Sustainable and Community Driven Adaptive Reuse of Underused Office Buildings in Arlington County, VA

An Interactive Qualifying Project Report submitted to the faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the degree of Bachelor of Science.

Published: December 14, 2023

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i. Abstract

Our goal is to create a system for determining the effectiveness of adaptive reuse for underutilized office buildings, particularly in Arlington County, Virginia. To better understand this area, we first compiled demographic data to identify the needs of the community. Then, we developed a few creative examples of adaptive reuse that emphasize sustainability and community engagement. By analyzing these examples, we were able to determine which factors contribute to successful buildings. The culmination of these observations resulted in the creation of a guide for the best practices in adaptive reuse projects that could be used by the county to educate developers and stakeholders on the overall reuse process.

ii. Acknowledgements

We would like to thank:

- Professors Adrienne Hall-Phillips, Lauren Mathews and Carol Stimmel for guidance in writing this report and presenting our work.
- Our sponsor Demetra McBride for taking the time to support our project and offering us valuable insights.
- Paul Roman and the Arlington Initiative to Rethink Energy (AIRE) Team for their information on the county's Green Building Initiative and continued guidance on the project.
- Steve Walz for setting up this project with Arlington County and connecting us with Marta Schantz from the Urban Land Institute.
- Our interviewees for providing us with helpful information on adaptive reuse:
    - Elizabeth King, Commercial Development Specialist for Arlington Economic Development
    - Roland K. Butzke, Account Executive for Siemens
    - Marta Schantz, Workplan Manager for the Urban Land Institute
    - Abbe Flores, Architect and Project Manager for Gensler
- Dean Kent Rissmiller for providing us with the wonderful opportunity to work on this project.

iii. Authorship

When writing and editing this paper, our process was very collaborative. To begin, each subsection was drafted by one person in the cohort. Then, others helped flesh out the section and update the section as new information came in. Last, the draft was edited by all cohort members to create the final blend of styles.

iv. Executive Summary

Our biggest advantage over other species is our ability to create things bigger than ourselves that complete challenges that never would have been possible alone. When it comes down to it, we can band together and focus everything on completing a project with high efficiency. Although, every advantage has its drawbacks. We tend to not consider the effects that our current projects will have on the future world. This leads us to the main issue of this project, the overabundance of carbon output in everyday society. To get a better picture of this widespread problem, we focused on one area of the United States: Arlington County, Virginia. In this area, there is an abnormally high vacancy rate of office buildings near the city center. Our project sponsor, Arlington County's Office of Sustainability and Environmental Management (OSEM) in the Department of Environmental Services, currently has a program called "Arlington's Initiative to Rethink Energy" (AIRE) that they are implementing to attempt a revitalization of these underused buildings. In addition to that, they are using the opportunity to find the best ways to lower carbon emissions in the buildings, while still making them more useful to the people. If buildings are renovated without sustainability in mind, then the cycle will just repeat, and nothing will change in the long run.

The most apparent case of this issue is underutilized office buildings. To get a grasp on this issue, the popular term "carbon footprint" needs to be defined in more detail. A carbon footprint can be broken up into 2 types: "embodied carbon" and "operational carbon." Operational carbon is more self-explanatory, it is the carbon emissions released from everyday use of the building, such as heating, cooling, ventilation, operating lights, or flushing toilets. This is the definition commonly used as a carbon footprint, but in reality, it is just a part of it. The other part, Embodied carbon, is more esoteric. It is the carbon released from the production of the building itself; From sourcing the materials to finishing the interior, the whole process produces a significant amount of carbon. This embodied carbon cost has been overlooked for most of modern engineering history. Nevertheless, it is imperative that it is minimized during construction. The best way to save on embodied carbon in the present is by taking an old building and retrofitting it into something more efficient. To meet this end, we offer a set of recommendations for building developers to use to reduce this carbon footprint.

The first step to helping developers is by understanding who is going to use the buildings in the area. We started gathering data on the surrounding community, the biggest part of which was a list from Arlington County's government of 124 office buildings in the county that were underused and in need of help. These types of buildings are the best for retrofitting because they offer the most potential for improving embodied carbon compared to just demolishing. This list was narrowed down by prioritizing the characteristics: building class, last major renovation date, and vacancy rate. After selecting a smaller set of buildings to investigate, we created several example reuses that would complement their overall histories and surroundings that keep embodied carbon to a minimum.

Based on city data statistics, we discovered that during the 2020-2021 pandemic, there was a significant decline in the majority of metrics, such as: population growth, employment, and utilization of buildings in the business sector. In 2022 and beyond, there was a noticeable bounce back in these statistics, showing that conditions in Arlington County have the capacity to support successful revitalization, they just need the right solutions applied to them for their potential to be realized. To get a better feel for the processes of adaptive reuse, we interviewed some professionals in the field. Based on their knowledge, we gained useful insight into the nuances of adaptive reuse.

After compiling all this data we obtained, we started to create our guide for the county, called the Evaluation Categories for Adaptive Reuse Projects Guide, or ECARP Guide. There are five categories of things to consider in our ECARP Guide: demand, surrounding assets, future proofing, operational carbon, and finally embodied carbon. The aim of our standards is not to outline a rigorous set of quantified standards, but instead to offer developers a process to think about what would work best for their own properties. To test this, we prepared several example reuse strategies using the rating categories of our standards. One such example would be an old office building that is retrofitted into a mixed-use building with luxury apartments on the higher floors with the bottom floors hosting a hydroponic farm, a brewery, and a restaurant. A reuse such as this would attract many new people to the area, as well as providing new things for the people already living nearby. Taking into account the current state of affairs in the county, we think that it would be best for them to incorporate these or similar standards into a government program that can educate

building developers on the best ways to implement building reuses save on embodied carbon, and help them realize the value of adding assets to the neighboring community is well worth the cost.

In the end, we must recognize that climate change is already happening and an important part of the path to move forward into a future of certainty is by helping the parts of society that contribute most to pollution and emissions to become something more beneficial to society than they were before.

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1. Introduction

Buildings that have been left vacant or unused create a less inviting atmosphere in neighborhoods around them, which negatively impacts the area's economy and reputation. Ever since the end of the COVID-19 pandemic, buildings have remained under-occupied in favor of remote work. This lack of use directly harms the reputation and desirability of these areas. By utilizing and revitalizing these spaces, the areas around them will have a better chance at developing an engaged and environmentally conscious community.

As of 2023, Arlington County has a high office vacancy rate of around 21.5% on average, equating to roughly nine million total square feet of vacant office space. This number increased from 15.2% in 2019 due to the COVID-19 pandemic and the resulting increase in reliance on remote work (Arlington Economic Development Community Planning, Housing & Development, 2023). The office buildings with these vacancies struggle to remain competitive in the commercial real estate market since there is such a low demand for their use. By shifting the office space to a new use that more closely aligns with community need, these buildings can become more economically stable and better support the local economy. Arlington County's Green Building Initiative intends to improve the use of these buildings while also helping to reduce their environmental impact. By retrofitting these buildings instead of demolishing and building new, the carbon emissions from building materials and construction can be diminished.

Our cohort helped Arlington County to expand its Green Building Initiative (GBI) in ways that will benefit the local community. We first identified new uses for an example office building by consulting with experts, identifying existing amenities in the neighborhood, and analyzing the county's demographics, which helped us to understand community needs in the area. Next, we obtained an analysis of the building's technical data from a County sponsored contractor to determine the overall compatibility of conversion to different uses. Lastly, our group identified building features that would function well together to decrease the carbon emissions of the lot, as well as provide a service to the area. By combining our technical research with an understanding of the community, we created a set of retrofitting guidelines to resolve Arlington County's problem with underutilized office infrastructure while helping to maintain its high standards for renewable infrastructure.

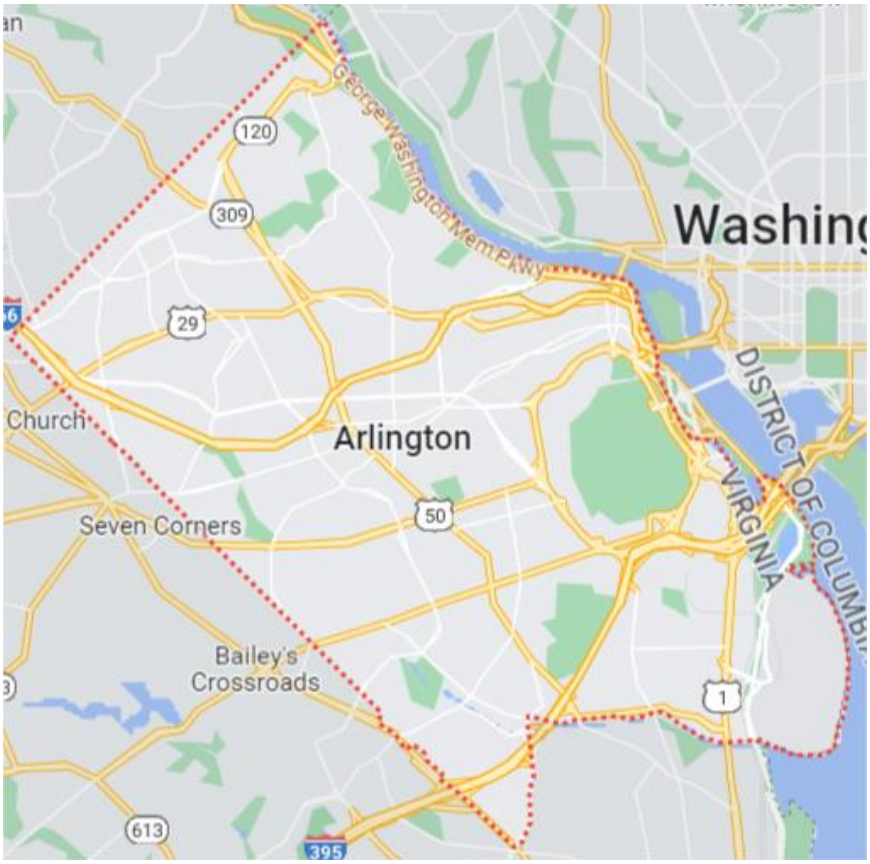
2. Background

This section will catalogue all of the preliminary research we did before coming to the project site. To start off, there is a brief history of Arlington County followed by an introduction of our sponsor, the Arlington County Office of Sustainability and Environmental Management. We will discuss how they work to meet the environmental goals of Arlington County through the Green Building Initiative (GBI). Next, we will explain the issue of vacant office space, which has become greatly exacerbated since the beginning of the COVID-19 pandemic. We will emphasize the relevance of this issue to Arlington County and then transition into a discussion of how to encourage new uses for these office buildings that can better support the economic and social needs of the community. After showing how the buildings can be reused, we will discuss both the planning required to retrofit a building as well as the actual process itself. While discussing the retrofitting process, we will emphasize the green building practices needed to reduce the overall carbon footprint.

2.1 History of Arlington County

In 1791, surveyors marked out a 100 square mile area spanning the Potomac River where the national capital would be built. In 1847, 25.8 square miles, the part of that area west of the Potomac River was seceded to the Commonwealth of Virginia. This area, as shown in Figure 1, contains modern day Arlington County. Surprisingly, the county is one of few in the United States that is not a city or town, but rather one continuous county, as ruled by the Supreme Court in 1922. Due to this, Arlington County has a unique government structure with a County Manager as the leader and three Deputy County Managers helping facilitate further responsibilities. Each deputy is the head of many different departments such as the Police Department or Economic Development (History of Arlington, 2023).

Figure 1 - *A map of Arlington County sourced from Google Maps.*



2.1.1 Arlington's Current Sustainability Efforts

Arlington County is nationally recognized for its efforts to create a sustainable urban community (Arlington County, Sustainability and Environment, n.d.). In fact, it was the first community in the United States to become LEED platinum certified. Currently, the Arlington government has a plan to become completely carbon neutral by 2050, named the Community Energy Plan (CEP). To further develop the CEP, the county formed a team back in 2008 within OSEM called the Arlington Initiative to Rethink Energy (AIRE). The AIRE team creates plans for improvements to energy usage, environmental impact, and upkeep of natural features in the County (Arlington County, Arlington Initiative to Rethink Energy, 2023).

