Incorporation of Sustainable Infrastructure into Affordable Housing Developments

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

In the city of Charlottesville, 1,866 low-income families find themselves trapped on a waiting list for federal housing aid, mirroring a nationwide challenge afflicting countless cities. These families must endure an average wait time of eight years, or seven for elderly or disabled individuals, before receiving the aid necessary to afford housing that does not exceed 30% of their combined income (Charlottesville, 2018). Charlottesville Redevelopment and Housing Authority emphasizes the extreme lack of affordable housing, with Virginia offering only 32 affordable units per 100 families in need (National Low Income Housing Coalition, 2023a, 2023b). As well as being in high demand, affordable housing dwellings and similar low-income family housing is commonly of extremely poor quality to the point that it negatively affects the health and lifestyle of residents (Mueller & Tighe, 2007; Resolution Foundation, 2023). Millions are in the same situation as those in Charlottesville, highlighting a pressing need for transformative solutions in affordable housing, a need that sustainable infrastructure looks to fulfill (Aurand et al., 2023).

A 2008 study suggests that low-income neighborhoods are 4.5 times less likely to have recreational facilities, a popular component of sustainable infrastructure, than high-income neighborhoods, due to lack of public funding and historical discrimination (Moore et al., 2008). Simultaneously, recreational and green spaces have been proven to boost mood and lower depression rates, a phenomenon that those who live in affordable areas unfortunately miss out on (Lee & Maheswaran, 2011). In fact, sustainable infrastructure of all types that is often reserved for expensive neighborhoods would create greater physical and social change when placed in low-income areas. These areas are often plagued disproportionately with more pollution and lower quality of life, meaning greater change would occur. Sustainable infrastructure can be a

cost-effective and proactive solution to solve potentially large and expensive problems before they occur (Dunn, 2010).

Sustainable infrastructure is a unique solution to mitigate both the lack and poor quality of affordable housing. Sustainable infrastructure reduces heating and cooling needs, mitigates damage from natural disasters such as hurricanes or flooding, reduces car dependency, and lengthens the lifespan of housing through various techniques. These traits allow residents to spend less on living expenses, yielding a greater number of housing options to be affordable, as well as a more stable housing environment. This is increasingly important amidst another decade of rent increases outpacing income growth, a leading cause of displacement among affordable housing residents (DeParle, 2023; Shindle, 2023).

Implementing sustainable infrastructure into affordable housing developments is challenging and often avoided due to limited budgets and the complex problem-solving involved with the process (Tan & Olanrewaju, 2019). However, A case study of housing certified through Earthcraft, an organization that awards housing in Georgia for using sustainable infrastructure and eco-friendly design, shows that there is not a significant difference in construction costs for an Earthcraft certified home versus a home of equal size and location that is not certified, though there is a 15% increase in the selling price for certified homes (Earthcraft, n.d.; Jeddi Yeganeh et al., 2019). This study proves that in certain cases sustainable infrastructure comes at no additional cost but is used as a selling point and an additional “amenity” to increase the selling price.

Albemarle County, similarly to many other counties, provides density incentives for developers that allow the original maximum density of a lot to be increased by up to 30% if at least half of the dwelling units allowed in the increase are affordable units (Affordable Housing

Bonus Factors, 2021). The combination of affordable housing and sustainable infrastructure would appease developers by allowing more density, and thus more housing units, lightening the need in Albemarle County for affordable housing, as well improving the resilience and lifespan of housing for low-income families. A strategy towards implementing sustainability into affordable housing is the Environmental Protection Agency's (EPA) "Smart Growth" strategy, in which accessible public transportation and sustainably engineered utilities are at the forefront (US EPA, 2013). Following EPA's Smart Growth provides basic strategic planning that allows housing to stay affordable and apply sustainable building techniques, but more techniques that apply to a broader assortment of developments may be necessary. This paper will explore how sustainable infrastructure can be incorporated into affordable housing without sacrificing cost.

Case Context

The origin of the lack of green spaces and other sustainable infrastructure in areas surrounding affordable housing can be traced back to the 1930's with a practice known as redlining. Redlining is a term originating from color-coded maps of cities created by realtors and public officials illustrating the associated risk of investing and mortgaging in an area, with red reserved for the areas with the most risk. Being based almost exclusively on racist pretenses, the red regions were frequently marked in areas inhabited by people of color. Over time, redlined neighborhoods experienced "disinvestment, vacancy, and abandonment," the effects of which can still be seen today, as once redlined neighborhoods show worse air, water, and noise pollution, greater risk for reproductive health disorders, and less access to green spaces and other urban amenities (MacNeil, 2023). These historically redlined neighborhoods often are those that contain large numbers of affordable housing units in a city, with a study done in New York City showing that over 71% of affordable housing units are located in low-income areas that were

once redlined, explaining the lack of sustainable infrastructure seen in affordable housing properties (Kawitzky et al., 2013).

