can be a significant barrier for many individuals and businesses. The upfront expenses involved in purchasing and installing solar panels, including the photovoltaic cells, inverters, and associated infrastructure, can be substantial. Despite decreasing costs in recent years, the initial investment remains a key consideration. Furthermore, while advancements have improved efficiency rates, solar technology still faces limitations in converting sunlight into electricity, especially in regions with inconsistent or low sunlight exposure. For optimal performance, buildings integrating solar panels ideally should already exhibit energy-efficient designs to ensure that the generated energy meets the structure's needs without placing an undue burden on the system. Therefore, for some projects, the requirement for lower energy levels or a considerable upfront investment might limit the feasibility of solar panel installations as the primary energy solution.

Ms. English, the architect of the CoHousing project, told us that for most of the projects her architecture firm takes on, it takes 20 years to recover through savings the initial cost of installation and building design required for solar energy harvesting. This long time horizon is not attractive to developers because the life of traditional solar panels are only around 20 to 25 years. So, by the time the initial cost is recovered, it is time to undergo that cost again. Furthermore, most of the savings for solar panels come from government tax incentives. The only state-level solar incentive offered in Texas is a property tax exemption for the value solar energy systems add to your home (Solar.com). As such, while solar panels are good for the environment, they are not the source of renewable energy we are recommending in terms of a fast return on investment.

The CoHousing Houston project integrated geothermal exchange systems into their design for heating and cooling. Geothermal energy presents a sustainable and efficient solution for water heating and HVAC (Heating, Ventilation, and Air Conditioning) systems in buildings. Utilizing the Earth's natural heat stored beneath the surface, geothermal systems tap into this renewable energy source to provide a reliable and consistent supply of energy for heating and cooling purposes. In water heating, a geothermal heat pump extracts heat from the ground and transfers it to the water, offering an energy-efficient alternative to traditional heating methods. For HVAC systems, geothermal heat pumps work by leveraging the relatively stable temperature of the Earth's subsurface to cool or heat indoor spaces. During the cooling season, the system extracts heat from the building and transfers it to the ground, while in the heating season, it draws heat from the ground to warm the interior. This process is highly energy-efficient, as it doesn't rely on external fuel sources but instead maximizes the Earth's thermal energy reservoir. Geothermal energy is a clean and renewable resource, producing minimal greenhouse gas emissions compared to traditional fossil fuel-based heating and cooling methods.

Additionally, geothermal systems are known for their long lifespan and low operational costs, making them a cost-effective and environmentally friendly choice for property owners looking to invest in sustainable energy solutions. Looking at how it is used in the cohousing project reveals more about its cost-effectiveness. The geothermal system reduces monthly energy costs as it is more energy efficient than conventional AC systems. It also has reduced long-term maintenance costs because there are less parts that may break down, and since there is no above-ground equipment, there is no wear-and-tear to roofs or other building parts due to the attached conventional AC system. The initial cost of the geo-exchange system is steep at $453,000 compared to the conventional option’s cost of $221,000 system. However, over 15 years, the extra cost of energy, water heating, and maintenance will result in a cumulative cost of $701,396 for the geothermal system and $888,491 for the conventional option (Appendix A). As such, geothermal is a very cost-effective alternative to buying electricity from a utility.

Water Efficiency—Stormwater Drainage

In Houston, stormwater management is a critical aspect of urban planning and infrastructure development due to the region's susceptibility to intense rainfall and potential flooding. As a result, the city has implemented stringent regulations regarding stormwater detention and drainage systems to mitigate the impact of heavy rainfall events. These regulations aim to control runoff, prevent flooding, and protect property, people, and the environment. Developers in Houston are typically required to incorporate stormwater detention systems into their projects. These systems are designed to temporarily hold and control the flow of stormwater, allowing it to be released at a controlled rate to prevent downstream flooding. Detention basins, ponds, or underground storage facilities are common components of stormwater detention systems. The size and design of these systems are dictated by city ordinances, considering factors such as the size of the development and the potential impact on local waterways.

