Revitalizing Low Income Communities Using Carbon Neutral Buildings

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REVITALIZING LOW INCOME COMMUNITIES USING CARBON NEUTRAL BUILDINGS

by

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of
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COMMITTEE APPROVAL

“Revitalizing Low Income Communities Using Carbon Neutral Buildings”

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ABSTRACT

Rochester New York, a city which thrived on manufacturing in the 1900’s, has declined over the years. The impacts of the economic down turn, suburbanization, and the highway system impeding pedestrian access to downtown Rochester, all took their toll on the city’s once vibrant urban fabric which has now deteriorated into surface parking and buildings in disrepair. The city of Rochester has started a conscious effort to rebuild its downtown which brings with it an increased population. This increased population begins to strain an already struggling municipality and city thus spreading the services provided by the municipality thin; causing yet another strain on the low-income communities. While the solutions for addressing these problems do nothing but raise our carbon footprint. At the global level, District 2030 has been leading the charge toward carbon neutrality and resource efficiency by developing a systematic approach toward achieving district or citywide carbon neutrality by 2030. With regard to the city of Rochester, since the increase in population is directly related to the increase in the city’s carbon emissions, I propose that the city of Rochester join District 2030 and become carbon neutral by the year 2030. To achieve this goal, my investigation will address the revitalization efforts of the city with an alternate and sustainable solution by (1) Determining the current energy consumption of the Rochester district, Beechwood, (2) Developing a schematic district level carbon neutral system to implement in Beechwood, (3) Determining the energy and CO$_2$ emissions offset in Beechwood and (4) Discussing the implementation of Carbon Neutral buildings to support the goal of carbon neutrality in Rochester.
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**NOMENCLATURE**

Btu – British Thermal Units

CO₂ e – Carbon Dioxide Equivalent

EUI – Energy Use Intensity

FAR – Floor Area Ratio

KBtu – Thousand BTU’s

LEED – Leadership in Energy and Environmental Design

MMBtu – Million BTU’s

NZEB – Net Zero Energy Buildings

PNEB – Positive Net Energy Buildings

SQFT – Square Feet
INTRODUCTION

Urbanization is transforming the world, and The Mckinsey Global Institute estimates that 1.6 billion people will move to an urban environment by 2030 [1]. That means by 2050 over 66 percent of the world will be living in an urban environment [2]. In order to support this demand, The Mckinsey Global Institute estimates about 900 billion SQFT will need to be developed across the world [1]; that would be 60 percent of New York State, as seen in figure 1. While this migration from rural or suburban environments is desired, it does come with a set of undesirable effects.

![Square Footage Comparison](NYC)

**Figure 1: Square Footage Comparison - NYS**

According to the United Nations, during this transition rapid and unplanned urban growth must be avoided as it threatens sustainable development. In some cities, unplanned or unmanaged growth has caused rapid sprawl, pollution, and environmental degradation combined with unsustainable production and consumption patterns [2].

If nothing were to change and urbanization were to go unmanaged many of our current resource figures would increase astronomically. To name a few, energy production would need to increase 80%, Green House Gas (GHG) emissions would increase by 50%, primarily due to energy production increase [3], as well as an 80 billion cubic meter increase in freshwater water demand [1]. While unmanaged urbanization can have these undesirable environmental effects, this
migration has had long time controversy with urban poverty; usually resulting in low-income communities. Cecilia Tacoli et al. states:

"Urban growth has been accompanied by the rapid expansion of unplanned, underserved neighborhoods with high concentrations of poor people [4]"

These communities face many challenges since municipal governments will not or are not able to provide adequate urban infrastructure such as schools, hospitals, public transportation and other facilities necessary for urban development when urbanization goes on unmanaged. Without adequate infrastructure, these communities cannot find formal jobs, and many live on land not suitable for residential construction or in places not built to construction standards. These places are what becomes of the urban environments of unmanaged urbanization.

With the above in mind, this thesis will focus on the effects that urbanization has on low-income communities and the carbon footprint to develop a framework which helps reduce the effects created. The framework will be created by using a network of positive energy buildings and neighborhood design guidelines to support urbanization and the community.

**Problem Statement**

Instead of allowing the built environment’s CO₂ contribution to rise, what if it could be reduced as new buildings were built, better yet what if these buildings could help reduce the negative effects of urbanization in low-income communities? The objective of this exploration is to develop an alternate framework using positive energy buildings to revitalize low-income communities, specifically in upstate New York in the city of Rochester, a typical north-east city. This exploration should be considered a supplement to other solutions rather than as the “fix all” solution. As George Martine et. al. states since urban environments centralize elements and activities it often creates opportunities for reducing environmental degradation [5]. This is not to say that affluent urban centers are not a threat to the environment, because while they do provide opportunities to reduce their effect, George Martine also states that “their Ecological Footprint is
greater per capita” than all other built environments. Therefore, it is important that as urbanization continues to develop in cities it is managed so “opportunities” are used to reduce and control the ecological footprint contributed by urban environments.