2.1.2 Arlington's Green Building Initiative

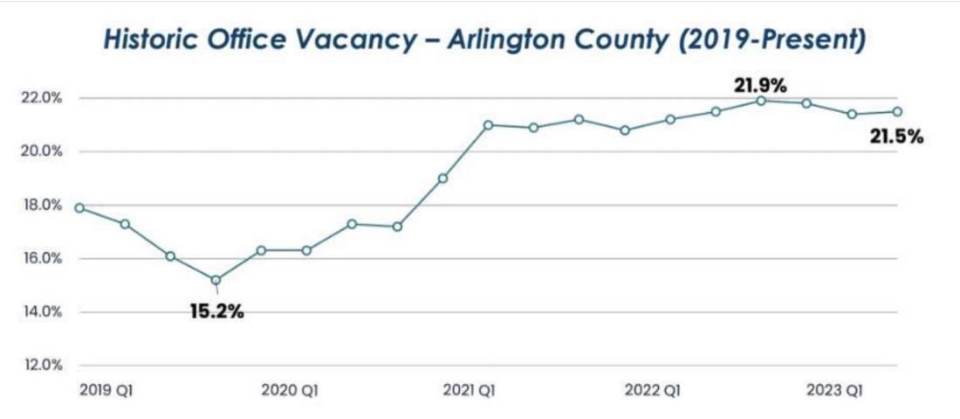
Arlington County has already succeeded in converting all of their government buildings to be carbon neutral, and now they are focusing on other building types in Arlington to meet this goal. To help convert more buildings, they started a new project called the Green Building Initiative (GBI).

This project's focus is awarding extra height or more rooms to developers who include sustainable efforts in their projects (Arlington County, Green Building Incentive Policy, 2023). This concept, known as bonus density, gives companies more space within a building to use, such as extra floors or more rooms, and is highly utilized when zoning retrofit projects.

2.2 Problems with Vacant Office Space

Ever since the COVID-19 pandemic, the demand for office space in urban areas has significantly decreased due to reliance on remote work (Poleg, 2023). This has left many of these spaces empty and underused. At the beginning of 2020, the office vacancy rate in the United States was 11.5%. It then increased to 15% during the height of the pandemic and as of late 2023, the vacancy rate has reached an all-time high of 16.1% (Colliers International, 2023). While office vacancies are an issue of national relevance, their impact on Arlington County has been especially problematic. The vacancy rate in Arlington County was 19.5% at the end of 2022. This was a significant increase from 16.6% at the end of 2020 (GazetteLeader, 2023). Figure 2 below shows the quarter-by-quarter vacancy rate in Arlington County from 2019 to 2023. Empty office buildings have the potential to negatively impact a city's community, especially in an evolving urban location like Arlington County.

Figure 2 - *Quarterly office vacancy rates in Arlington County during 2019 to 2023 (DeVoe, 2023)*



2.2.1 Economic Impacts of Office Vacancy

It is unlikely that the usage of empty office buildings will recover anytime soon since many people are not returning to work even as the pandemic is waning. This is due to several factors such

as fear of illness, mental health, and lack of access to childcare (Ferguson, 2023). Because of the reduced foot traffic from office workers, businesses in the surrounding area such as public transportation, restaurants, boutiques, and other retail outlets are losing the revenue they need to stay in business. In New York City, 40,000 retail sector jobs were lost in 2019 and have yet to return (Poleg, 2023). Additionally, local governments are losing revenue from wage and property taxes (Basiouny, 2022). Roughly half of Arlington County's tax base is from commercial real estate, so the empty office building crisis is having a major impact on their local economy (Beeton, 2023).

2.2.2 Retrofitting vs. Demolition

Vacant office buildings often need to be retrofitted or reconstructed to create new uses for the space. Retrofitting is when the existing materials and systems within a building are updated to increase energy performance and the overall lifespan of a building (U.S. Department of Energy, n.d.). Retrofitting is often cheaper and can be accomplished in a faster timeline than a full reconstruction of a building (Decuypere et al., 2016). The environmental impact of a retrofit is also significantly lower than reconstruction. According to the United Nations in 2016, if their complex had been demolished and replaced it would have taken 35-70 years before the increased operating efficiencies of the new building would offset the carbon emissions caused by the new construction (Khairi et al., 2017). Additionally, retrofitting projects produce 50-75% less carbon emissions than constructing a new identical building (Rosenbloom et al., 2023). This is due to the 11% of global greenhouse gas emissions produced from manufacturing building materials such as steel, concrete, and insulation. These emissions make up a building's total embodied carbon, which is the overall CO2 emissions produced during the entire life cycle of a building (Weir et al., 2023).

Despite the many advantages of retrofitting over demolition, demolition should still be considered for specific cases. For some buildings, the potential to retrofit may be limited by the main structure of the building, making significant changes more difficult and costly. Older buildings might need complete overhauls of internal systems, such as piping or ventilation systems because of their inefficiencies (Khairi et al., 2017). Poor utilization of the space given due to the limitations of technologies at the time of construction can lead to increased cost when attempting to make large scale changes. These changes might be extremely costly or require additional changes later in their lifecycle which can significantly harm the ROI (return on investment) of the building (Decuypere et al., 2016). Because of this, the demolition and later construction of a new building that is built with

sustainability and green capabilities in mind might be a better option. Nevertheless, retrofitting has the potential to greatly reduce the environmental impact of buildings and reduce a city's overall contribution to climate change.

2.3 Adaptive Reuse of Vacant Office Buildings

Many communities across the U.S., including Arlington County, are pursuing adaptive reuse to combat the empty office building crisis. In 2022, roughly 25% of all adaptive reuse projects in the U.S. involved converting vacant office buildings (M. Miller, 2022). In Arlington's neighbor, Washington DC, the Downtown DC Business Improvement District (BID) president (as of November 2023) was tracking 23 office-to-residential conversion projects, with four under active construction (Flynn & Brice-Saddler, 2023). Adaptive reuse is the process of revitalizing buildings that have outlived their original purpose (Jones, 2022). While it can involve historic preservation, the main goal is to develop new uses for a building that will bring it up to date with contemporary technological and social needs (Ward & Heiser, 2020).

In recent decades, the sustainability of adaptive reuse projects is becoming increasingly important since 11% of global greenhouse gas emissions come from building materials such as concrete, steel and insulation (Weir et al., 2023). A famous quote by architect and sustainability expert Carl Elefante states "The greenest building is the one that is already built" (Elefante, 2023). While adaptive reuse is increasing in popularity, there are challenges to overcome in converting a building from one use to another. Zoning codes, real estate values, and structural issues are a few examples of factors that need to be considered (Baker & Mo, 2023).

2.3.1 Commercial to Residential

In the 1990s and 2000s, New York City converted 59 office buildings into residential space for 12,000 apartments (examples of such a conversion are seen in Figure 3). This was done with a mix of relaxed zoning laws, streamlined planning procedures, and tax incentives (Poleg, 2023). However, retrofitting offices into residential buildings is not straightforward. The lighting, electricity, heating, air conditioning and plumbing in an office building are very different from that of an apartment building (Baker & Mo, 2023). Appliances such as stoves and refrigerators, which are more commonly found in residential buildings, draw a significant amount of power. Commercial buildings, in contrast, contain appliances and fixtures with lower power demands, such as lighting,

projectors and copy machines. Most office buildings also have centralized heating and air conditioning, whereas a residential building needs to have separate heating and cooling for each unit (Baker & Mo, 2023).

Figure 3 – *A floor plan conversion of office (left) to pod housing (right) (Omgivning, 2023)*

2.3.2 Commercial to Mixed Use

Another form of adaptive reuse of vacant office buildings is known as “mixed-use.” A mixed-use building is usually defined as a single building that houses three or more significantly sized and revenue producing businesses (Banas, 2020). Since mixed use often contains a residential component, it shares similar retrofitting challenges explained in the previous section. Examples of businesses that do well sharing building space with residential development include retail stores, restaurants, and entertainment venues (Banas, 2020). One advantage that mixed use buildings have over buildings with solely residential zoning is that they can reduce carbon emissions from transportation since people living in the development can simply use the businesses in their building without needing to drive a car or use public transit to access other businesses in the city (N. A. Miller & Miller, 2003). Despite the many advantages to mixed use development, it often has a higher upfront cost to construct and is more difficult to plan due to zoning policies (Ryle, 2022).

2.3.3 New and Emerging Uses

Due to the challenges of converting office space to residential or mixed use, developers are imagining other uses for empty office buildings. In response to the vacant office building crisis, Arlington County has started the process of modifying their zoning policies to allow for more uses

(Beeton, 2023). The list of uses proposed so far includes everything from packaging warehouses to higher education to makerspaces and urban agriculture (Beeton, 2023). Some of these uses like packaging warehouses and urban agriculture would be a commercial to industrial conversion while makerspaces would be a reclassification within commercial use since they would be open to the public. In Figure 4, a local business in Arlington County called Area 2 Farms repurposed an old paper company warehouse into an urban farm. While the existing building was already zoned for industrial use, it shows an example of indoor urban agriculture that could be adapted to work in vacant office buildings. In some of these cases, the existing office space needs little modification. Higher education can easily adapt to use the office space as is or put up a few walls for classrooms (Beeton, 2023). However, in cases such as urban agriculture, the modifications required would be more extensive.

Figure 4 – *An indoor farm used in Area 2 Farms in Arlington County, VA. (Source: Pender, 2023)*

2.4 City Planning for Adaptive Reuse Projects

Local governments need to prioritize both human health and the surrounding environment in their overall planning for their adaptive reuse projects to be as beneficial as they can be to their local community. For example, by planting more trees and expanding green space, a city can offset

carbon emissions and promote mental health at the same time. Making a city more walkable can reduce the emissions from vehicles while simultaneously encouraging people to be physically active (Cafasso, 2021). One strategy to achieve these goals is known as “smart growth”. To help understand smart growth, the Smart Growth Network developed a list of 10 basic principles as shown in Figure 5 below.

Figure 5 - *10 Basic Principles of Smart Growth. (Concord Greenspace, 2023)*

2.4.1 Defining Smart Growth

Smart growth can be defined as “a range of development and conservation strategies that help protect our health and natural environment and make our communities more attractive, economically stronger, and more socially diverse.” (SmartGrowth, 2015). Adaptive reuse projects are becoming crucial to the success of smart growth because they can achieve many principles on this list. For instance, an office to residential conversion helps to fulfill the principle “Various Housing Opportunities” (orange). Office to mixed use expands upon this by achieving “Attractive Communities” (pink) and “Transportation Choices” (light blue). One of the most important principles that all adaptive reuse projects fulfill is “Direct Development” (dark blue), which deals with the improvement of existing infrastructure. With any adaptive reuse project, it is also

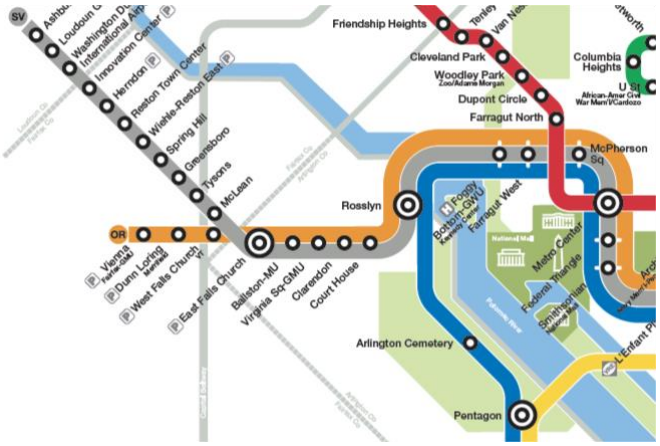
important to consider the principle of “Stakeholder Consideration” (teal), as it encourages community and stakeholder collaboration in development decisions.