Furthermore, Houston's drainage systems play a crucial role in managing stormwater effectively. Unfortunately, flooding is a common issue in Houston due to the city’s flat nature and clay soil. Houston utilizes pavement, a poor absorbing material, frequently throughout the city for sidewalks and roads. To help alleviate the city’s flooding, proper drainage and flooding infrastructure must be put into place. Currently, many storm or rainwater drainage systems in Houston are overground systems that allow water to filter through and end up in underground pipes, which then eventually lead them into the city’s various bayous. This so-called gray infrastructure is more susceptible to flooding, as it prioritizes rapid water drainage into a basin, which can lead to bayous overflowing with rainwater.

We therefore propose implementing underground stormwater drainage structures as one possible solution to Houston’s flooding problem. Instead of relying on traditional gray infrastructure to solve the city’s flooding issue, this proposed solution is a type of green infrastructure which prioritizes a slower water flow rate by allowing each detention site to essentially act as a sponge, soaking up water and preventing the bayous from overflowing too quickly. In this system, parking lots within multi-family homes or complexes can be angled to funnel rainwater towards an underground detention system, which utilizes overground plants as a natural filter for the water. The plants are able to catch any trash and large disposables to help prevent the pollution of Houston’s bayous that would otherwise occur with traditional overground water detention systems. They also help clean the water that is absorbed through their roots, acting as a natural filter before the water leads into bayous. The water that is collected through these plants then stays in an underground detention basin before flowing into the stormwater pipes. At a flow rate 1/12 the rate of a traditional water flow, this system is able to better prevent flooding from occurring by significantly reducing the speed of water flow. This is therefore considered a sustainable solution as it seeks to optimize the natural rainwater drainage process and build protection against one of Houston’s most pressing environmental obstacles. Appendix B demonstrates how this solution is utilized in the CoHousing Houston project.

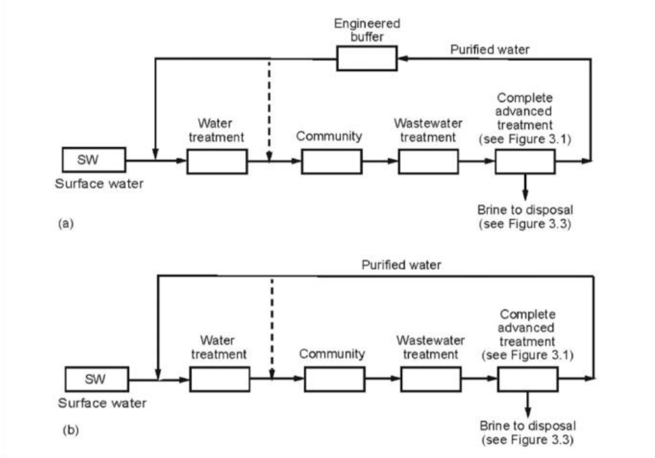
As the more responsible solution to prevent flooding and polluting of our bayous, underground water detention systems are in fact also more cost-efficient than overground systems. There are two ways that these systems can yield a return on investment. First, in scenarios where land acquisition costs for an overground system are substantial, the cost of installing an underground detention system might be more economical. This cost-effectiveness is particularly evident in dense urban environments where available land is limited and expensive, making underground solutions a financially prudent alternative. Currently, above-ground stormwater drainage systems not only have the cost of the structure itself but also the cost of the physical plot of land it is built upon. If the detention system is underground, however, no additional land will be needed. In a scenario such as this, there is thus an immediate return on the investment of building an underground detention system.

Even if a development already has ample land for an overground detention system, the sustainable underground system can still save money. The utilization of underground stormwater detention systems provides an avenue for rainwater harvesting and subsequent reuse, offering a sustainable approach to water management. The collected rainwater can be repurposed for activities such as irrigation, reducing reliance on the city's potable water supply for non-potable purposes. The financial savings derived from this dual-use approach, coupled with the conservation of a precious resource, contribute to a long-term payback period. For the cohousing project we looked at, the reduced demand for city water for irrigation led to substantial savings, making the initial investment in the underground system not only environmentally responsible but also economically advantageous. In this case, the initial investment is calculated to be recovered in 7-8 years.