Despite the low quality of many affordable housing units, many are slowly becoming unaffordable, displacing residents that once depended on the low pricing. Recent inflation has driven landlords to increase rent prices to account for increased labor costs and other expenses. Independent of inflation, rent prices have seen additional growth through "rent gouging," in which landlords increase rent "unconscionably" because of a shortage or monopoly (Serota, 2002). A study of rent prices from 2009 to 2021 saw an average increase of 42%, and up to 85% in metropolitan areas, with rent increases outpacing income growth in 42 of the 50 most populated areas in the country (Geeks, 2023). These increases have left low-income families helpless as their rent, utilities, and general living expenses eat up a larger portion of their income every year, while their salary stays almost stagnant.

When incorporating sustainable infrastructure into affordable housing, an emphasis should be placed on fostering resilience by reducing energy usage, increasing green space, using green construction techniques, reducing stormwater runoff, and more. Resilience in affordable housing essentially protects residents from unknown and fluctuating conditions such as weather, housing costs, and housing quality, and allows a soft recovery in the presence of difficulties. Among these are practices such as improved insulation, low energy amenities, adaptive reuse, and grey water systems. For example, the green building technique of urban forestry is able to lower urban heat island effects and allow for a more regulated climate inside of buildings, reducing a units reliance on the HVAC system, which in turn can lower utility costs, making units more affordable (McPherson et al., 1997). Despite the constant development of new green

infrastructure technologies, affordable housing has not seen substantial change. To enact this change, the core philosophy and methodology of developers need to be addressed.

Green Infrastructure, Ethics, and Affordable Housing

The U.N. Committee on Economic, Social, and Cultural Rights states that the human right to housing consists of seven parts, three of which are affordability, habitability, and availability of services, materials, and infrastructure (Tars, 2021). Though within housing, quality and affordability are often mutually exclusive. The incorporation of sustainable infrastructure into affordable housing is of utmost importance to furthering human rights and providing equitable improvement to quality of life for millions of people.

Thomas Seager's Sustainable Engineering Science approach is a framework that is a perfect fit for analyzing the relationship between affordable housing and sustainable infrastructure. This approach classifies certain sustainability-related engineering issues as "wicked problems." Wicked problems often revolve around social issues that are resistant to straight forward fixes, thus requiring specifically engineered solutions. Seager specifies that wicked problems of sustainability in engineering often require solutions that incorporate ethical awareness, adaptability and resilience, and cross-disciplinary expertise, qualities often overlooked in conventional solutions (Seager et al., 2012). Bryan Norton, in his paper *Sustainability: A philosophy of adaptive ecosystem management*, outlines five key characteristics of wicked problems: "difficulty in problem formulation, multiple yet incompatible solutions, open-ended timeframes, novelty, and competing value systems or objectives" (Norton, 2005). The incorporation of sustainable infrastructure into affordable housing exhibits all these characteristics, meaning an alternative solution must be found.

The current approach to both sustainability within the housing market and affordable housing is the 'Business-As-Usual' approach. This method tends to overlook environmental and social issues, or optimistically assume business as usual addresses these problems without considering their broader contexts. This approach is typically one that allows for advances in technology although it “disproportionately benefits the rich” who can afford such innovations (Woodhouse & Sarewitz, 2007). The Business-As-Usual approach can best be seen when viewing attempted solutions to the affordable housing crisis. Landlords attempt to create more affordable housing by renting out deteriorating or dilapidated houses at an affordable rate, often leading to displaced or injured residents, creating more of a financial burden and worsening the affordable housing crisis (Local Housing Solutions, n.d.).

The approach that Seager argues works best for solving wicked problems is known as sustainable engineering science, a methodology that covers what business-as-usual fails to by reviewing ethical requirements beyond professional ethics, using a resilient and anticipatory perspective rather than risk management, and allowing for interdisciplinary research. To fully understand sustainable engineering science, wicked problems can be reinvented as “conditions to be governed,” and the approach viewed as managing these conditions, rather than solving the problem. This change in perspective allows for wicked problems to be viewed as several smaller but broad, interdisciplinary, constantly fluctuating issues. This recontextualizes sustainable engineering science as a plan to mitigate the effects of each issue through creating resilience in all parts of the system and anticipating further issues.