An ecological footprint can mean many things in reference to the built environment, though normally it is assumed to be the carbon footprint created by the city. Unfortunately, many sources contribute to this footprint; but this thesis will focus on just two sources the building sector and the transportation sector, which together contribute 71.9% of the annual CO₂ emissions in the United States as seen in figure 2 [6].

![CO₂ Emissions by Sector](image)

*Figure 2: CO₂ Emissions by Sector*

While energy and carbon emissions are important, as discussed above urban poverty is part of the discussion as well. This is considering that according to the World Bank, poverty levels on the global scale were at 25% [7], and at the national scale according to the census bureau in 2014 they were at 14% [8].
While this is an admirable improvement over the global scale as seen in figure 3, the United States is a developed country and has the possibility to be poverty free according to Heniz Kohler [9]. While this investigation is not focusing on the elimination of poverty, the possibility of it means that there is room for improvement.

In order to address these two problems, the framework discussed above will be implemented and the results will help determine if this solution supports the community and the environment as well as if the solution is economically feasible.

**Literature Review & Case Studies**

The following literature review and case study section is an exploration of positive energy buildings and community development plans that push the sustainability agenda touching on proposed concepts, academic inquiries, current research, and established projects in climates comparable to Rochester.

**Literature Review**

“The Fundamental Distinction is that between an urban and a rural settlement. An urban settlement is one that contains a sizeable population in a small area. It therefore has a density too high for the practice of agriculture within the settled area and a population too big to be mainly engaged in agriculture in the surrounding area. A rural settlement, on the other hand, is
sparsely settled. Each individual household may be separated from others by a substantial amount of open land; or the households may be clustered in villages so small that the villages can nearly all practice agriculture on the surrounding land.” [10]

To understand urbanism, the difference between urban and rural settlements in the above quote is the broad definition being used in this investigation, it defines the developmental differences in both environments in relation to agriculture and the population, but this relationship can be expanded to many different resources. Therefore, Kingsley Davis states that urbanism has been around since the technology was around to sustain it, showing that urbanism and technology are directly correlated [10]. The clearest example of this correlation starts with agriculture, in the earliest cities or “towns” it is estimated that 50 to 150 farmers were needed to support one city dweller because of the labor-intensive process [10]. This was altered by the development of new technologies, specifically the technologies that produced efficiency. From this point on, urbanism developed anything from medieval towns to the first cities in northern Europe.

When discussing urbanization, or the migration of people from rural environments to urban environments, two topics are always included in the discussion: urban poverty and suburban settlements. These topics are included for many reasons; urban poverty, which will be discussed later in the paper, is included for many reasons but the main reason according to George Martine et. al. is that “urban poverty is growing and already much larger than generally depicted in the global figures” which naturally means it becomes more visible as urbanization grows [5]. Suburban settlements are included for other reasoning best brought up by Kingsley Davis as with all urbanization as the society becomes more advanced it can develop an extreme amount of suburbanization or “fringe” settlement. When the fringe area develops, the urban population continues to grow but the fringe area expands more rapidly in comparison [10]. Kingsley states that this effect happens with all urbanization once the society becomes advanced enough to support it. The suburban fringe reacts quite differently as the population expands, it starts dense around the urban center, but density decreases as the suburban area expands further and further away from the
urban center which is typical. But what make this a dangerous side effect is what Timothy Beatley states in the following quote, “One of the worst offenders is American cities; American cities are wasteful of both land and resources, with only a couple cities showing any sense of ecological limits or environmental constraints” [11]. As Timothy Beatley suggests as the suburban fringe develops its density is far less causing a “wastefulness of both land and resources.” This wastefulness occurs when you support this kind of expansion; unfortunately, American governments have been far too supportive when it comes to suburban expansion. Elise Bright mentions that while “many federal policies have adversely affected central cities, perhaps none have done more damage than those that favored new construction over rehab and Greenfields over infill, and placing the central city at a competitive disadvantage and causing thousands of abandoned buildings” [12]. While federal polices seem to be the cause of over developed suburban environments, municipal and city governments are forced to overcome this barrier as these polices begin to change [12]. While in recent years it seems that local governments have been trying to overcome this barrier, sadly they cannot overcome these barriers alone.