Water Efficiency - Water Reuse

Water reuse is the process of recycling and cleaning water to make it safe and usable for purposes such as drinking, industrial processes and groundwater replenishment. Recycling water results in less wastage of water, and helps to reduce the increasing impact of droughts or water shortages. It has the potential to be less expensive than other forms of accessing water such as water desalination or importing water. Further, it is less energy intensive than desalination and importing water, and leaves a lower carbon footprint. Federal funding is also available to reuse projects through Title XVI of the Reclamation Projects Authorization and Adjustment Act of 1992.

To determine an ROI for sustainable infrastructure, we investigated Direct Potable Reuse (DPR), which involves treating and distributing water without the need for an environmental buffer. Indirect Potable Reuse was also considered, but according to a study by the WateReuse Association this is a less feasible option as it requires the need for an environmental buffer, which makes it "infeasible for many communities because there are many locations in which a sustainable surface water or groundwater buffer system in not available" (Raucher & Tchobanoglous, 2014). The process used in DPR is shown below:



Proposed flow diagrams for DPR: (a) with engineered buffer and (b) without engineered buffer

Recycling water is already a process used throughout the United States. For example, "General Motors saves $2 million a year by capturing and reusing stormwater for cooling towers at its Detroit-Hamtramck assembly plant" (WateReuse Association).

Financial Benefits of Direct Potable Reuse

As mentioned, potable reuse can often be less expensive than other sources of new water. In 2014, the WateReuse Association found that the cost range of potable reuse was $820 to $2000 per acre-foot (1 AF = 325,851 gallons). In comparison, seawater desalination from the San Diego Carlsbad facility was estimated to cost between $2080/AF to $2330/AF, while seawater desalination from the West Basin Municipal Water District was estimated to cost between $1500/AF to $2000/AF. Imported water, in comparison, costs around $1300/AF, although the study expected this to increase to $2000/AF by 2020 (data is available in Appendix C). From this, direct potable reuse is a beneficial option to pursue. It is less expensive than other solutions, while also offering a less energy-intensive approach to creating safe water for communities. Water reuse initiatives can be implemented at a larger level in the form of plants, or within a sustainable development itself through the use of integrated design.

b. Adaptive Reuse

Introduction

Adaptive Reuse is the practice of repurposing existing buildings and infrastructure so that it can serve a new purpose, offering developers both residential and commercial opportunities. Adaptive reuse is environmentally beneficial and sustainable as it can produce lower carbon emissions than standard real estate projects as fewer materials are required in the building process and the redevelopment of old infrastructure can improve energy efficiency. It is also beneficial to local communities as adaptive reuse projects enable previously underutilized spaces to be properly utilized and optimized, which brings greater economic activity to an area where a project has been completed.

In terms of the ROI for adaptive reuse, it can be seen through raising the value of a building above what was paid for its refurbishment. Furthermore, spaces can be used following redevelopment to generate further income, such as leasing space to businesses as POST Houston has accomplished.

Benefits and Challenges

One of the major benefits of adaptive reuse is that construction can be less expensive. This is in part because a lot of a building's structures are already in place, meaning a developer doesn't have to expend major resources to build them. Further, adaptive reuse projects can take less time, meaning less money has to be spent on worker salaries for the project. In 2018, a consultant at MGAC estimated that adaptive reuse construction costs per square-foot could be lower than the cost of construction for a new build in the US Mid-Atlantic Region:

Building Type	New Build	Historic Adaptive Reuse
Higher Education Classroom	$425 - $550 SF	$325 - $475 SF
High School Classroom	$300 - $500 SF	$275 - $375 SF
Commercial Office	$250 - $300 SF	$225 - $300 SF
Museum	$700 - $1,300 SF	$600 - $900 SF

There are also substantial tax credits to be found with adaptive reuse projects. At the local level, Tax Increment Reinvestment Zones (TIRZ) can provide funding for reuse projects by designating an area as a Reinvestment Zone for issues such as "deteriorated or deteriorating structures," (City of Houston) which could enable an adaptive reuse project to be designated as a reinvestment zone. At the state level, the Historic Tax Credit can provide a 1-year tax credit for 25% of the cost of improvements. At the national level, Federal Historic Tax Credits can subsidize up to 20% of construction costs for an adaptive reuse project if a building is designated as a certified historic structure. Further, under the Inflation Reduction Act, an improvement in Energy Use Intensity (the amount of energy used per square foot annually) can lead to a tax credit of $2.50 for a 25% improvement in EUI up to $5.00 for a 50% improvement in EUI.