One example of how “Stakeholder Consideration” plays a significant role in smart growth is in the East Russell neighborhood in Louisville, Kentucky. This predominantly Black urban community was declining in the late 1980s due to middle class residents moving to other areas of the city (U.S. Environmental Protection Agency, 2023). In 1992, a collaboration of local businesses, unions, foundations, nonprofits, philanthropic groups as well as federal, state, and city governments supported the construction or refurbishment of over 600 homes in the area (U.S. Enviromental Protection Agency, 2023). This contributed to substantial revitalization of the neighborhood, which has made it the community with the second highest property value increase in Louisville since 2000 (U.S. Environmental Protection Agency, 2023).

2.4.2 Smart Growth in Arlington County

Smart growth was a term coined in the early 1990s to describe a new approach to urban development. At its inception, smart growth was designed to combat urban sprawl (Knaap et al., 2022). Since then, its definition has adapted to include more contemporary issues such as climate change, social equity, and public health (Knaap et al., 2022). Arlington County is a pioneer in smart growth, even employing its strategies before the term was coined (Arlington County, n.d.). In the 1960s, during expansion of Washington, D.C.'s metro light rail system, Arlington County decided to concentrate mixed use development along the new orange line connecting Arlington to D.C. (Figure 6). This development became known as the “Bulls Eye” concept and has continued to increase walkability and transportation options (Arlington County, n.d.). In addition to reducing the urban sprawl of Arlington County, the “Bulls Eye” development has led to 40% of residents taking public transportation to work and 16% not owning cars (Arlington County, n.d.). Overall, this contributes to a major reduction in the area's carbon footprint (Arlington County, n.d.).

Figure 6 - *DC Metro Orange & Silver Line connecting Arlington to DC. (DC Metro, 2023)*



2.5 Best Practices of Green Building Design

In an adaptive reuse project, it is important to not only consider the individual efficiency, but also the environmental impact on the world around it. One way to mitigate this impact is by using innovative green building design practices such as increasing natural lighting, installing high efficiency HVAC (heating, ventilation, and air-conditioning), and reducing the quantity of Volatile Organic Compounds (VOCs) (Lockwood, 2006). Implementing these features would help a building become less harmful to the environment and more of a passive house. These standards ultimately lead to lower carbon emissions and would help a city achieve carbon neutrality over time (De La Garza, 2021). While green building features are important for lowering carbon emissions, the location and surrounding area can play an even greater role in the sustainability of a building. Arlington County is an ideal location for green building design since a lot of emissions that usually come from personal vehicles are offset by the vast public transit system.

2.5.1 Building Standards in the Real World

Every city has a wealth of preexisting buildings, so how can an owner of these properties begin to address environmental problems? Choosing between retrofitting or demolishing is the first step. No matter which option works best for the project, if the building is not redeveloped with sustainable modifications, the problems will persist. To counteract this, there are many different building standards that exist to tell the outside world that this building is not wasteful when the certification is earned.

The United States Green Building Council is a nonprofit organization with the goal of transforming the way that buildings are designed and operated. They are known for their widely used set of standards known as Leadership in Energy and Environmental Design (LEED). LEED outlines a system of standards that rate buildings' efficiency with criteria such as transportation, sustainable sites, water efficiency, and general atmosphere. (U.S. Green Building Council, 2023). As shown in Figure 7, LEED has 4 different levels of certification. The lowest is just "certified"," and then there is "silver," "gold," and at the top: "platinum." Buildings can earn points based on including different green building technologies and practices.

Figure 7 - *LEED Certification Levels (University of California Merced, 2023)*

Historically, LEED buildings have been rated based on their design plan and conceptual phase but have not been checked after the project is completed. Due to this, most of their requirements tend to be based in an ideal world and consequently have not always performed at their predicted levels. Note that LEED Version 4 has "an expanded focus on metering and monitoring, which encourages building owners to track energy, water, ventilation rates. With this, teams consider and work toward higher levels of performance for projects at every stage. (LEED Rating System). Despite this historic weakness, adopting building standards such as these are important because of the pressure developers face to add sustainable systems when designing new buildings or improvements. According to a study from Carnegie Mellon University, when a city enacts a policy requiring buildings to get a standard level of certification, the LEED score of the area per capita increases by an average of 0.02 (Adekanye, O. G., 2020). This shows that when building certifications are introduced, the overall quality of an area will increase.

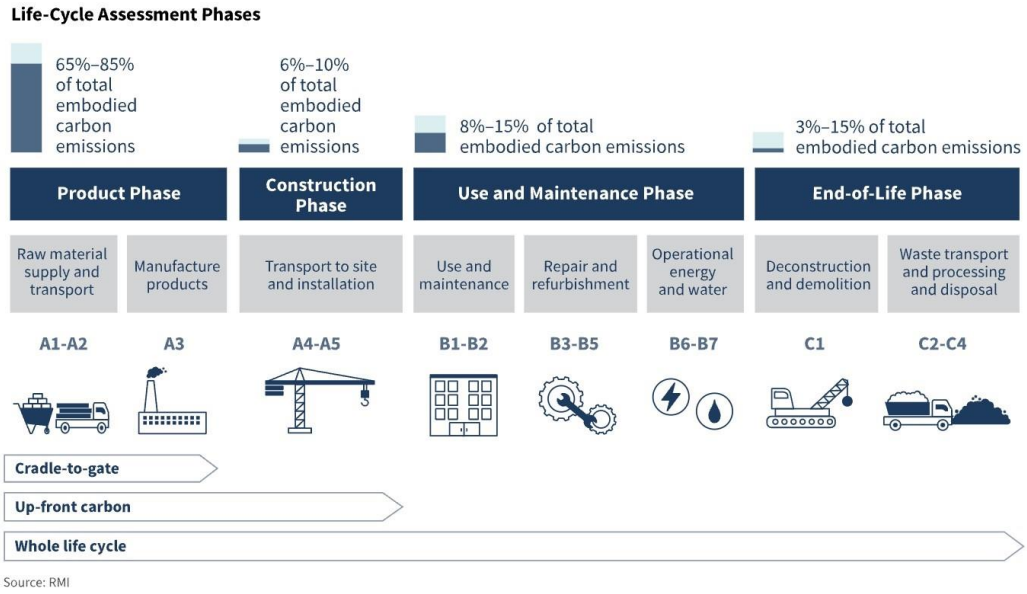
2.5.2 The Challenge of Sustainable Building

There are many organizations that want to throw their hat into the ring of solving the issue of building efficiency. Among them all, there is one who is known for creating the most rigorous set of standards of them all. This is the International Living Future Institute (ILFI). According to the ILFI, the world has not done enough in recent years to address climate change. They warn that the coming years will see scarcity of resources such as food and water, and that they aim for their standards to try and impact this downwards trend (International Living Future Institute, n.d.). Given the troubling circumstances, the ILFI outlined a set of standards called the "Living Building Standard," which sets out to define the way that a building can be completely self-sufficient in every way, from producing its own power to growing food for its inhabitants' lunch. It uses seven tenets, which it calls petals, to describe a way for buildings to have less of an impact on the world around them, decreasing its pollution. These tenets are titled as place, water, energy, health/happiness, materials, equity, and beauty. Although the goals of these standards are ambitious and important, the requirements are often out of the range for a typical green building project. These petals are not all-or-nothing, though, and can be individually achieved.

2.5.3 Defining Embodied Carbon

The main goal of any building hoping to become greener is to minimize carbon emissions. Up until recently, green building experts have mainly focused on reducing only the operational carbon emissions. Operational carbon refers to the CO2 emissions produced during everyday use and maintenance of a building. Currently, operational carbon accounts for 28% of greenhouse gas emissions which is greater than the 11% which comes from building materials. However, with an increase in construction, it is expected that the emissions from building materials will exceed operational emissions by 2050 (Underwriters Laboratories, 2020). The need to address carbon emissions from construction has led to the creation of a new term called embodied carbon. Embodied carbon describes the greenhouse gas emissions that occur during the lifespan of a building from the initial sourcing of material through end-of-life (Weir et al., 2023). Embodied carbon creates a more compressive picture of all the different types of emissions produced from a building. See in Figure 8 each phase of the building life cycle with what percentage of carbon emissions are produced during the respective phase.

Figure 8 - *Embodied carbon emissions produced in each building phase. (Weir et al., 2023)*



3. Methodology

The goal of this project is to identify sustainable and community driven adaptive reuse opportunities for high vacancy office buildings in Arlington County and educate local governments and developers on the benefits of adaptive reuse. To accomplish this goal, we have outlined three main objectives.

3.1 Objective 1:

Develop a Social and Environmental Profile of Arlington County Through Community Data to Better Inform Adaptive Reuse of Buildings

The purpose of this objective is to gain a better understanding of Arlington County's people, economy, and environment in order to determine adaptive reuse strategies which are compatible with the community in Objective 3. To complete this, we analyzed the county's demographics and local news to understand the people that currently live in Arlington County. We then gathered data on the county's zoning policies and housing market to gauge the overall demand for housing and current development trends in the county. For the final data collection in this objective, we looked at health and environmental data to identify any potential socioeconomically vulnerable areas of the county as well as any potential climate risks to buildings in the area.

3.1.1 Demographic Data

We gathered demographic data such as population, income, unemployment rate, age, and educational attainment through the U.S. Census, City-Data.com and the Arlington County 2023 Profile developed by their department of Community Planning, Housing and Development (CPHD). We used this data to understand any general trends in the county's population and economy. Next, to develop a more thorough profile of people living in Arlington, we used the Claritas Potential Rating Index for Zip Markets (PRIZM) tool to identify the top demographic groups in the county and their needs, desires and behaviors. We also supplemented this data through an analysis of local Arlington news sources such as ARLnow, WTOP, and GazetteLeader. This involved scanning each publication's website over the past year to find any significant issues, events and activities in the county.

3.1.2 Zoning, Development and Housing Data

We gathered zoning and housing data through the Arlington County 2023 Profile. This document contains a map of the zoning for each section of the county and the three main development corridors: Rosslyn-Ballston, Columbia Pike and Richmond Highway. We used this map to determine areas with high potential for adaptive reuse if they are rezoned. For housing data, we gathered metrics such as total new housing units, housing unit types, average assessed value, average apartment rent and number of committed affordable units. The purpose of this data was to assess the current housing market in Arlington and determine if converting an existing office building to residential could be beneficial for increasing affordable housing.

In addition to gathering data from the county's 2023 profile, we conducted a semi-structured interview with Elizabeth King, a commercial development specialist from Arlington Economic Development (AED). AED is an economic development agency which partners with the Arlington government to help achieve their building development goals. See Appendix B for sample questions. The goal of this interview was to better understand the challenges that Arlington County is facing in the commercial real estate market and how adaptive reuse could be a potential solution to the problem.

3.1.3 Health and Environmental Data

We sourced data on citizen health from Arlington County's Community Health Dashboard. We used their health equity index map developed by the Conduent Healthy Communities Institute. The health equity map measures socioeconomic need that is correlated with poor health outcomes. We also used their food insecurity index map which is a measure of food access correlated with economic and household hardship. For environmental data, we used the EPA's Environmental Justice Screening Tool to map the county's flood risk and the 100-year flood plain.

3.2 Objective 2:

Evaluate Vacant Office Buildings in Arlington County and Select One of Them for Proposed Adaptive Reuse Solutions

In this objective, we started by analyzing a list of office buildings in Arlington County to determine potential candidates for adaptive reuse. We narrowed down the list of buildings based on metrics like vacancy and age to find a few examples that we could use to tailor our recommendations to Arlington County. Next, we interviewed experts in green building infrastructure to better understand how adaptive reuse can help to make buildings more sustainable. With the help of the county's Green Building Program Manager Paul Roman, the embodied carbon and operational carbon impact of adaptive reuse and new construction was calculated for the example buildings.