When approaching sustainability in affordable housing with the wicked problem framework, the Business-As-Usual approach falls short. Each affordable housing development operates within a unique social, economic, and environmental situation, making a one-size-fits-

all solution to incorporating sustainable infrastructure impractical. Using a sustainable engineering science approach, a plan to incorporate resilient sustainable infrastructure that can adapt to changes like climate change and sea level rise as well as social and economic disparities faced by residents such as rent fluctuations, inflation, or a recession is necessary. This raises the question: In U.S. cities, what will a plan to incorporate sustainable infrastructure into affordable housing entail?

Research Method

To investigate this research question, several case studies of successful affordable housing developments that have incorporated sustainable infrastructure and design were performed. The sustainable engineering science approach for wicked problems provided a clear pathway for examining these developments. Sustainable infrastructure that was used in each development was examined for its relevancy to the three categories outlined by this framework: ethical awareness, adaptability and resilience, and cross-disciplinary expertise. From there, the technology was viewed in the context of the entire development to determine why it fits into that category, and what its intended purpose is. Data was gathered from digital and physical sources that describe the methods and techniques used to implement various sustainable infrastructure into each development. The infrastructure found was then broadened to be inclusive of more situations, or contextualized to the specific situations in which they would work best. The studying of these cases allows for the formulation of a specific sustainable infrastructure plan that can be implemented to affordable housing developments around the globe.

The Via Verde development was selected for use in this study for its award-winning sustainable design and national recognition in architecture and affordable housing. Located in the South Bronx of New York City, the design was determined by the winner of a national

competition for design in affordable housing (Donovan, 2012; US EPA, 2014). Having become a reference point of architects around the globe, the development has sparked debate about the necessity of high end design in low-income subsidized housing (Schalliol, 2016). Via Verde's sustainable design focuses mainly on rainwater reuse and productive green spaces that create an outdoor environment. This development is particularly interesting as it is located in the inner city, presenting challenges in terms of space constraints and environmental quality. The development and its large courtyard are shown in Figure 1.

Figure 1. Via Verde and its Central Courtyard (Source: Sundberg, n.d.)

The Bellfield Townhomes development by Onion Flats, seen in Figure 2, was selected for its unique focus on ultra-affordability and being net zero energy. Located in Philadelphia, Pennsylvania, the development is Passive House certified, a lesser-known certification as compared to LEED that focuses specifically on energy reduction and reuse (Onion Flats Architecture, n.d.). The development was also constrained by an extremely low budget of $130

per square foot, significantly less than the average $350 per square foot construction costs for multifamily properties in the United States (Janover, 2023).

Figure 2. Belfield Townhomes' Rooftop PV System (Source: Onion Flats Architecture, n.d.)

A third development selected for analysis was Crest Apartments, located in Los Angeles, California. This development, seen in Figure 3, was built in conjunction with the Skid Row Housing Coalition, a non-profit dedicated to housing the homeless population and improving the urban aesthetics of Skid Row, a notoriously run-down neighborhood in Los Angeles. Although the development does include multiple environmentally sustainable techniques, the focus during design was on social sustainability and the rehabilitation of the chronically homeless and their reintroduction to society. This development was selected for this unique approach to sustainability, as well as its location, providing a broader coverage of the country.

Figure 3. Crest Apartments' Unique Design (Source: SWA Group, n.d.)

Results

The broad strategies that all three developments employ to achieve strong social, physical, and economic resilience are creating community, reducing the cost of living, increasing quality of life, and mitigate climate change impacts. Specific technologies employed in each development are outlined in Table 1. Through the integration of green spaces, community gardens, and pedestrian friendly architecture, developments foster a strong sense of community. Community creation is vital to ensuring social and physical resilience, especially in the face of crisis, as well as lowering risks leading to resident displacement. The next strategy, reducing the cost of living, is achieved through on-site renewable energy, high performance insulation, energy

Table 1. Specific Technologies Employed in Each Development

Strategy	**Via Verde**	**Belfield Townhomes**	**Crest Apartments**
Creating Community	• Green Spaces • On-Site Social Services	• Green Spaces • Substance Abuse Counseling	• Green Spaces • On-Site Social Services and Medical
Decreasing Cost of Living	• PV System • Water and Energy Efficiency • Low Construction Costs • Public Transit	• Net Zero Energy • Super-Insulation • Ultra-Airtightness • PV System • Low Construction Costs • Public Transit • Prefabrication	• PV and Thermal System • Public Transit • Prefabrication
Increasing Quality of Life	• Active Design • Community Gardens & Green Spaces • Public Transit	• Green Spaces • Public Transit	• Green Spaces • Community Oriented Architecture • Public Transit
Mitigating the Effects of Climate Change	• Green Spaces • PV System • Rain Harvesting • Native and Drought Tolerant Vegetation	• Green Spaces • PV System • Native Vegetation	• Green Spaces • PV and Thermal System • Permeable Pavement to Bioswale • Native and Drought Tolerant Vegetation