Overall, adaptive reuse can be a financially beneficial form of sustainable infrastructure due to potentially lower costs of construction, as well as substantial tax credits that can help cover the cost of construction.

While there are many potential benefits of adaptive reuse, there are also significant challenges. For example, from our interview with Mr. Liu, we learned that every project is vastly different, and can be more difficult to conduct than a new build project. This poses financial difficulties as each project will have very different costs, and according to Mr. Liu, an architect is required before any plans have been made to acquire a building for reuse to judge what sort of costs a developer might face with a specific project. This makes generalizing adaptive reuse as a potential sustainable infrastructure project to developers impractical which makes encouraging it as a concept difficult. Further, there can be many unforeseen challenges in adaptive reuse. For example, the discovery of contaminated (or “hot”) materials such as asbestos leads to a far more expensive demolition process. Due to the risk of these materials, demolition also needs to be very precise. Adaptive reuse projects offer less flexibility in construction, due to developer constraints to the structures already in place. The lack of flexibility also comes from governmental institutions. From Mr. Liu, we learned that the high use of tax credits leads to more government interference in a project, while the fact that a reuse project often involves redeveloping historic buildings causes greater scrutiny by organizations such as the Texas Historical Committee and the National Park Service. Interference from these organizations can slow down or stop the construction process, as well as increase costs. In the case of POST, the developers were forced to remove trees from the top of the building as greenery hadn’t been there previously. Further, they were not allowed to install windows on parts of the building as the building didn’t historically have windows.

While adaptive reuse can have many financial benefits, we would not recommend it as a sustainable project to pitch to developers due to the many different challenges it poses.

V. Recommendation and Next Steps

Our recommendation to the West Houston Association is to pitch the idea of integrated design to developers building single or multi-family homes in the Houston area. We believe that this is a viable financial solution with a strong return on investment that would attract developers to projects. Integrated design projects would consist of the combined use of the three solutions suggested: implementing energy-efficient designs into buildings such as the use of geothermal energy in air conditioning, using design methods to conserve energy, and improving water drainage systems through the use of underground detention systems. Therefore, we believe that the use of integrated design of multiple sustainable infrastructure measures in a single project would help to maximize the potential ROI for a developer.

While integrated design is potentially the best use of these resources, the different projects pitched under this could all be implemented independently to generate a return on investment. For example, the geo-exchange HVAC could be implemented in single-family homes as a stand-alone piece to reduce energy costs and lower the necessity of maintenance fees, while stormwater drainage solutions could be implemented in driveways. It is important to note that the upfront cost of these solutions is greater than non-sustainable developments, so the return on investment would only be seen in the long term.