3.2.1 Building Selection Process

Elizabeth King from Arlington Economic Development provided us with a list of 124 underused office buildings in Arlington. After obtaining this data, we started by sifting through and narrowing down which buildings to look at as the best examples to learn from for the purposes of this project. The dataset had a wide range of information, but not all of it was relevant. In order to find the most ideal retrofit candidates we decided that the building we looked at should have the following criteria: built before 2000, vacancy rate of greater than 50%, and no history of retrofits since construction. We also believed that the building class should be either B or C, since a higher class would offer less room for improvement. A building's vacancy rate being high means that it is not being well utilized. We did not want our recommendations being used to displace existing usage of the space, so the emphasis was placed on buildings with higher vacancy rates. By cross-checking

all these criteria with each other, a short list of the best few buildings was produced. Our sponsor Demetra McBride contacted the owners of the buildings from this list to secure physical tours of the buildings. This would be helpful to our cohort so that we could more closely inspect the building's interior and energy systems, learn more about how they worked, and learn about how easily they could be replaced. For buildings that we did not get to tour, we inspected the exteriors using Google Maps to identify any significant features that might be useful for an adaptive reuse project.

3.2.2 Green Building Interviews

To better understand how specific building features affect the sustainability of an adaptive reuse project, we conducted a number of semi-structured interviews with experts on green buildings, embodied carbon and building renovation. The first person we interviewed was Paul Roman, the Green Building Program Manager for Arlington County. We asked him about green building incentives in the county, what building features are typically upgraded in an adaptive reuse project and which green building features can lead to the greatest reduction in carbon emissions. The next interview was with Roland K. Butzke, who is an Account Executive from Siemens. His specialty was similar to Roman's, but since he has more experience in planning renovation projects, we asked him specifically about zoning, community input and financial aspects of retrofitting. The next person we interviewed was Marta Shantz, workplan manager for the Urban Land Institute. To target her expertise, we asked about the usage of embodied carbon calculators in the industry, and how they can be used to optimize the sustainability of adaptive reuse projects. The final interviewee was Abby Flores who is an Architect and Program Manager at the consulting firm Gensler. Since her focus is on the conversion of office buildings into residential space, we asked her questions about what aspects of a building make it fit for such a conversion.

3.2.3 CARE Tool Embodied Carbon Analysis

Through the interviews with Marta Schantz and Paul Roman, we learned about the Carbon Avoided: Retrofit Estimated (CARE) Tool developed by Architecture 2030. The purpose of this tool is to estimate and compare the carbon impacts of adaptive reuse with new construction. Roman explained to us how the tool uses parameters such as the buildings characteristics (total floor area, number of floors), building usage (multi-family residential, etc.), percentage of reuse, and the county's energy reduction targets to determine the total embodied and operational carbon of

adaptive reuse and new construction. It also estimates the carbon impact if nothing is done to the current building. The tool produces graphs of the total carbon over 30 years as well as how the carbon changes over time. This change overtime graph can be extrapolated to 50 years or more. After getting an overview of the tool from our interviews, Paul Roman was able to do a professional analysis of the 10 buildings from our list to determine how the new usage of the buildings could impact the overall carbon footprint. We used the results of this analysis to ascertain which method would be better for each given building.

3.3 Objective 3:

Develop Retrofit Strategies that Will Allow the Selected Building to Be Repurposed According to the Needs and Desires of the Local Community, and Assess the Sustainability Impacts of Such a Transition

The third objective combines our findings from Objectives 1 and 2 to identify adaptive reuse strategies for office buildings in Arlington that are compatible with the community. We determined potential new building reuses using Objective 1's research on the county's demographic data, economy and environment. Next, we identified the top new uses and combined them together to create mixed-used examples that encourage community engagement, sustainability, health and wellness. Then, using Objective 2 data we evaluated how well the existing structures of our top example office buildings would work with the mixed-used examples. The last part of this objective outlines a guide we made for adaptive reuse projects based on our findings in Arlington County. This guide is called the Evaluation Categories for Adaptive Reuse Projects Guide (ECARP Guide), which rates projects based on a variety of social and technical categories.

3.3.1 Evaluation of Potential New Uses for Underused Office Buildings

Using the social, economic and environmental factors we identified in Objective 1, we brainstormed potential new uses for underused office buildings. The uses were separated into two main categories: primary and secondary. The primary uses are more residential, with living spaces making up a large portion of the building. The secondary uses are mostly services and amenities that utilize the ground floor space. This allows residents to have easy access to services and amenities that may otherwise be difficult to reach, while still keeping them available to the public. This mixed use creates a level of community engagement in which all parties benefit.

3.3.2 Adaptive Reuse Examples for the Arlington County Community

After individual analysis of each reuse, we combined the primary and secondary uses together to form four examples of mixed-use strategies. This involved taking one of the primary residential uses and combining it with two or more compatible secondary uses. We paired up uses that support each other in terms of increasing quality of life or positively impacting the environment. For instance, an easily accessible health clinic for senior citizens and an urban farm that can supply residents with food without producing the emissions associated with transportation would make a good pair. In addition to ensuring that the adaptive reuse examples support the community and environment, we also considered how well they might integrate with existing features of our example buildings such as parking spaces, plazas, ground floor area, roof space and windows.

3.3.3 Evaluation Categories for Adaptive Reuse Projects (ECARP)

In our final deliverable to the county, we developed a guide called the Evaluation Categories for Adaptive Reuse Project (ECARP) Guide to educate and assist developers in successfully pursuing adaptive reuse projects. This guide was developed by our group from observations we made during the process of collecting community data and interviewing green building experts. Our group decided to focus on the community engagement and sustainability aspects of adaptive reuse projects to help ensure that developers are reusing a building in an impactful way that actively supports the area in question. We developed a set of core categories relating to community engagement and sustainability that can be used by developers to evaluate their projects. While the categories were developed based on analysis of Arlington County, the intention is that it could be used by any developer in any jurisdiction.

4. Results & Discussion

In this chapter, we will present and discuss the results produced by the methods outlined above. Each section mirrors its counterpart methodology section to make cross referencing easier.

4.1 Objective 1:

Develop a Social and Environmental Profile of Arlington County Through Community Data to Better Inform Adaptive Reuse of Buildings

Arlington County is a young, highly educated and affluent community with low unemployment and many jobs in the government, business and technology sectors. Most of the county is zoned for residential use, however, there remains a great need for housing. To increase housing, some areas are being rezoned as mixed use in order to allow office space to be adapted to residential. The Columbia Pike area is slightly less affluent, has less access to health care and food, and is at greater risk of flooding and pollution.

4.1.1 Demographic Data

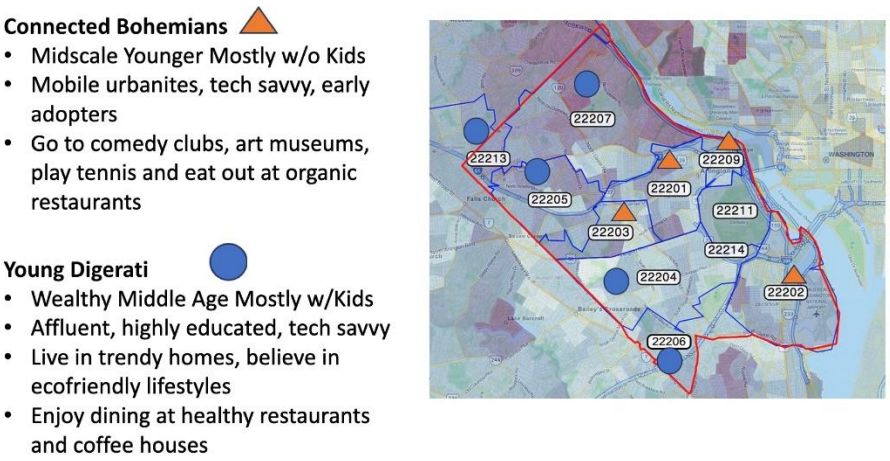
The U.S. Census shows that the county's population was 238,643 at the 2020 census, but then declined during the pandemic. The estimate for 2022 was 234,000 (U.S. Census Bureau, 2022). However, according to the Arlington County Community Planning, Housing and Development Department (CPHD), the population has increased bringing the 2023 estimate to 237,300 (Arlington CPHD, 2023). This shows that the area is still a desirable place to live, since they were able to bounce back quickly from such a large decline in population.

The U.S. Census lists the median household income of county residents as $137,387 in 2022 which is slightly higher compared to that of the DMV (District of Columbia, Maryland, and Virginia) area, which sits at $111,252 (City-Data, 2023). The unemployment rate in the county decreased by 1% from 2021-2022 and now stands at 2.1% compared to the rest of the DMV which is at 3.4% (Data USA, 2023). According to CPHD, the major industries in the county are professional and technical services, which account for 27.6% percent of jobs followed by other services (21.3%) and government (20.8%). Some of the top private employers in the county are Accenture (business services), Amazon (electronic shopping), Bloomberg BNA (legal, tax and business news), Lidl (grocery stores), Nestle (food) and the Virginia Hospital Center (medical services) (Arlington CPHD, 2023). Considering the median income, unemployment rate, major industries and employers combined we see that Arlington is a wealthy community with a strong economy and lots of businesses in the technology and government sectors.

Looking at the distribution of age groups from the local CPHD data, the largest group in the county is 25–34-year-olds, with an overall median of 35.1 years (Arlington CPHD, 2023). Compared to the median national age of 38.9 years, Arlington has a relatively young population. In addition to

having a young population, the county is also highly educated with 76% of people aged 25 or older having earned a bachelor's degree or higher (City-Data, 2023).

Figure 9 – *Zip Code Analysis of Arlington County Demographic Groups (Map Source: ARLnow, 2015)*



Using the Claritas Potential Rating Index for Zip Markets (PRIZM) tool, we identified the top 5 demographic groups in each zip code of the county. Each demographic group is given a distinctive name such as "Connected Bohemians" in order to more easily distinguish between them. Please see Appendix C for the full list of groups and their descriptions. Displayed in figure 9 above are two groups that showed up most frequently in Arlington zip codes. Both groups share similar interests and behaviors such as being tech savvy and enjoying healthy dining. Group 1 is younger than group 2 and tends to not have children. They also dwell in more urban areas of the county such as the Rosslyn-Ballston corridor (22209, 22201, 2203) and Crystal City (22202). Group 2 is slightly older than group 1 and is more likely to have kids. They are in the more suburban areas of the county and are more affluent and highly educated.

In our analysis of local news, a list of which can be found in Appendix D, we found that in addition to having an abundance of jobs in the technology and government sectors, there were also a large amount of successful tech startups. Most of them tended to be software companies, examples including GoTab (an online food ordering platform), Brazen (which manages virtual career fairs & online hiring), Interos (financial tech), and Govini (machine learning). Another observation that we made from local news is that Arlington is a physically active community with many bikers, runners

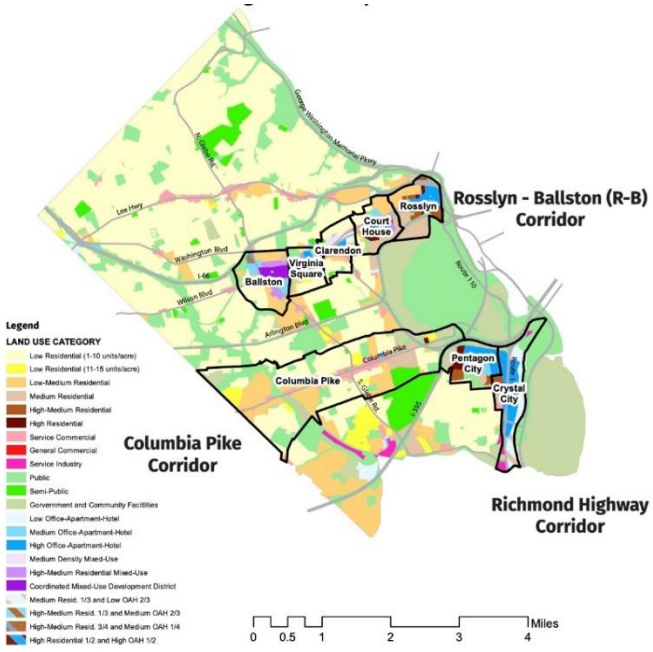
and swimmers. Arlington is also a very dog-friendly community; one article from ARLnow states that the county was ranked number one in the U.S. by Yelp in terms of dog friendliness. A prime example of this is the county's active Animal Welfare League.