and water efficient appliances, community gardens, and public transportation. Additionally, prefabrication and green construction practices reduce upfront costs, substantially decreasing overall cost of living and boosting economic resilience, allowing residents to continue renting through inflation and price increases. These practices allow for a massive reduction in general living expenses, vastly improving the economic resilience of affordable housing. To improve resident's quality of life, the developments integrated community gardens, green spaces, and design that encourages healthy living, as well as creating access to public transit, counseling, and social services. This approach increases the quality of life of residents and ensures strong social

resilience of a development. To minimize the effects of climate change, the developments used key practices of efficient stormwater management, productive green spaces, and sun shading devices are crucial to reducing the threat of damage from climate change effects. By creating this physical resilience, developments are constructed for longer lifespans and can serve low-income families for longer.

Ethical Awareness

Ethics is extremely important when considering affordable housing, as this subject involves many people of differing backgrounds, experiences, and abilities, especially with all three developments housing formerly homeless individuals. The inclusion of on-site social services is an invaluable component of the developments, with Via Verde housing low-income and formerly homeless residents, Belfield Townhomes housing solely the formerly homeless, and Crest Apartments housing formerly homeless veterans. Recognizing the diverse needs and challenges faced by residents, such as traumatic events during homelessness, these services are essential for supporting a healthy community (Goodman et al., 1991). With these resources, residents are more equipped to flourish in their new homes, helping to foster a smoother transition and reintegration back into society. This not only provides a safe and stable environment but empowers residents towards independence and improved quality of life.

Furthermore, all three developments emphasize the ethical importance of public green spaces. These areas are both aesthetically pleasing and essential to forming community with neighbors. By encouraging residents to engage with one another, neighbors meet, and relationships are formed. Community resilience formed through these means comes to fruition when emergency situations, from natural disasters to an accidental fire alarm, require people to fall back on their neighborhood relationships.

Available social services and the presence of relationship-forming public green spaces reflect each development's commitment to ethical awareness and addressing the complex needs of residents. A common theme throughout these strategies is the push to create vibrant communities, both for the comfort of residents, and to ensure a safe and inviting environment. Community cultivation is essential to creating resilience and sustainability in the social systems of an affordable housing development.

Adaptability and Resilience

When considering frequent displacement, low quality housing, and economic instability, it is imperative for affordable housing to be designed for adaptability and resilience, physically and economically. Each development boasts a broad range of strategies aimed towards adaptability and resilience, but the most relevant approaches were decreasing the cost of living and mitigating the effects of climate change, though there is overlap between the two. Developments looked to lower the cost of living by maximizing energy and water efficiencies, thus minimizing utility costs through on-site renewable energy, water efficient appliances, and intensive insulation, as well as providing ample access to public transportation. Additionally, through a reduction in upfront costs with methods of prefabrication and local or recycled material usage, developers aimed for a more efficient and affordable construction to guarantee lower rental costs.

With urban flooding and the heat island effect more relevant than ever, each development paid close attention to properly reducing climate change impacts (US EPA, 2022). The developments integrated intensive stormwater management techniques like maximizing pervious surfaces with green space and collecting and treating site runoff, as well as cooling methods like

urban forestry and sun shading. With these measures, the buildings and their residents are prepared for disaster and protected from the rapidly worsening impacts of climate change.

Cross Disciplinary Expertise

With thoughtfully designed green spaces, friendly urban design, and unique prefabrication, cross disciplinary expertise is a more understated theme in the developments, though still relevant to their successes. For example, a productive green space requires the expertise of urban planners to maximize community benefits, landscape architects for the best design and aesthetics, engineers to determine soil types and drainage capacities, and environmental scientists to evaluate biodiversity and ensure a healthy ecosystem. Crest Apartments actively participated in this collaboration, working closely with the landscape architects at SWA Group. These architects designed the green spaces to be "flexible, multi-layered, and multi-textured," using a diverse range of drought-resistant native tree and bush species to mirror the diversity of residents, while simultaneously lowering water usage for irrigation (SWA Group, n.d.). Via Verde, originating from an architectural design competition, placed significant emphasis on urban design and aesthetics, utilizing the expertise of urban planners, engineers, and construction managers. Through their usage of recycled materials, cross-ventilation, daylighting, plentiful green space, and the stair-like building shape, the development seeks to promote "wellness and social well-being," and "emphasize a relationship to the natural world" (ArchDaily, 2014; Donovan, 2012). Although all three developments utilized prefabrication to some extent, Belfield Townhomes took full advantage of this technique to lower costs and environmental impacts. Using the insight of manufacturing experts to ensure precision, the prefabrication process constructed almost the entirety of the building's components in each

prefabricated unit, including framing, insulation, electrical, plumbing, and finishes such as doors, windows, tiles, and paint.