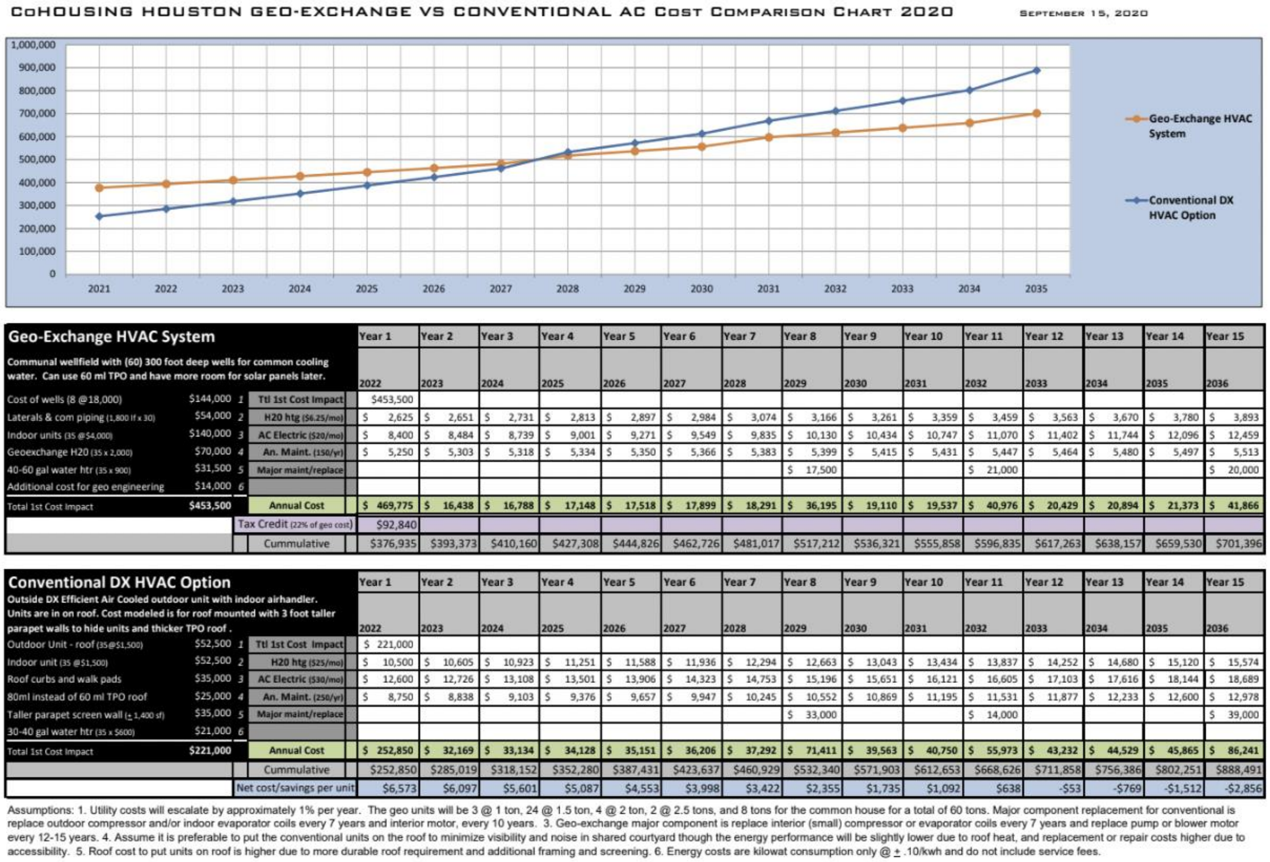
Water reuse through DPR can generate a return on investment as it is less expensive than other forms of water, such as imported water or the process of seawater desalination. The difficulty with implementing this as a solution is finding a place in Houston where a water treatment plant could be built. However, given the less costly nature of DPR, and the fact it is environmentally sustainable, especially with rising water demands, we believe that it is a potentially beneficial solution that can be implemented fully in the longer term.

While we were able to identify potential projects with positive returns on investment that the West Houston Association could implement, the final project we looked at, adaptive reuse, is *not* something we would recommend for this project. While there are definite financial incentives to adaptive reuse (potentially lower construction costs, tax credits heavily financing the project, etc.) and community character can be maintained, it is difficult to propose to developers as a wider concept due to the difficulty of generalizing it to apply to *any* adaptive reuse project. Additionally, developers can be frustrated and costs of refurbishment can increase mid-project due to them being slowed down by the discovery of contaminated materials or government interference. This could make developers less inclined to work on adaptive reuse projects again. While we don't believe we can justifiably pitch adaptive reuse as a sustainable initiative that can generate an ROI for this project, it is something we recommend that the West Houston Association researches further, as projects can potentially be financially beneficial depending on the individual building.

Overall, our recommendation is to pitch the concept of using multiple sustainable features in developments to developers and use integrated design to generate a return on investment for sustainable infrastructure projects. We also believe that each of the sustainable solutions we have found could be used independently of each other, and nevertheless prove to be financially profitable and environmentally sustainable, since we recognize the integrated solution may not always be viable.