Another major observation we made from local news articles is that Arlington is frequently getting new restaurants, markets and boutiques. Many of the restaurants serve healthy food and the markets often place an emphasis on local businesses. In 2022, the real estate investment trust company JBG Smith began redeveloping a water park in Crystal City to include a set of food kiosks. They signed a deal with 9 local restaurants to serve a diverse range of cuisines.

4.1.2 Zoning and Housing Data

In the Arlington County 2023 Profile, 53% of residents are listed as living in one of three major planning corridors. These planning corridors show high potential for new jobs especially in Rosslyn-Ballston corridor where most of the county's development is taking place and Richmond Highway where the new Amazon HQ2 is located (Arlington CPHD, 2023). In Figure 10 below, we examine the zoning of these corridors:

Figure 10 – *A map of Arlington County's 3 major development corridors and the land use zoning for each area of the county*



Based on this, we can see that most areas of county are zoned for some type of residential use. Columbia Pike and parts of Rosslyn-Ballston are predominantly residential while Richmond Highway has more mixed used with a significant area of office-apartment-hotel zoning (blue). The Ballston section of the R-B corridor has a large coordinated mixed-use development district (purple) which is potentially helpful in aiding adaptive reuse projects.

According to the 2023 Profile, 70% of committed affordable housing units are in the 3 development corridors. To increase affordable housing, 5,800 units have been added in the past 5 years, about a 1% increase each year. Despite the increase in housing, average apartment rents and assessed housing values continue to increase. Average apartment rent increased 3.4% from 2020-2021. Additionally, the assessed values of houses and condominiums increased 3.5% from 2022 to 2023. While the housing market is expensive in Arlington, there are still many younger people moving to the area to work in the technology sector. Many of these people rent instead of owning their residential space as evidenced by 57% of the county being renters. Additionally, 54.4% of housing is single non-family units (Arlington CPHD, 2023).

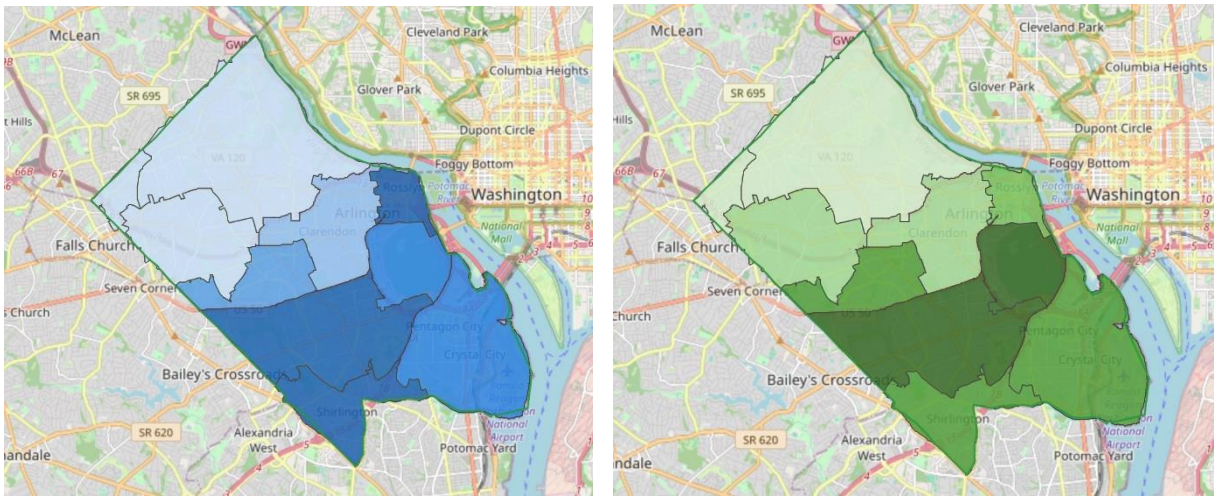
In our interview with Elizabeth King from Arlington Economic Development, she explained how retrofitting vacant office buildings could help to reduce housing costs in Arlington County by creating a greater abundance of housing. However, she warned that since many of the commercial buildings in the county were built specifically for office use, it is now very challenging to convert them into residential. This is why she said we should consider luxury housing in our study, since wealthier individuals might be more willing to pay for the upgraded and green features in an adaptive reuse project. For this reason, in Objective 3, we included this option in one of our mixed-use examples.

4.1.3 Health and Environmental Data

In terms of health equity and food insecurity, the areas in Arlington of greatest need are in the southern parts of the county closer to Alexandria, VA as shown in Figure 11 below. This area is in the Columbia Pike corridor which is the only area of the county where less than 70% of the population is white. Racial disparities with corresponding lower incomes have led to this area having less access to healthcare and food. In designing adaptive reuse projects for this area, it is

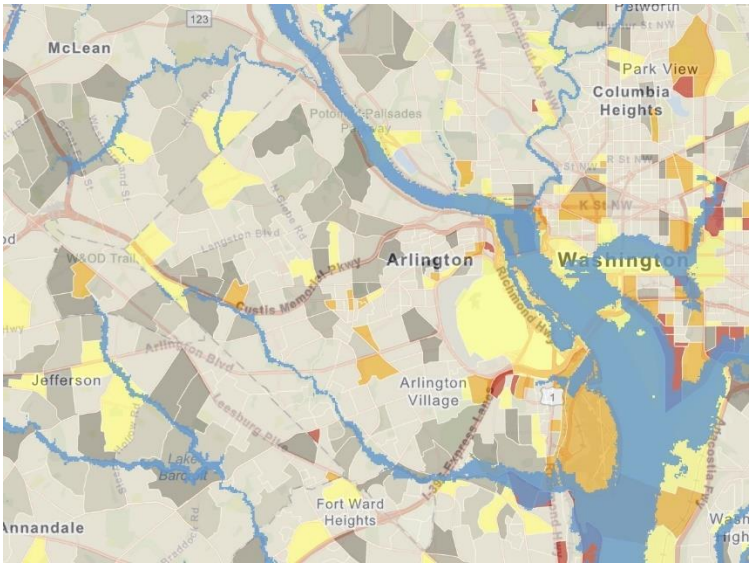
important to consider how the new use of an existing building could help to better serve these communities.

Figure 11 – *A map of Arlington County's Health Equity Index (blue) and Food Insecurity Index (green), darker color means an area of greater need*



For environmental data, the flood risk and 100-year floodplain for Arlington was mapped through the EPA's Environmental Justice Screening Tool. In Figure 12 below, we can see that the areas with the greatest flood risk include Arlington Cemetery, Washington National Airport and Crystal City. There is also flood risk in areas close to Four Mile Run, which is a large stream that flows through south Arlington and empties into the Potomac River. If a developer is interested in pursuing adaptive reuse of a building in Arlington County, they should examine the localized area that the building is in and consider how they might need to design the structure to be more resilient for future flood events.

Figure 12 – *Map of Flood Risk in Arlington County compared to U.S. overall. Yellow is 80-90 percentile; light grey is 50-60 percentile. Dark Blue denotes the 100-year floodplain.*



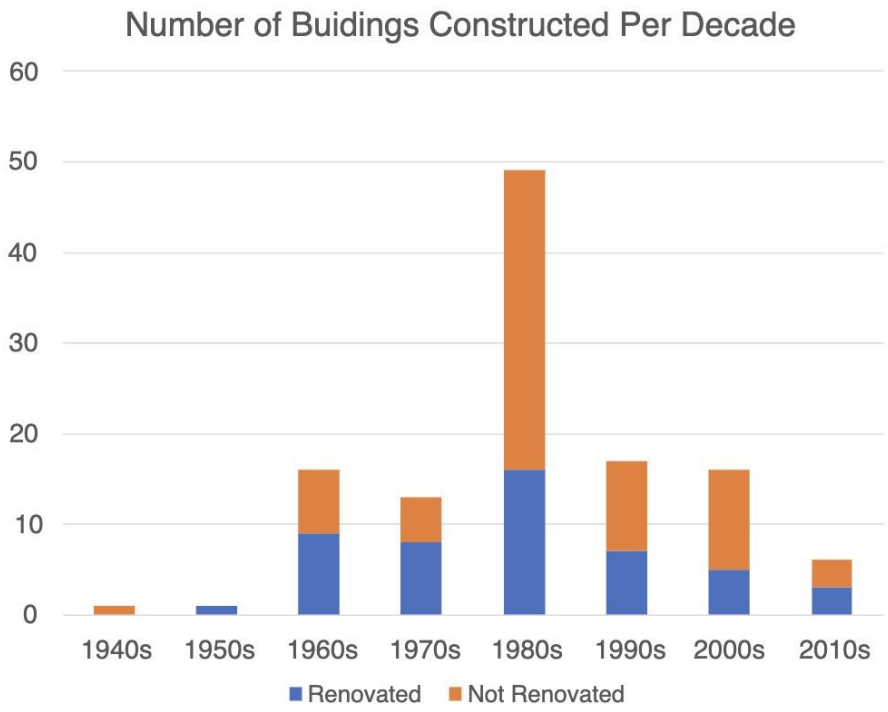
4.2 Objective 2:

Evaluate Vacant Office Buildings in Arlington County and Select One of them for Proposed Adaptive Reuses

4.2.1 Building Selection Process

In the list of 124 office buildings from Arlington Economic Development, there was an average vacancy of 31.7%, which is the percentage of total vacant floor space. Most of the buildings were built between 1960 and 2000 with a large number (49) of them being built in the 1980s (see Figure 13 below). Fifty of the 124 buildings have been partially renovated in the last 2 decades for office use. Last, 75 of the buildings are class A with all the remaining buildings being class B except for one which is class C.

Figure 13 – *A graph of how many buildings from the AED list were built per decade and their renovation status.*