While suburbanization may have exploded because of poor polices, people have been trying to eradicate and prevent it since the beginning. One of the major solutions is smart growth, Smart growth consists of a one idea; infilling central city developments using mixed use, mixed income, and transit centered development [12]. According to Nico Calavita smart growth can be summarized into the 6 principles listed below.

“1. Creation of a more Compact Urban Form by Limiting Sprawl at the metropolitan fringe

2. Revitalize existing communities through infill and good community design while optimizing existing public facilities

3. Enhancement of the Tax Base of the Inner City and first Ring suburbs through regional tax base sharing

4. Redesign of old and new developments on the basis of “new-urbanism” principles that call for mixed use centers, job-housing balance, pedestrian-
friendly communities, grid-street patterns, alleys, porches, and other elements that make neighborhoods vital and diverse.

5. Reorientation of the transportation system to reduce the dependence on the automobile.

6. Preservation of wildlife habitats, prime agricultural lands, and open space, especially at the urban fringe.” [13]

What is clearly visible in this quote is the concise idea of what smart growth is, it establishes a baseline on how to help redevelop the metropolitan areas that have sprawled past their extents. While this thesis investigation will be focusing specifically on points 1, 2, 4, and 5; points 3 and 6 will be taken into consideration and briefly discussed as they are part of smart growth as a whole but are considered outside the scope of this investigation. As with the implantation of any idea, challenges will need to be overcome. Most of the challenges that occur with implementing smart growth as a solution to suburban settlement go hand in hand with Urban Poverty. While they are not necessarily identical, they are congruent, meaning that by addressing the issue under urban poverty, a more prevalent issue, allows for the mitigation in both topics.

Urban poverty maintains a complex relationship with urbanization; it consists of understanding the scale, dealing with cultural and political impediments, and economic issues [13]. Poverty is difficult to define as not everyone will agree on a constant definition, but a definition is required in order to discuss and measure urban poverty. According to Heinz Kohler, there are two ways to define poverty, on an “absolute basis” and on a “relative basis” [9]. For example, in an absolute basis if the poverty line was set at $20,000 per household then anybody below the line is considered in poverty and anyone above the line is considered “non-poverty”. While an absolute basis is a setline or number, a relative basis is based on a percentage of the median household. For example, if the percentage was 20% of the average household income and the average household income was $10,000, then the poverty level would be $2,000, but in a relative basis if the average household income was adjusted the poverty level would be adjusted as well [9].
In the United States, poverty has been defined on an absolute basis, but since the 1960’s has used a more complex relative basis system. This system takes into account differences in income, family size, sex and age of the head of household, but this system still has some flaws when including assets or temporary income. In 2015, the national poverty level ranges from an annual salary of $12,082 to $49,117 [14]. Since the national poverty level is used to establish the poverty level when compiling the census data for the United States this investigation will rely on census data to determine the amount of poverty in these low-income neighborhoods.

While determining the scale of poverty in an area is important, understanding if poverty can be eliminated and what causes it is a necessity. Heniz Kohler states “Poverty in the United States could be eliminated if we cared to do so. This happens to be a lucky circumstance. It is certainly not a statement one could make about every country in the world [9]”. To establish the possibility of elimination, the redistribution of the country’s wealth from rich to poor shows that when it’s divided equally, all residents are above the poverty level [9]. While this investigation does not focus on eliminating poverty, knowing that it is a possibility makes it feasible to reduce urban poverty.

To reduce or even eliminate poverty, the causes of urban poverty need to be defined. In a majority of urban environments, the major causes of poverty are the lack of availability to a formal job along with the inability of urban municipalities to provide the urban infrastructure required whether it be public transportation or facilities necessary for urban growth [4]. While these problems came from the over development of the suburban environment causing jobs to move and the underdevelopment of public transportation system to begin, the cause of these events is directly related to zoning [15]. While zoning codes have been around, two supreme court cases Corrigan vs. Buckley and Euclid vs. Ambler created the urban fabric of today’s cities in relation to low income communities.