VI. Appendix

Appendix A: Geo-Exchange HVAC System vs. Conventional DX System



CoHOUSING HOUSTON GEO-EXCHANGE VS CONVENTIONAL AC COST COMPARISON CHART 2020

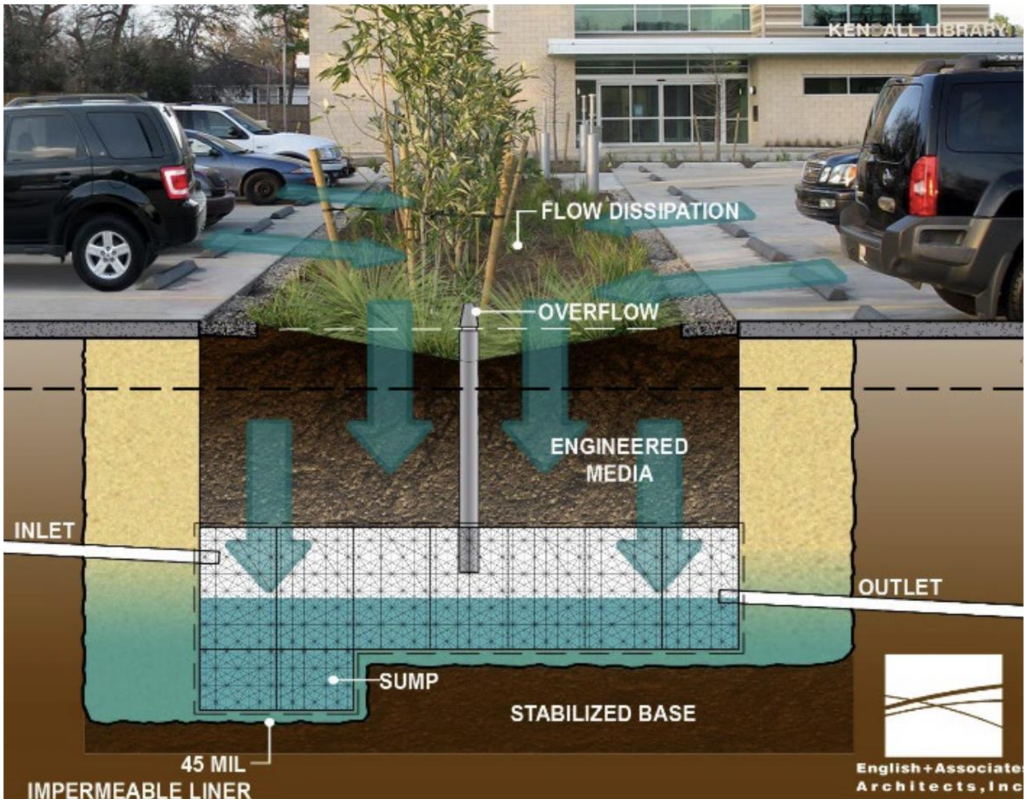
SEPTEMBER 15, 2020

Geo-Exchange HVAC System				Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Communal wellfield with (60) 300 foot deep wells for common cooling water. Can use 60 ml TPO and have more room for solar panels later.				2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Cost of wells (8 @18,000)	$144,000	1	Ttl 1st Cost Impact	$453,500														
Laterals & com piping (1,800 lf x 30)	$54,000	2	H20 htg ($6.25/mo)	$ 2,625	$ 2,651	$ 2,731	$ 2,813	$ 2,897	$ 2,984	$ 3,074	$ 3,166	$ 3,261	$ 3,359	$ 3,459	$ 3,563	$ 3,670	$ 3,780	$ 3,893
Indoor units (35 @$4,000)	$140,000	3	AC Electric ($20/mo)	$ 8,400	$ 8,484	$ 8,739	$ 9,001	$ 9,271	$ 9,549	$ 9,835	$ 10,130	$ 10,434	$ 10,747	$ 11,070	$ 11,402	$ 11,744	$ 12,096	$ 12,459
Geoexchange H20 (35 x 2,000)	$70,000	4	An. Maint. (150/yr)	$ 5,250	$ 5,303	$ 5,318	$ 5,334	$ 5,350	$ 5,366	$ 5,383	$ 5,399	$ 5,415	$ 5,431	$ 5,447	$ 5,464	$ 5,480	$ 5,497	$ 5,513
40-60 gal water htr (35 x 900)	$31,500	5	Major maint/replace								$ 17,500			$ 21,000				$ 20,000
Additional cost for geo engineering	$14,000	6																
Total 1st Cost Impact	$453,500		Annual Cost	$ 469,775	$ 16,438	$ 16,788	$ 17,148	$ 17,518	$ 17,899	$ 18,291	$ 36,195	$ 19,110	$ 19,537	$ 40,976	$ 20,429	$ 20,894	$ 21,373	$ 41,866
			Tax Credit (22% of geo cost)	$92,840														
			Cummulative	$376,935	$393,373	$410,160	$427,308	$444,826	$462,726	$481,017	$517,212	$536,321	$555,858	$596,835	$617,263	$638,157	$659,530	$701,396