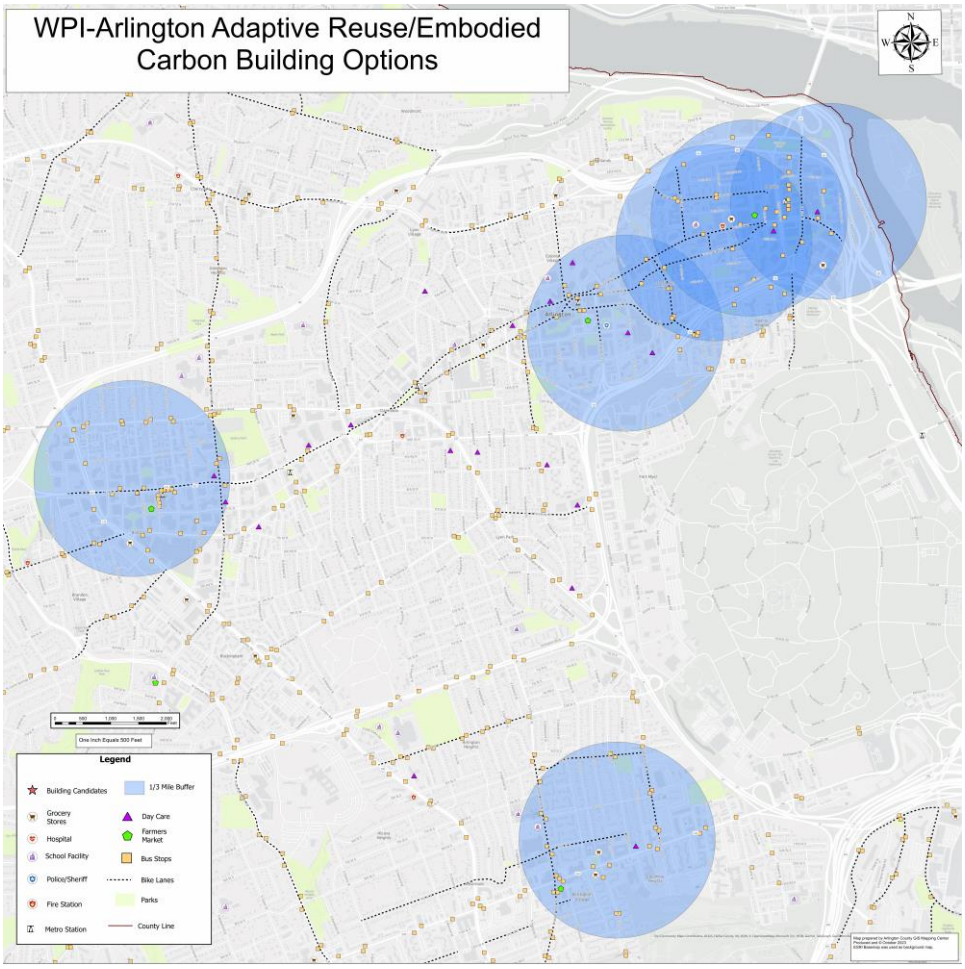
After narrowing the large list of buildings to six, we had 5 left with a vacancy greater than 50% as shown in table below. The sixth property has a vacancy of only 14%, however it was included in the final list because it is an older class B building constructed in 1968 which means it likely has aging and outdated systems. Due to confidentiality requests, we are unable to disclose the specific addresses of these properties. Instead, the building's approximate location within Arlington County is listed in the table. In addition to the high vacancy and/or vintage, all of these buildings have never been renovated, which is another motivation to pursue retrofitting or adaptive reuse. The last column is building class, which shows that most of the properties have a lower quality class B rating while two of them have the higher quality class A rating. One likely reason for these two properties having a class A rating is due to their slightly newer construction in 1986 and 1990. However, they still have a rather high vacancy percentage, meaning they were worth considering despite having greater existing performance.

Table 1 - *A table showing the top six properties selected from the initial AED list*

Property #	Building Neighborhood	Vacancy %	Year Built	Building Class
1	Rosslyn	66.9	1966	B
2	Courthouse	62.4	1987	B
3	Arlington Village	59.6	1970	B
4	Ballston	51.9	1990	A
5	Rosslyn	59.2	1986	A
6	Rosslyn	14.9	1968	B

Next, we submitted the list to the Arlington County GIS department to map the surrounding assets to these buildings. Again, due to confidentiality requests we cannot show the exact locations on the map, however an approximate 1/3-mile radius is shown in Figure 14 below. Most of the buildings are located along the main Roslyn-Ballston corridor of Arlington. This closely follows the Washington Metro heavy rail Orange Line train which means that five of these buildings are located within 1/3 mile or less of a Metro stop. The building located in Arlington Village notably lacks easy access to a Metro stop, however it still has many buses stops. In addition to the Arlington Village building lacking a metro stop there are some other amenities missing around the other buildings. The Ballston property is missing a nearby school, fire station and police station. The Arlington Village building is also missing a fire station and police station. Due to both these properties lacking these crucial services nearby, they were removed from the list.

Figure 14 – *Map that highlights locations helpful to everyday life. The blue circles are 1/3-mile radius that have a vacant office building somewhere within, the exact locations are hidden for privacy reasons.*



The four remaining buildings were all within 1/3 mile of each other and shared similar amenities. We selected the Courthouse property because the owner allowed us to tour the building to gather further information. While this property is not the oldest on the list, it does have the second highest vacancy rate and is close to the Courthouse Metro stop, a farmers' market, police station, school and day care. It is also in the heart of the Roslyn-Ballston corridor with lots of bike lanes and parks in proximity. Upon touring the building, we discovered that the bottom floor is leased by a business and the other floors are vacant. Some of the vacant floors are completely empty with no carpeting, walls, or ceiling tiles while others have been recently renovated for office use. A few of the building systems have been updated such as the elevators and lighting, but the main systems such as heating, cooling and fire safety have changed little since the property was built in 1987. The

building has a simple rectangular floor plate and an average slab height of ten feet. This means it would likely work well for residential conversion which works best with square and rectangular shaped spaces as well as an acceptable floor to ceiling heights. In terms of the roof, we noticed that aside from a few smaller rooms and a cooling tower there is a decent amount of space for potential greenery, solar panels, a rooftop terrace, or other amenities. Next, looking at the ground level there is a large, covered plaza and an open space next to the building which could be used as a seating area for a restaurant, playground for a daycare, dog park or other outdoor amenity. Lastly, the building has a multi-level below ground parking garage which could be adapted to include amenities such indoor sports or laundry rooms. However, the space could also be used to house new sustainable building features. Adding systems like battery storage or water recycling tanks could increase the sustainability of the building while also taking advantage of the underutilized space.

4.2.2 Green Building Interviews

Paul Roman, the Green Building Program Manager for Arlington County, was our first interviewee. He told us about how the GBI program is strongly recommending that every new building project should update to LEED Gold. To meet this standard, retrofitting projects should be focusing on lowering operational and embodied carbon. He explained that the best ways to reduce operational carbon emissions include improving water efficiency, installing LED lighting, electrifying heating systems, adding daylight sensors to conserve artificial lighting usage, and installing renewable energy systems such as solar panels. Meanwhile, the best ways to reduce embodied carbon in existing buildings would be to renovate walls and ceilings with more sustainable materials, utilizing Forest Stewardship Council (FSC) wood, using recycled content in carpeting and ceilings, using lower-carbon concrete, and participating in material takeback programs. Our next interviewee was Roland K. Butzke, an Account Executive for Siemens. When we asked Butzke about adaptive reuse standards, he explained the dangers of blindly designing to a set of standards. Adaptive reuse projects have many moving parts, so it is easy to overlook something during development.

After learning about the planning and standards involved in adaptive reuse from Roman and Butzke, we then looked at the specific tools used in the process. We first interviewed Marta Schantz, a Workplan Manager for the Urban Land Institute, who told us about the industry's way of categorizing the stages of a building. The stages are broken up Product (A), Construction (B), End of

Life (C), and Beyond Life Cycle (D). Each stage is further broken into substages (ex. A1, A2) as needed to show each major step in the building's life. The most important part of this was how operational carbon comes from a portion of stage B and the rest produces embodied carbon. This is contrary to popular belief where embodied carbon is some small aspect of a building's carbon footprint but in actuality, it is the majority.

During our next interview with Abbe Flores, an Architect and Project Manager for Gensler, we learned about how existing buildings are assessed for adaptive reuse. The company that she is a part of, Gensler, uses their own scoring criteria to determine the compatibility of a retrofit. Their biggest considerations with 30% each are a building's form and its floor plate. The form of the building is so important because if a building has an awkward shape, then it is going to be difficult to put new uses into that space. Similarly, it is desirable to have as few holes in the floor plate as possible because each one only lowers the structural integrity by a small bit, but they really add up. Each hole is also another space for heat to escape from, lowering the efficiency of the building. The next most important category is the servicing at 20%. This takes the parking and actual state of repair of the building into account. Tied for last at 10% is site context and envelope. Despite being the smallest percentage, the site context and envelope do matter quite a bit. The context of the site refers to the structure's neighbor buildings and the general zoning of the area. The envelope encompasses a building's exterior, which is responsible for protection of the interior from the outside elements.

4.2.3 CARE Tool Embodied Carbon Analysis

In such a densely populated area, we reasoned that setting up a reuse plan involving multiple uses would be both more useful for the county as well as being an attractive new destination for the county's residents. Our top building choices were evaluated using the CARE tool mentioned previously. Due to our cohort's relative inexperience with the hard data involved, and the expertise required to use the CARE tool, these calculations were done by Paul Roman, from the Arlington County government. These calculations allowed for a high-level comparison of the predicted carbon impact of an adaptive reuse project versus new building construction. Using this data, we can more accurately assess the buildings in Arlington County that we deemed ideal for retrofitting.

One of the main goals of adaptive reuse is to lower the carbon footprint of the building. The calculations for how drastically this footprint can be lowered are dependent on the existing building's floorplan, construction materials used, and preexisting infrastructure. Each of our adaptive reuse assessments were done for multi-family apartments with mixed use on the bottom floor. This approach would offer the best insight into a range of uses we intend for the county to utilize. An assessment of one of these buildings is shown in Figures 15 and 16. Figure 16 shows a comparison of the three options over a 30-year period. The first option is to do nothing, which is the total operational carbon cost to maintain the building at its current state. Reuse & Addition is a combination of the embodied carbon cost required for new installations, such as building systems or insulation, combined with the new operational carbon cost with the new infrastructure in place. Lastly, creating an entirely new building would be the combination of the total embodied carbon cost for demolition and reconstruction for a larger building as well as the operation carbon costs after construction. Figure 16 shows another visualization of the same data, offering a timeline of carbon emissions over the same 30-year period.

Figure 15 – *Total Embodied and Operation Carbon Emissions of Courthouse Area Property Adaptive Reuse and New Construction over 30 Years*

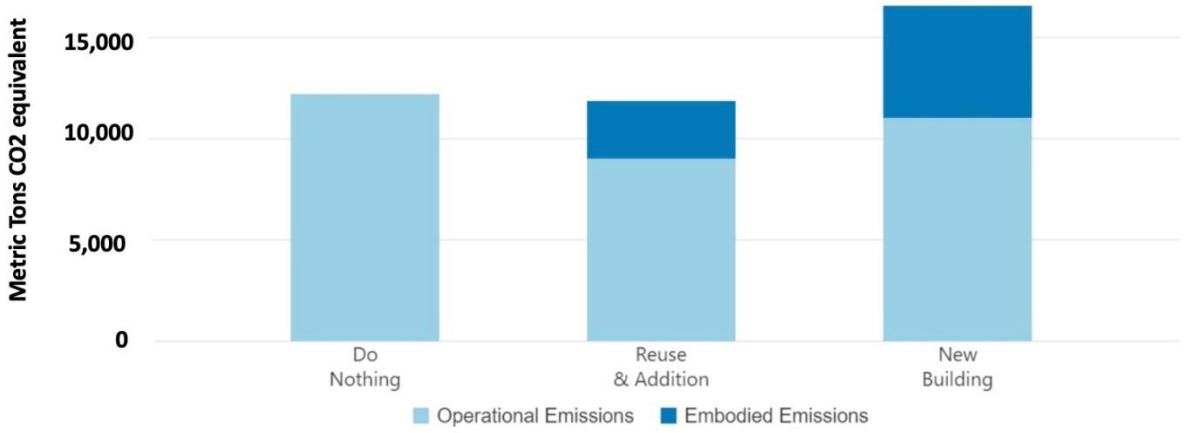
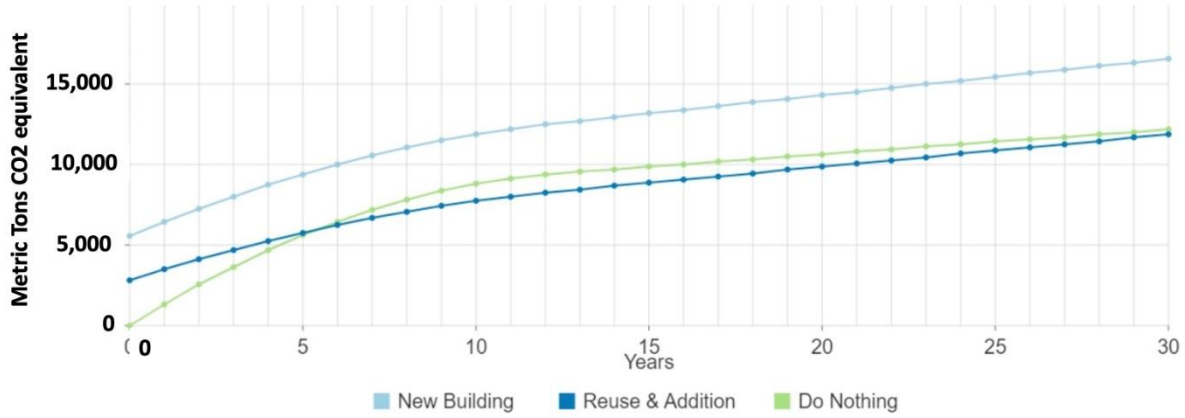


Figure 16 – *Cumulative Carbon Emissions over time for Courthouse Property Adaptive Reuse and New Construction*



A better example for adaptive reuse can be seen in Figures 17 and 18. This example shows the potential that adaptive reuse can have for reducing the carbon footprint of existing buildings. This data can also show how new construction should only be seen as a last resort. Although a new construction would allow for an almost 50% reduction in operational carbon cost, this is offset by the embodied carbon required when demolishing and reconstructing. Figure 18 illustrates how negligible this difference is over a 30-year period by showing how similar the carbon footprint is after 10 years.