Corrigan vs. Buckley in 1926 started the development of these low-income communities by allowing racially restrictive covenants in neighborhoods throughout the nation. What this
establishes is that a resident that lives in the restrictive covenant is not allowed to sell or rent their home to blacks or other minority groups [16]. Their use was so extensive it caused 80 percent of Chicago to be controlled by these covenants. While these covenants pushed minorities to the urban core beginning the solidification of the “Getto” and begun urban sprawl due to the segregation this case supports it is just the beginning. The real adjustment to the zoning policies was due to the supreme court case of Euclid vs. Ambler. This case set the precedent for a zoning ordinance to decide and uphold how to divide undesirable uses. In particular, this case discusses the relation of apartment buildings and uses they promote in the same vicinity as a single-family home [17]. In the end, the court decided in the favor of the town of Euclid stating that an apartment building next to a single-family home would in fact decrease the property value therefore making it constitutional and within the towns rights to enforce this policy. But this policy is what formed conventual zoning in to what it is today; the division of uses that are considered to be a nuisance to others [17]. What this case allowed for is the single use districts that are used today, creating and dividing many uses that cities and neighborhoods use for diversity. This includes uses such as commercial, residential, and industrial all becoming separate entities causing the sprawl and lack of diversity that currently surrounds most American cities. While conventual zoning has limited the way, cities grow there is a new form of thinking that urbanism that is slated to help reverse these effects.

When thinking about urbanism, urban sustainability is the next step. Cities will play an important role in addressing several problems such as growing consumption and population, global warming, and sprawling land consumption just to list a few. Out of the many different methods available in urbanization this investigation will focus on smart growth, form based code, and urban policies.

Each of these methods is based on 4 Principles that Timothy Beatly outlines below:

“Principles of Urban Sustainability:

1. The principle of urban management
2. *The principle of policy integration*

3. *The principle of ecosystems thinking*

4. *The principle of cooperation and partnership* [12]

Each of the principles are equally important and relates to how the urban environment operates and grows. Management, integration and cooperation all coincided with each other, creating a series of steps to implement these solutions. This leaves one remaining principle, ecosystems thinking, which Timothy Beatly says “emphasizes the city as a complex organism characterized by flows as continuous processes of change and development. [12]” This results in the understanding of what a specific city both needs and produces. This understanding allows for the comparison between cities and how the city plays a role in the overall scheme. This type of thinking and understanding combined with the implementation process of the other three principles establishes the baseline for urban sustainability.

Something in common between all of these methods is the implementation of efficiency. As urbanism begins in massive migrations of people, efficiency of our urban environments is important because inefficient environments can cause the unwanted side effect of suburbanization. Smart growth as discussed above is the most prevalent solution to solving this problem of efficiency in urban environments as it consolidates uses into one area helping to reduce many of the resources used in urban areas [13]. One limitation of smart growth is that it acts more as a guideline rather than an enforceable code. This is where form based code comes into play and supplements smart growth techniques.

Form based code according to the Form-Based Code Institute is “A land development regulation that fosters a predictable built result and a high-quality public realm by using physical form as the organizing principle for the code” [18]. Form-Based code uses the base idea of smart growth where it tries to implement efficiency by consolidating uses and creating a unique urban fabric, but goes a step further by deciding on things such as building type or mix of building, number of floors and site to building ratio. Generally, Form-Based code has five main elements; a
regulating plan, public standards, building standards, administration, and definitions. These five elements alone allow for communities or cities to have greater control over the development of their community plans. Along with these five options, communities have the ability to add supplemental elements such as architectural standards, landscape standards, signage standards and environmental resource standards to further narrow in on the design of their community plan [18].

In comparison to conventional zoning code, the form-based code is quite comprehensive considering that conventional zoning divides by building use rather than building form and only dictates items such as density, parking, maximum building height and floor area ratio (FAR) [18]. It may seem that there are no flaws to form-based code but as Lolita Inniss states many people contest that “the reliance upon the “community” to formulate design standards through the charrette process has the potential to further isolate those who are already disadvantaged” [19]. What Lolita states will be addressed in two segments, the first segment addressing the community and how they develop the design standards and secondly how the already disadvantaged might become even more isolated. The community addressing and developing the design standards is a good method as it allows for the personalization of the plan to the community but this creates a problem as well. For example, if the community or board is uneducated in what a community needs to thrive and only address what the community wants, the design standards may actually do more harm than good [19]. This goes in line with the second idea: that as the community decides on these design guidelines if there is no representation or “voice” for the disadvantaged, then many flaws may be present that can result in centralization of all the disadvantaged creating low-income communities. This is not to say that Form-based code will not work because as Lolita States “There is no doubt that form-based code may hold promise for the revitalization of old cities and for the creation of new ones” [19]. The flaws occur when a system as structured as the conventional zoning code is replaced by a community developed zoning code.

Having addressed these problems and solution, as addressed in the problem statement urbanization allows many different opportunities to happen, and the correlation between
urbanization and technology is strong. So as urbanization continues to take hold in the world, implementing technology into these opportunities not only helps reduce our carbon footprint but help support urbanization as well as revitalize our low-income communities.