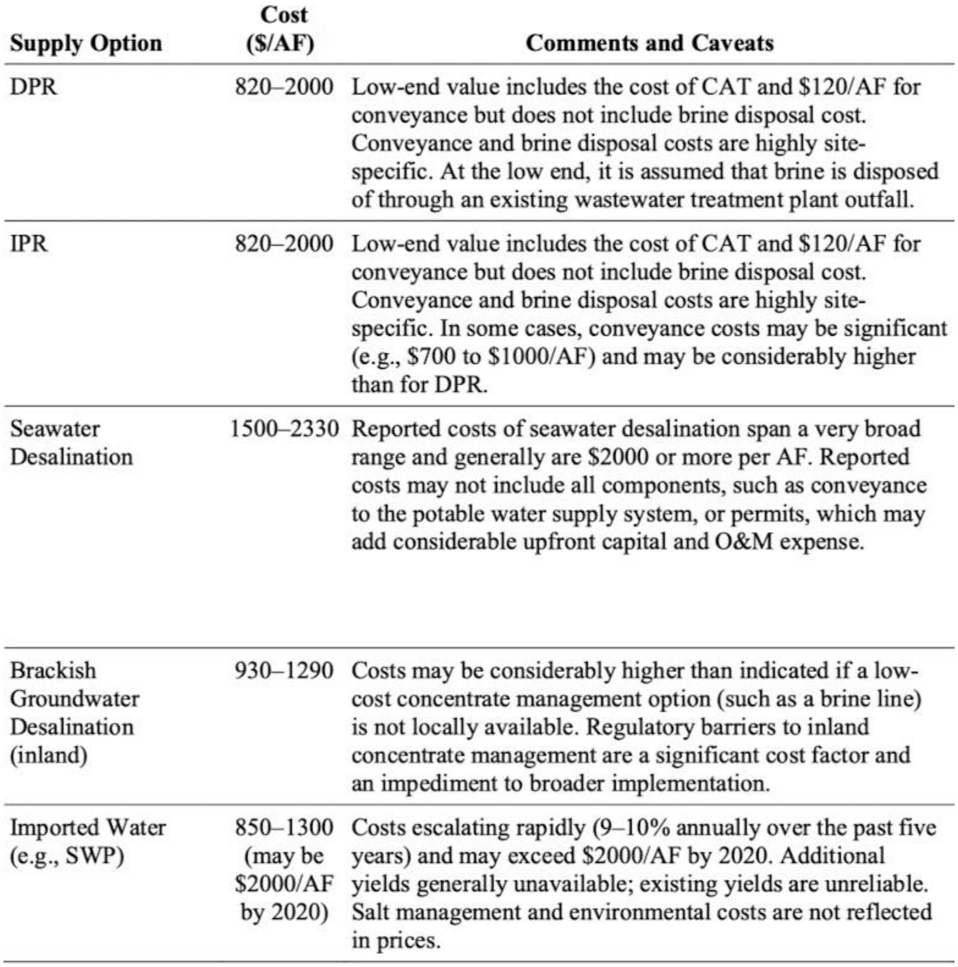
Conventional DX HVAC Option				Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Outside DX Efficient Air Cooled outdoor unit with indoor airhandler. Units are in on roof. Cost modeled is for roof mounted with 3 foot taller parapet walls to hide units and thicker TPO roof .				2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Outdoor Unit - roof (35@$1,500)	$52,500	1	Ttl 1st Cost Impact	$ 221,000														
Indoor unit (35 @$1,500)	$52,500	2	H20 htg ($25/mo)	$ 10,500	$ 10,605	$ 10,923	$ 11,251	$ 11,588	$ 11,936	$ 12,294	$ 12,663	$ 13,043	$ 13,434	$ 13,837	$ 14,252	$ 14,680	$ 15,120	$ 15,574
Roof curbs and walk pads	$35,000	3	AC Electric ($30/mo)	$ 12,600	$ 12,726	$ 13,108	$ 13,501	$ 13,906	$ 14,323	$ 14,753	$ 15,196	$ 15,651	$ 16,121	$ 16,605	$ 17,103	$ 17,616	$ 18,144	$ 18,689
80ml instead of 60 ml TPO roof	$25,000	4	An. Maint. (250/yr)	$ 8,750	$ 8,838	$ 9,103	$ 9,376	$ 9,657	$ 9,947	$ 10,245	$ 10,552	$ 10,869	$ 11,195	$ 11,531	$ 11,877	$ 12,233	$ 12,600	$ 12,978
Taller parapet screen wall (± 1,400 sf)	$35,000	5	Major maint/replace								$ 33,000			$ 14,000				$ 39,000
30-40 gal water htr (35 x $600)	$21,000	6																
Total 1st Cost Impact	$221,000		Annual Cost	$ 252,850	$ 32,169	$ 33,134	$ 34,128	$ 35,151	$ 36,206	$ 37,292	$ 71,411	$ 39,563	$ 40,750	$ 55,973	$ 43,232	$ 44,529	$ 45,865	$ 86,241
			Cummulative	$252,850	$285,019	$318,152	$352,280	$387,431	$423,637	$460,929	$532,340	$571,903	$612,653	$668,626	$711,858	$756,386	$802,251	$888,491
			Net cost/savings per unit	$6,573	$6,097	$5,601	$5,087	$4,553	$3,998	$3,422	$2,355	$1,735	$1,092	$638	-$53	-$769	-$1,512	-$2,856