While cross disciplinary collaboration may not always be necessary, its use is a strong indicator that a project will be well rounded in scope and excellently executed from all perspectives. The analysis of how the developments utilized cross disciplinary expertise in the creation of vibrant green spaces and environment and community centered architecture, with an important goal of increasing resident's quality of life. Through these strategies, residents are retained, and communities grow stronger. Additionally, prefabrication plays a critical role in the ideas of reducing upfront costs, and by association the cost of living for residents, showing cross-disciplinary expertise as a multifaceted idea.

Discussion

The results of this case study align with other useful tools for creating sustainability and resilience in affordable housing. EPA's Smart Growth Strategy for affordable housing emphasizes that the location of housing and its proximity to public transportation greatly affects its affordability, as well as energy efficiency affecting utility costs, both of which appear in the findings of the case study. A case study conducted by Build Change, a company specializing in disaster relief housing, examined resilient housing initiatives in Colombia, Nepal, The Philippines, and Dominica. The study revealed that the most effective physical methods for creating resilient housing include reducing the risk of damage from natural disasters, prioritizing improvements in building performance, focusing on structures with existing solutions, and encouraging voluntary incremental risk reduction improvements. Although this study does not exactly align with the case study done of sustainable infrastructure in affordable housing, the

methods of reducing risks and prioritizing building performance were broad enough to apply to this study, and the results of the case study showed similar results.

Utilizing Thomas Seager's sustainable engineering science approach was an extremely effective method to analyze the sustainability of each case. The framework provided a clear guide to how analysis should be structured, giving three specific viewpoints to explore the development's sustainable infrastructure strategies from. Additionally, the three components of the sustainable engineering science approach aided greatly in determining the overarching sustainability of developments during the selection process. The ethical awareness component provided a unique opportunity to view how the developments provided accessibility to its residents and how they aimed to retain the specific populations they are housing.

The largest limitation to this study was the lack of publicly available information specifically relating to the sustainability of developments, especially in developments outside of the United States. This limited the cases available to study down to a select few, all of which were in the United States. The information pertaining to these cases was largely surrounding the architectural prowess of the building, and less so on the sustainable infrastructure used. Some developments included a full list of the exact equipment, devices, and materials used, while others provided virtually no mention of the sustainability, and even the U.S. Green Building Council that operates the LEED rating system had no information on the building's certification.

To further the accuracy of this study, a cost benefit analysis of specific sustainable infrastructure features of developments being studied would provide financial reasoning to include specific additions. However, information availability again hinders this from becoming actuality. Locating several cases from different countries, climates, and cultures, all with specific information would yield a much more accurate study that allows for a more fruitful comparison.

The implementation of sustainable and green infrastructure into affordable housing has not progressed far because of a major lack of research and development in the field (Tan & Olanrewaju, 2019). The cause of the lack of research can be attributed to the lack of a universal definition of sustainable and green infrastructure, leading to unclear research boundaries. By formulating a project-specific definition for sustainable infrastructure, boundaries are more clearly defined, and research can be performed. The importance of this research cannot be understated, as the current state of affordable housing shows an extreme inequality and injustice for affordable housing residents, something that can and should be undone by the improvement of technology in this field.

Conclusion

This research underscores the importance of incorporating sustainable infrastructure into affordable housing to ensure the resilience of people, our built environment, and the planet. The comprehensive analysis of three sustainable affordable developments shows that creating community, lowering the cost of living, improving quality of life, and mitigating the effects of climate change are four pivotal steps in ensuring robust resilience. By prioritizing these findings, policymakers, planners, engineers, advocates, and residents can pave the way for an equitable, sustainable, healthy, and resilient future.

This case study proves that sustainable infrastructure can and will increasingly be incorporated into affordable housing developments in the future. The goals of using sustainable infrastructure to create community, lower the cost of living, improve quality of life, and minimizing the effects of climate change provides engineers and planners with four basic checkboxes to ensure a well-rounded, sustainable, and resilient housing development. By ensuring resilience and sustainability on all fronts, affordable housing will improve lives,

stimulate the economy, and assist in the reversing of climate change while simultaneously protecting from its harmful effects. Low-income households deserve quality, sustainable, reliable, and resilient homes, and sustainable infrastructure has been proven to provide this.

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