**Understanding NZEB & PNEB**

In order to take advantage of the opportunities that urbanization presents, I believe the technological advances in Net Zero Energy Buildings and Positive Energy Buildings in recent years will allow for the greatest impact. Net Zero Energy Buildings or NZEB and Positive Net Energy Buildings or PNEB have become very popular solutions to help combat the 40% CO₂ contribution made by our built environment. The confusion begins on what defines NZEB and PNEB?

The simple definition for NZEB is a building that uses energy efficient techniques and produces enough energy annually to sustain itself, therefore having a net energy use of zero. This is extremely similar to PNEB, where instead of having a net energy use of zero it would actually have a negative net energy use which is illustrated in figure 4.

![Construction Type Comparisons](image)

*Figure 4: Construction Type Comparisons*

The confusion begins happening when trying to determine a system boundary for the project. Since the system boundary does dictate whether the building is considered a NZEB, it can be confusing to compare different NZEB’s, but P. Torcellini et. al. in 2006 tried to create a consist condition. P. Torcellini et. al. believes that there are four possible definitions or system boundaries to this term.
NZEB, net zero site energy, net zero source energy, net zero energy cost, and net zero energy emissions, each with their own set of values [20]. Since PNEB and NZEB are similar, this thesis exploration will focus on the two most used definitions, Net Zero Energy Cost and Net Zero Energy Emissions but slightly adjusted to be used in relation to PNEB’s.

Net zero energy cost is defined by P. Torcellini as “the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year [20].” In order to use this definition to as a system boundary for positive energy buildings it needs to be adjusted to say; the amount of money the utility pays the building owner for the energy the building exports to the grid is greater than the amount the owner pays the utility for the energy services and energy used over the year.

Net zero energy emissions is similar but defined by P. Torcellini as “produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources [20].” Adjusting this system boundary is the same as above the PNEB must produce more emissions-free renewable energy than it uses from emissions-producing energy sources.

When establishing the system boundaries for this investigation “A Common Definition for Zero Energy Buildings” published by the U.S. Department of Energy [21] was also used. In this the U.S. Department of Energy states that the system boundary can be as straight forward as a single property or as intricate as a complex [21]. This means that if you have a home and the home has its renewable resources with its footprint than the system boundary would be the buildings footprint. Understanding how a system boundary applies to a home allows for the interpretation of what the system boundary will be for this investigation. In order to apply a system boundary to a district it would be like applying it to a complex of buildings. So, for this investigation rather than having it be at the building footprint it will be at the district boundary. This means that any building with in the district that produces or consumes energy will be counted as one creating a system of individual buildings. This system boundary will specifically take into account Energy consumption by all the
buildings in the district, and energy production from the renewable energy sources on the Positive energy and net zero energy buildings and homes.

With the systems boundaries that will be referred to in this exploration determined one problem remains, NZEB and PNEB are usually only concerned with the building scale, this is only one aspect of a community, which is where the district 2030 program picks up.

Districts 2030

In 2010, Districts 2030 was developed to look at the community scale much like LEED ND. The main difference being District 2030 is meant to help establish goals for creating and maintaining sustainable urbanization, focusing on the aggregate demand and reduction of greenhouse gases for the entire district specified within the city [23]. When established, District 2030 set out knowing that there is two parts to every community, existing and new. For this reason, District 2030 set different goals for each part. The goals contain three categories for reduction Energy use, Water Use, and CO$_2$e from Auto and Freight travel each varying for new and existing construction or infrastructure that are shown in the figures 5 & 6.

As the figures illustrate, to comply with the District 2030 challenge existing districts must have a 50 percent reduction in all categories by 2030, whereas for planned districts a 50 percent reduction in two categories is required at the beginning and a carbon neutrality in the energy
category by 2030 is required. To better explain how these charts, work a description of each category will be given for the scenario of a new planned district. To start the districts water consumption and the CO2 production must be reduced by 50% in comparison to the districts baseline which is determined by using specific figures supplied by the district 2030 program. The next and last category is energy consumption, this category requires that there is an initial 70% reduction in energy consumption in comparison to the baseline, but also an additional 10% reduction every 5 years in until 2030 at which point the district will be carbon neutral.

In order to achieve these goals Districts 2030 relies on many aspects such as a non-competitive environment, private-public partnerships, and funding from these partnerships. Districts 2030 relies on a non-competitive environment so that the districts can provide support and other information in between districts especially within districts. District 2030 states that the most important part of their program is based upon their private-public partnerships, this is because these relationships allow for the communications of ideas, systems, and funds that all contribute to the goals of the district.