Figure 17 – *Total Embodied and Operational Carbon Emissions of Arlington Village Property Adaptive Reuse and New Construction over 30 Years*

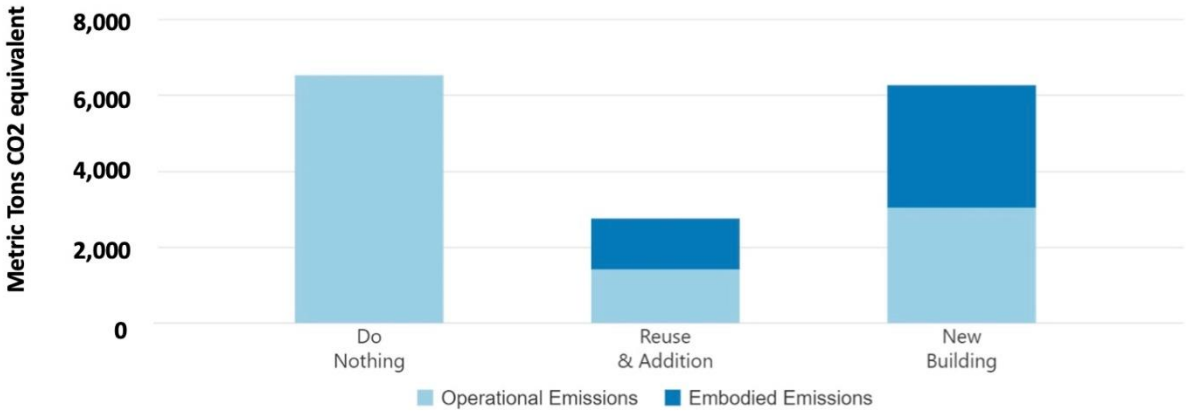
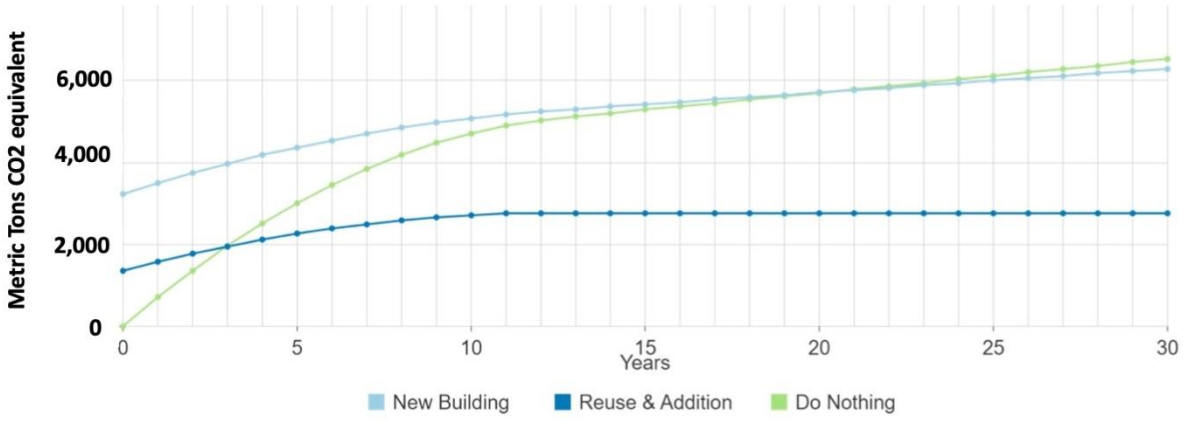


Figure 18 – *Cumulative Carbon Emissions over time for Arlington Village Property Adaptive Reuse and New Construction*



4.3 Objective 3:

Develop Retrofit Strategies that Will Allow the Selected Building to Be Repurposed According to the Needs and Desires of the Local Community, and Assess the Sustainability Impacts of Such a Transition

Using the community data we obtained in Objective 1, we brainstormed 4 different types of residential space to be the primary use for office buildings in Arlington. We then brainstormed a set of secondary uses that can provide building residents with food, entertainment, and other amenities. These primary and secondary uses were then combined into 4 mixed-use examples of adaptive reuse that we recommend for Arlington County. Finally, using what we learned about the office buildings in Arlington and green building infrastructure in Objective 2, we developed 5 core categories for our ECARP guide.

4.3.1 Evaluation of Potential New Uses for Underused Office Buildings

For our brainstorming of primary uses (for upper floors), we mainly focused on uses with residential zoning such as affordable housing, luxury housing and senior housing. We also considered hotels even though they are commercial use, due to the fact that they share a lot of similarities with residential floor plans. Using these 4 primary uses, we created a range of mixed-use examples with each primary use.

Each of these primary uses offers several benefits to the Arlington Community. Affordable housing is a great option due to the fact that Arlington's housing market is highly competitive combined

with a high demand for housing. Luxury housing is excellent for the affluent population in Arlington who are younger and looking to live in trendier and cutting-edge neighborhoods. Senior housing is less applicable to Arlington due to its young population. However, that does not mean there is no demand, and due to the community's high rate of being physically active, a combination of senior housing and amenities focused on health and wellness would be helpful to both communities. Lastly, hotels would be well utilized since Arlington has a growing population of tech startups, which seems likely to result in increasing numbers of business travelers to the area.

In Table 2 below, we brainstormed a list of secondary uses (for the ground floor) with a wide range of uses, from dog parks and museums to urban farms and fulfillment centers. However, most of the uses we are proposing are commercial—restaurants, retail, laundromat, etc.

Table 2

Potential secondary uses (ground floor) for underused office buildings

Day Care	Co-working Space	Private School/Technical School
Dog Park	Laundromat	Theater/Auditorium
Dog Day Care	Urban Farm	Fulfillment Center
Museum	Makerspace	Brewery
Night Club	Mini-Storage	Recreation Center
Art Gallery	Retail	Restaurant
Urgent Care	Library	

4.3.2 Adaptive Reuse Examples for the Arlington County Community

Our cohort put together four designs for a mixed-use adaptive reuse of a building in Arlington. These four plans all center around some sort of housing development, as the supply of residential buildings is at a premium. The main consideration made when combining different types of residential spaces with other amenities was their compatibility with one another. For example, some kinds of entertainment venues in the same building as a residential unit would not work well together due to the noise pollution of the former.

The first of our designs is a combination of a boutique hotel, a museum, and a retail area. The retail area would cater to both residents of the area and the guests from the hotel above it. The museum could focus on an Arlington-specific topic, such as the history of the county or famous people from it, or it could fill a niche unfulfilled by the major museum district of Washington D.C., such as a flag

museum. In either case, this will give hotel guests a tourist attraction just an elevator ride away, something for the people of Arlington County to visit, and another museum for tourists of the whole metropolitan area to be able to visit.

Figure 19 – *First Floor Model of Travel and Tourism Example*

Our second proposed plan revolves around an apartment building with several amenities open to the surrounding area. A local business partner laundromat on the ground floor would incentivize people to move to the apartment portion of the building, especially if residents are given reduced rates to use the facility. A bike storage area and a dog park next to the building would also be welcome services for the population of the county, who own more dogs and bikes than the average American. A market space that local businesses could set up vendor stalls in could work in the lobby, as the businesses could sell to both the surrounding public as well as the residents of the apartments.

The third plan proposed would be more upscale, centered around luxury housing. A brewery or restaurant as the ground floor attraction could be supplied with goods from an urban farm, like either a greenhouse capstone floor or an open-air garden. Possible amenities could include EV (Electric Vehicle) parking spaces in the basement for residents to charge their vehicles, a coworking space to work out of one's home but not far away in an office, or a makerspace for engineers to tinker. The building would champion some of the more drastic carbon limitation technologies, as the residents of such a building would be able to afford to fund such measures.

Our final reuse example is centered around a senior living center, with more recreational facilities than the previous three. The top and middle floors would be housing, whereas the bottom few floors would contain community centric amenities such as a pickleball court, auditorium or theater, or a yoga studio. These facilities could be free to the residents of the senior living center, but also remain available to the surrounding citizenry, perhaps through a club membership program. A senior living center, and its surrounding community, could be enhanced by co-locating medical services such as an urgent care center.

4.3.3 Evaluation Categories for Adaptive Reuse Projects (ECARP)

When determining the best solutions for adaptive reuse, often, the first steps typically involve studying the floorplan and systems of the building without the preexisting uses in mind. While this is simple and effective for large scale projects and developers that regularly retrofit buildings, this process is not practical when attempting to lower embodied carbon costs and foster innovative design. Our approach involves looking at adaptive reuse with a focus on the utilization of preexisting infrastructure to guide better implementation of creative reuses. In order to better guide design choices made when looking at adaptive reuse projects, our team developed a set of guidelines for developers and designers to keep in mind. These guidelines can be broken down into five main sections; Embodied Carbon, Operational Carbon, Surrounding Assets, Demand, and Future Proofing. Each of these categories attempts to further break down the design and decision-making processes of adaptive reuse.

Embodied Carbon and **Operational Carbon** make up the technical components of adaptive reuse design. Embodied carbon, as previously expanded upon, encompasses the total carbon used in the collection, manufacturing, transportation, and demolition of materials used in the building. When looking at embodied carbon as a category for adaptive reuse design, it is important to understand ways to use the existing space or systems with minimal large-scale changes. However, this may seem to directly contradict the category of operational carbon through technical analysis of the building's system usages. Exchanging the preexisting systems for new and more sustainable designs lowers the costs for heating, electrical, and water usages. However, many times these systems will cost more embodied carbon to install than the amount of carbon emissions that would be saved in a fifteen-year lifecycle. This idea is further explained by the category Future Proofing later in this section.

When designing for adaptive reuse, it is important to design for the people that will be using the building. This breaks down into the social categories of **Surrounding Assets** and **Demand**. Surrounding Assets focuses on businesses and points of interest in close proximity to the desired adaptive reuse project. This category is utilized by understanding how each of these points of interest can help increase the utilization and marketability of the project. Buildings with easier access to public transportation will result in high foot traffic and therefore marketability for retail space. Other times a building might be in close proximity to essential services like grocery stores or laundromats. This can make a building more ideal for adaptive reuse as residential space over other uses. By understanding and evaluating these criteria buildings can better utilize each other and create a more integrated community. Demand relates to how likely populations are to utilize the adaptive reuse solutions presented. Solutions that cater towards larger populations may have an easier time finding a foothold in their given market. At the same time however, solutions that provide an essential service to underserved, and often smaller, populations might find a more niche and less competitive place in the market.

The final category, **Future Proofing**, revolves around the idea of buildings being reused again in the future. While conducting an adaptive reuse project, it is important to keep future projects in mind. During the design process it is important to keep in mind how the building might be used in the future. This can consist of looking at multiple different reuse solutions and comparing the previous 4 categories already presented. When attempting to future proof a design, decisions based off future infrastructure improvements are important to consider such as added transportation options or other large scale city projects currently being proposed. In tandem, it is also important to look at the proposed solution's lifecycle. Eventually, the new infrastructure that was put into place may not be competitive with other solutions on the market. It is important to understand how these internal infrastructure changes might lower operational costs for the next project presented in the future for this building. The end goal of Future Proofing is to allow buildings to be considered for reuse, adaptive or not, throughout the core structure's lifetime rather than demolition.