Assumptions: 1. Utility costs will escalate by approximately 1% per year. The geo units will be 3 @ 1 ton, 24 @ 1.5 ton, 4 @ 2 ton, 2 @ 2.5 tons, and 8 tons for the common house for a total of 60 tons. Major component replacement for conventional is replace outdoor compressor and/or indoor evaporator coils every 7 years and interior motor, every 10 years. 3. Geo-exchange major component is replace interior (small) compressor or evaporator coils every 7 years and replace pump or blower motor every 12-15 years. 4. Assume it is preferable to put the conventional units on the roof to minimize visibility and noise in shared courtyard though the energy performance will be slightly lower due to roof heat, and replacement or repair costs higher due to accessibility. 5. Roof cost to put units on roof is higher due to more durable roof requirement and additional framing and screening. 6. Energy costs are kilowat consumption only @ ± .10/kwh and do not include service fees.

Appendix B: Underground Water Detention System - CoHousing Houston



Appendix C: Comparative Costs of Water Supply Options



Supply Option	Cost ($/AF)	Comments and Caveats
DPR	820–2000	Low-end value includes the cost of CAT and $120/AF for conveyance but does not include brine disposal cost. Conveyance and brine disposal costs are highly site-specific. At the low end, it is assumed that brine is disposed of through an existing wastewater treatment plant outfall.
IPR	820–2000	Low-end value includes the cost of CAT and $120/AF for conveyance but does not include brine disposal cost. Conveyance and brine disposal costs are highly site-specific. In some cases, conveyance costs may be significant (e.g., $700 to $1000/AF) and may be considerably higher than for DPR.
Seawater Desalination	1500–2330	Reported costs of seawater desalination span a very broad range and generally are $2000 or more per AF. Reported costs may not include all components, such as conveyance to the potable water supply system, or permits, which may add considerable upfront capital and O&M expense.
Brackish Groundwater Desalination (inland)	930–1290	Costs may be considerably higher than indicated if a low-cost concentrate management option (such as a brine line) is not locally available. Regulatory barriers to inland concentrate management are a significant cost factor and an impediment to broader implementation.
Imported Water (e.g., SWP)	850–1300 (may be $2000/AF by 2020)	Costs escalating rapidly (9–10% annually over the past five years) and may exceed $2000/AF by 2020. Additional yields generally unavailable; existing yields are unreliable. Salt management and environmental costs are not reflected in prices.

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