Since the development of Districts 2030 in 2010, Grand Rapids, MI; Pittsburgh, PA; Seattle, WA; Toronto, CA; and Ithaca, NY are among the cities that have committed to the challenge. This thesis will specifically investigate Toronto and Ithaca as they have a similar climate to Rochester, NY.
Ithaca has chosen to-do the district 2030 challenge in the downtown center of their city which can be seen in figure 7. According to Peter Bardaglio, Ithaca is working to provide a ground breaking high performance building district using Architecture 2030 to provide performance targets while seeking to prove that these buildings will be the most profitable [24]. Most notably Peter Bardaglio mentions that High performance buildings have proven track records of simultaneously increasing business and property profitability, reducing environmental impacts, and improving occupant health [24]; Ithaca’s main reason for becoming part of districts 2030. By completing this district Ithaca will not only support the notion that high performance buildings can help the surrounding community but also set an example of how districts can make these improvements financially viable, sustainable focused, and multi sector driven in order to maximize profitability and prosperity for all involved. This example as well as the others discussed below will show that a district can be small but still be an asset to the overall goal.
While Toronto’s and Ithaca’s goals line up there is a couple differences between the districts, the main difference being that Toronto’s district is about 25 million square feet. The size of the district is a huge undertaking and once completed will be a great example for a large-scale district. In order to complete this, Jeff Ranson lists many things that Toronto will complete but the most influential is District Scale thinking. According to Jeff Ranson district scale thinking allows for the creation of aggregated goals which helps create traction and support for larger discussions. These larger discussions help with ideas like shared infrastructure, policy, and programs that help the surrounding community.

District 2030 (Continued)

District 2030 will be helpful to this investigation in a few ways, it not only establishes the timeline for the period of investigation but it helps further establish the carbon and energy metrics that this investigation relies upon for the environmental metrics of this paper. To better determine the social metrics for this paper the organization Leadership in Energy and Environmental Design has developed multiple programs that deal with this aspect.
Leadership in Energy and Environmental Design: Neighborhood Development (LEED: ND)

While NZEB and PNEB focus on the building level, and Districts 2030 starts to look at district level consumption there have been a few attempts to investigate and establish a system for looking at a city or community and measuring or improving its efficiency and health. One of the most popular systems is LEED, Leadership in Energy and Environmental Design, This system is designed to outline green building practices and metrics to try to develop a standard in the green building industry. Over the years, this system has developed from dealing primarily with buildings, to dealing with specific uses and even neighborhood design.

LEED: ND is one of the United States Green Building Councils (USGBC) new additions to the LEED rating systems. According to the USGBC “LEED for Neighborhood Development (LEED ND) was engineered to inspire and help create better, more sustainable, well-connected neighborhoods. It looks beyond the scale of buildings to consider entire communities [21].” This is an interesting approach as it begins to apply the ecosystem thinking discussed by Timothy Beatly [12]. LEED ND engineered this system around three main categories smart location and linkage, neighborhood pattern & design, and green infrastructure & buildings [22]. These categories are made up of different credits each reinforcing the idea of the main category. While each credit will not be discussed, each category establishes an urban design idea. Smart Location and linkage tries to develop the urban environment and create a network of transportation and pedestrian systems. This goal is accomplished by assigning credits such as brownfield remediation and preferred location. Both give credit for not developing on a “Greenfield”, previously undeveloped site, and preferred location also gives credit for having connectivity established through how many intersections surround the site [22]. While condensing urban environments is an important task these environments must also be desirable and livable. To achieve this, LEED: ND uses credits such as mixed-use neighborhoods and community outreach and involvement. These both provide a resilient neighborhood and community-centered neighborhood allowing the community to adapt as it grows. While these are all important as urban environments continue to grow and hold more
people, managing their effects on resources will become equally as important. That is why green infrastructure and buildings is becoming an increasingly more popular topic. It was engineered to address some of the concerns raised in the introduction such as the rise in CO2 creation or the rise in electrical consumption or even the rise of water consumption by a staggering 80 billion cubic meters [1].

While these categories start a solution for urbanism and how to offset its adverse side effects there is one fundamental problem with systems like LEED. As technology increases and buildings become smarter, the “human” factor can become a big hindrance. While a building can decide what is most energy efficient method to achieving comfort at a general level all humans have a different perception or habit. This habit or perception maybe turning the light on when there is enough ambient light to complete the task. For this reason, some LEED Buildings may actually perform no better than non-LEED buildings over time. Therefore, it is not the systems that cause the problem, but the “Human” Factor making education the biggest reducer in these systems. This being stated, LEED has made many accomplishments and brought attention to many different aspects of building design and neighborhood design that would have gone unnoticed otherwise.

In the development of the categories and credits above a comprehensive database and establishment of metrics was engineered to support community health and balance environmental side effects. For this reason, in this thesis LEED ND will be used as a resource when developing and establishing standards or metrics.