5. Recommendations

We created a set of reuse recommendations to be used by building developers, county departments such as AIRE, or others in the industry who are considering an adaptive reuse project. Below, we elaborate on a few of the specific recommendations for the Arlington County sponsor to consider incorporating into a future program.

5.1 Government-Private Partnerships

In order to encourage more developers to pursue adaptive reuse projects, we recommend that the county start a building repurposing task force with members drawn from several departments of government: development, planning, permitting, green buildings, and capital finance. This task force would walk developers through every part of the process, gathering the necessary data on the ECARP Guide's categories: embodied carbon, operational carbon, demand, surrounding assets, and future proof. The task force would be part of a broader adaptive reuse program in which the county lists priorities for new building uses, provides requirements for meeting green building standards, and instructs developers on criteria for ranking buildings. The last essential part of the government-private partnership is providing financial incentives for adaptive reuse. We recommend that the county start a 10 Year Capital Improvement Plan with design grants, construction grants, and potentially even an adaptive reuse competition where the developer with the most creative reuse is awarded a prize grant for their project.

5.2 Expanding ECARP

While we identified some important aspects of adaptive reuse projects in our ECARP Guide, the categories are evaluated based on qualitative observations such as simply improving the heating system for operational carbon or looking for a building that is close to a bus stop for surrounding assets. Our team recommends that the ECARP Guide be expanded into a more quantitative process that involves specific numbers describing the buildings and community. For instance, reusing a specific percent of the existing building would give your project a higher rating in the embodied carbon category. We think that the ECARP Guide could eventually be developed into a set of standards like LEED where the adaptive reuse project receives points in each category, and they would add together to yield an overall score.

6. Conclusion

This project aims to help Arlington County assess and understand the designs of different adaptive reuse solutions for underutilized office space. This was achieved through the careful consideration of the residents living in the county as well as the environmental impact of retrofitting. We determined that the young affluent nature of the county's population lends itself to luxury and single person housing as the best residential reuses of office buildings. We also learned amenities such as dog parks, recreation centers, restaurants, urban farms and retail are the most compatible with the interests of community members. In terms of environmental impact, we learned that adaptive reuse has the potential to reduce 50% or more of carbon emissions when compared to new construction. If the county is able to offer financial incentives to developers for adaptive reuse, they can work to reach their goal of carbon neutrality of 2050 while also increasing the utilization of office buildings by the community.

Depending on the solutions proposed, different populations will require different wants and needs to be met. By understanding and meeting these requirements, adaptive reuse projects can be more successful and more helpful to the communities they are built for. Due to the multidisciplinary nature of an adaptive reuse project, many different experts can offer a variety of solutions that need to be pieced together. The careful consideration and understanding of what and why these solutions are proposed can be used to better design the most ideal solutions. Through the utilization of processes created by this project, Arlington County will be able to identify and establish the best adaptive reuse plans possible in order to combat high office vacancy rates. The ECARP Guide covers basic yet necessary strategies to ensure the future health and prosperity of the county's building market. As the government offers more incentive programs and attempts to allocate more resources to its revitalization, these strategies will help developers understand the main obstacles presented and allow for more creative and meaningful adaptive reuse solutions.

7. References

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8. Appendices

Appendix A

Informed Consent Agreement for Participation in a Research Study

Informed Consent Agreement for Participation in a Research Study Investigator: Prof. Adrienne Hall-Phillips, Prof. Lauren Mathews

Contact Information: gr-DC23-ArlingtonCounty@wpi.edu, ahphillips@wpi.edu, lmathews@wpi.edu

Title of Research Study: Embodied Carbon Incentives for Repurposing Unused Office Buildings in Arlington County, VA

Sponsor: Arlington County Office of Sustainability

Introduction

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits,

risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study:

The purpose of this study is to assist Arlington County in expanding their Green Building Initiative (GBI). This will be accomplished by studying vacant office buildings and recommending best practices for green retrofitting and reuse of the buildings.

Procedures to be followed:

We will be interviewing experts to gain a better understanding of adaptive reuse and embodied carbon, which will enable us to implement green practices into our recommended building design. As a participant, the duration of your participation is only this interview session, nothing will be expected of you outside of this session.

Risks to study participants:

There are no risks to participating in this study.

Benefits to research participants and others:

There are no benefits to participation, the interviews are solely to gain information for our study.

Record keeping and confidentiality:

Recordings of the interview sessions will be kept in a private Google Drive folder accessible only by the primary investigators and four student investigators. Recordings may be shared with the Arlington County Office of Sustainability. Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identifies you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury:

No injuries should be suffered during participation. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: Professor Adrienne Hall-Phillips at ahphillips@wpi.edu, Professor Lauren Mathews at lmathews@wpi.edu, the WPI IRB Manager Ruth McKeogh, 508 831- 6699, Email: irb@wpi.edu or the WPI Human Protection Administrator Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu. Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit. By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

Date:

Study Participant Signature: _____

Study Participant Name (Please print): _____

Appendix B

Interview Protocols

Elizabeth King (Arlington Economic Development)

- How was the list of empty office buildings developed?
- What makes a building ideal for retrofitting?
- Do you have any advice on the criteria we should use to select a building?
- Are there any current examples of retrofitted buildings in Arlington?
- What areas of Arlington are most in need of revitalization?

Paul Roman (Green Building Program Manager) and Roland K. Butzke (Siemens)

- Do zoning policies restrict the scope of your project?
- What are the most difficult building conversions to make?
- Commercial to residential, commercial to mixed use, etc.

- How do you consider community input when planning an adaptive reuse project?
- Which green building standards do you typically follow in your building projects?
- What green features can be implemented in an existing building?
- Which green building features have the greatest impact on carbon emissions?
- How do green building incentives help make a project more cost effective?

Marta Shantz (Urban Land Institute)

- What is the best way to use embodied carbon calculators such as EC3?
- How accurate are tools like EC3 at calculating embodied carbon?
- How do you compare the embodied carbon from retrofitting vs. demolition?
- Which building processes produce the most carbon?
- What parts of the retrofit process should we focus on?
    - How can we save the most embodied carbon?

Abbe Flores (Gensler)

- What do you do as a Certified Life Cycle Executive?
- What processes are used to select a building for adaptive reuse?
- Which specific phases in the embodied carbon life cycle should we focus on for adaptive reuse?
- Which green building standards do you typically follow in your building projects?
- What features embody the most carbon and what are some ways to mitigate its impact?
- How would you recommend that we use embodied carbon calculators such as CARE, EPIC, etc.?
- What recycling methods are used to save embodied carbon at the end of a building's life?
- What effective ways are there to estimate the embodied carbon of an existing building?

Appendix C

Supplemental Data for Claritas Zip Code Analysis in Objective 1

Figure 20 – *Claritas demographic groups in each Arlington County zip code*

22201	22202	22203	22204
Connected Bohemians	Connected Bohemians	Connected Bohemians	Young Digerati
Young Digerati	Urban Elders	Young Digerati	Connected Bohemians
The Cosmopolitans	Young Digerati	Money and Brains	Aspiring A-Listers
Money and Brains	Money and Brains	Urban Elders	The Cosmopolitans
Urban Elders	Aspiring A-Listers	Aspiring A-Listers	Money and Brains
22205	22206	22207	22209
Young Digerati	Young Digerati	Young Digerati	Connected Bohemians
Money and Brains	Connected Bohemians	Movers & Shakers	Young Digerati
Urban Elders	The Cosmopolitans	Upper Crust	Urban Elders
Aspiring A-Listers	Aspiring A-Listers	Money & Brains	The Cosmopolitans
Connected Bohemians	Money and Brains	Networked Neighbors	Aspiring A-Listers
22211	22213		
Asprining A-Listers	Young Digerati		
Urban Elders	Networked Neighbors		
Connected Bohemians	Movers & Shakers		
American Dreams	Upper Crust		
American Classics	Gray Power		

Figure 21 – *Descriptions of Claritas demographic groups*

Connected Bohemians	The Cosmopolitans
Mobile urbanites	Educated and upscale
Most liberal lifestyles	urbane couple in America's fast growing cities
Tech savvy	vibrant social scene surrounds older homes
young singles, couples, families ranging from students to professionals	Eco-friendly lifestyle
Early adopters, quick to check out the latest on Instagram	Enjoy eating at organic/health food establishments
Go to comedy clubs, art museums, tennis and eat out at organic restaurants	
	Money and Brains
Young Digerati	high incomes
Tech savvy	advanced degrees and sophisticated tastes
Live in fashionable neighborhood on the urban fringe	Married couples with few children
Affluent and highly educated	Live in fashinable homes on small, manicured lots
live in trendy homes and condos, owned rather than rented	Expensive cars
Belive in ecofriendly lifestyles	Enviromnetally conscious individual
Enjoy dining at organic/health food restaurants and coffee houses	Donate to political causes, the arts, public radio
Networked Neighbors	Upper Crust
family portrait of suburban wealth	Haven for wealthy empty-nesting couples over 65
Expensive homes and manicured lawns, high-end cars	Residents earning $100,000+
Married couples with children	Postgraduate degree
high technology use, graduate degress, six-figure incomes	Expensive cars, eating at upscale restaurants
corporate executives, managers and business professionals	traveling to europe

Figure 22 – *Descriptions of Claritas demographic groups (continued)*

Urban Elders	Gray Power
Downtown neighborhoods of metros	Wealthy older couples
More renters than owners	Living just beyond the nation's beltways
Enjoy cultural options	Had white collar jobs, now in retirement
Frequently attending marathons, art museum exhibits, comedy clubs	Enjoying comfortable home homes and apartments
	Like to travel, follow golf and contribute to public radio
Aspiring A-Listers	
Urban renters focused on their social lives	American Dreams
Out and aout often	Upper middle class in urban area
Spend heavily on status brands and dining out	Enjoy shopping at deparment stores
Interested in a wide variety of sports and large vibrant cities	Enjoy attending college sport events
	Enjoy vacationing in cities across Europe
Mover & Shakers	
Dual income couples, highly educated	American Classics
typically between 45 and 64	Older and retired
Executives and white-collar professionals	Lower-midscale income
Business bent to this segment	Comfortable lifestyle
Enjoy visiting investment websites, reading business publications	Below average use of technology
	Finding entertainment outside of the home

News Articles Used in Local New Analysis:

https://www.arlnow.com/2023/11/29/goodwill-redevelopment-plans-receive-largely-positive-feedback-mixed-with-some-concerns/
https://www.arlnow.com/2023/11/27/county-approves-more-missing-middle-projects-after-trial-date-set-for-lawsuit/
https://www.arlnow.com/2023/11/16/arlington-to-move-forward-with-pickleball-courts-at-walter-reed-after-mulling-a-pause/
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https://wtop.com/business-finance/2023/07/6-years-running-arlington-is-the-fittest-city/
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https://www.arlnow.com/2023/11/06/to-spur-vehicle-electrification-this-crystal-city-startup-is-tackling-the-hurdle-of-charging-infrastructure/
https://www.arlnow.com/2023/11/06/gmu-completes-the-shell-of-a-new-computing-school-on-its-mason-square-campus/
https://www.arlnow.com/2023/11/08/upscale-market-and-cafe-foxtrot-opening-soon-in-ballston/
https://www.arlnow.com/2023/10/27/a-new-boutique-has-opened-in-clarendon/
https://www.arlnow.com/2023/10/30/snouts-stouts-indoor-dog-park-and-bar-set-to-open-next-month-in-green-valley/
https://www.arlnow.com/2023/10/30/cyclists-and-runners-can-grab-free-lights-and-high-visibility-vests-this-week/
https://wtop.com/arlington/2023/06/arlington-roads-closed-saturday-and-sunday-for-armed-forces-cycling-classic/
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