**Methodology**

Throughout this section, the methodology of this investigation will be discussed and applied to the city of Rochester, specifically the section of Rochester, NY known as Beechwood.

**Metrics**

When re-developing communities, it is important to have a way to measure the success or failure of the project. To accomplish this, multiple metrics will need to be used as there is not just
one metric that can explain a community’s health. For this investigation since efficiency and community health is key, the three categories of sustainability; environmental, economic and social shall be used. These categories allow for a broad range of metrics to be selected while maintaining a balance across important issues in a community.

Environmental:

District Energy Consumption: (Average Per Resident X District Residents)

Energy consumption can mean many things; but for this paper energy the focus will be on the electrical consumption of the built environment. This consumption will be determined based on average use per resident in the district. To determine the average, the annual energy consumption for the city of Rochester was divided by the total number of residents which gave an average per resident. Using this data district wide, energy consumption per year can be interpolated using census data.

District Energy Use Intensity: (Total District BTU/Total District Square feet)

Using the district energy consumption above, a district wide energy use intensity will be established for both an ideal scenario and the proposed solution. For this investigation energy use intensity will be in units of Btu/SQFT, this allows for the energy consumption to be divided by the district square footage.

District Emissions: (Total BTU x (CO2 e/BTU) = Total District CO2 e)

The last metric in the environmental category is district emissions, this will be the measure how much CO2 the district produces on an annual basis. This will be determined using the average CO2 e per Btu produced for the area, then multiplied by the number of Btu’s for the district.
Social:

Quality of Life:

Quality of life is an important metric when determining city health. This is because quality of life helps determine whether people want to live in the district. If people want to leave in the district that give the district more funds to continue making it a desirable place to live. While quality of life is subjective it is based upon many factors but mainly diversity and transportation which will be focused on next.

Transportation:

Transportation is a key factor in a city’s quality of life. This correlation exists because if a city is dependent upon the automobile it can cause the spread of required uses or resources in a city; resulting in a lack of availability to all residents. Whereas if the city is dependent upon methods such as biking, walking or use of public transportation all the required resources will be within the available radius. A good example of this metric is the LEED: ND metrics reduced automobile dependence and bicycle network and storage. This metrics both work toward providing alternate modes of transportation to and from all the areas within the district [25].

Surrounding Density & Diverse Uses:

Surrounding Density and Diverse Uses or Mixed-use development is integral with transportation methods because this metric will measure city health or quality of life within the city. When a city or district has enough density and diverse uses the reliance on the automobile is significantly reduced and reliance on walking, biking and public transportation is increased. According to Ryan Donahue most people will walk ¼ mile for a bus stop, but for a rail station that bumps up to ½ mile [26]. Supporting the Van Herzele and Weidemann comment that “the maximum walking distance may differ according to the function a space fulfils” [27]. Therefore, the density and the uses within an area relate
directly with the transportation system that should be provided. To establish this measurement, the density of the district will be established along with the amount of uses provided within the district.

**Economic:**

**Cost (Total Cost):**

When addressing any form of framework or construction there is always an economic side. While costs might usually, be one of the more important metrics in this investigation it will purely be used as a comparative tool in the investigation. Since the value can vary based on regions and the type of work being completed, an estimation will be made using the costs from the case studies of positive energy buildings. Once established, this will create an overall cost for the proposed option.

**Payback period:**

This metric will be used to help determine the amount of time required by this proposal to establish a payback period. This is useful because as the district becomes more efficient in the social and environmental aspects, it also becomes more profitable, creating an exponentially shorter payback period.

**Proposed Solution**

For this investigation, a comparison between an ideal city, Carbon Neutral City: Central Chicago, will first be presented. Then Rochester as a whole will be analyzed before narrowing down to the proposed district and implementing the proposed solution. Once the proposed solution is analyzed and results shown a comparison between the ideal city and the proposed solution will be drawn to establish the effectiveness of the solution.
Carbon Neutral City: Central Chicago

In recent years, many cities have either committed to the District 2030 challenge or have completed studies determining energy usage. Central Chicago has completed the most comprehensive look into a carbon neutral city by looking into many topics such as building energy demands, urban matrix, transportation, smart infrastructure, water, waste, energy, community engagement, and funding. While this project has yet to be completed, it is a great foundation to use as an ideal scenario when looking for a city to compare the proposed district to. Since this investigation is focusing on Central Chicago as an ideal carbon neutral city, the following section is only the anticipated figures for reduction in the specific metrics outlined above and all figures will be from “Toward Zero Carbon: The Chicago Central Area Decarbonization Plan” by Adrian Smith and Gordon Gill [28]. While the book above covers mainly the investigation into the feasibility of carbon neutrality an interpolation from this data can be made to cover the discussed metrics above.

Location

The plan for a carbon neutral Central Chicago was chosen for many reasons but most of all it was chosen because like Rochester it represents a typical city in a like climate, allowing for a comparative analysis between the two and creating a channel for the interpolation of data.
Climate Information

Chicago’s carbon neutral plan was chosen as a comprehensive comparison because of its similar climate. This comparison can be seen below in the two psychometric charts in figures 9 & 10 from climate consultant.

Figure 9: Rochester, New York Psychometric Chart

Figure 10: Chicago, Illinois Psychometric Chart
As figures 9 & 10 depict, Rochester’s and Chicago’s climates are more or less identical. Psychometric charts are used to represent a climate and because they plot 3 different categories for any length of time, generally these spans are broken down into months or a full year. The three categories that make this climate representation are Wet Bulb temperature, Dry bulb temperature, and Relative humidity. When plotted together these three categories start to give a clear representation of a city’s climate. To better understand these charts, figure 11 shows how the placement of the green dots relates to climate. As we can see the chart is broken down into 5 climate regions Cool, Moderate, Warm and Humid, Warm and Dry, Hot and Humid, and Hot and Dry. The best way to determine what zone a city falls in is to look at where the majority of the dots fall in the graph. For example, using figure 11, Rochester and Chicago would both have a majority of the graph in the cool climate zone but extend into the moderate range in the warmer months. All this comes together to develop a predominantly cold climate with moderate summers.

*Figure 11: Psychometric Chart Climate Regions*
Social Surrounding Density and Diverse Uses:

When investigating Central Chicago, they analyzed the comparison of CO₂ emissions in Mixed use cities and in suburban sprawl. In this study, they found that a suburban sprawl type environment consumes about 17,000 kWh/year/person. This is especially important when discussing urban environments like Chicago; Since Central Chicago is a mainly commercial it causes this escalation for consumption in kWh/year/person because of the inclusion of the energy to travel back and forth. As they continue to investigate the central loop, the addition of residential continues to promote both surrounding densities and diversified uses and quality of life while continuing to help the city grow. This follows the many aspects of successful urban design ideas as it allows for the required uses and items to all be centrally located for everyone to have access to, which help solve transportation contributions.

Transportation:

As pointed out above adjusting the urban matrix allows for a reduction in the need for personal transportation; increasing use of mass transit. By reducing personal vehicle use and promoting mass transit carbon off gas is great reduced. This is reinforced even further by creating walkable environments. Walkable environments are created by taking the above diverse uses and creating them all within a ½ mile, as done in this investigation when supplying new residential and mercantile areas to a high density commercial environment the environment begins to supply the required uses to create a quality environment.

Quality of Life:

While the current environment is a habitable environment, the quality of life while subject is low. When urban environment contains a majority of commercial use and limited
housing, or is a major concentration of any one use it causes the district to constantly be underutilized. This can create poor living conditions, such as not have the access to resources such as schooling, fresh food and everyday items. Since the plan for Chicago addressed this in the first topic by diversifying the neighborhood with uses, thus improving the quality of life. While the quality of life is a qualitative measure they do discuss it in the study stating that by improving the district uses, district amenities, and updating the neighborhood appearance the quality of life was greatly improved in the central Chicago.

While socially this experiment is an obvious success the next step to see how the project rates environmentally.

Environmental

District Energy Consumption:

When discussing the energy consumption in central Chicago it was determined that the suburban sprawl environment of central Chicago consumed 17,000 kwh/year/person. This is largely due to central Chicago’s mainly commercial downtown causing a need to travel from the suburbs to downtown for work and other needs. This means that Chicago in its existing state consumes 22,540,000 kWh/year in electricity, and 140,000 therms/year in natural gas. In order to adequately supply this in renewable energy it was calculated that it would take a 4.5mile square solar island or approximately 140,000 acres of wind farms. Since neither of those options is feasible they decided to improve the efficiency of the downtown city. They did this in a multitude of ways but the most important areas being Energy Production, Building Efficiency, Urban Matrix, Mobility or Transportation, and Smart Infrastructure. While all of these category’s help reduce carbon emissions and EUI the biggest help is Building efficiency as it helps with energy production as well. In the Central Chicago experiment, they were able to improve the average existing building efficiency by about 60%. Meaning that they could reduce the
overall need for power by about that reduces the size of the renewable energy sources considerably which also will contribute to District EUI and Co2 Contribution.

**District EUI (Energy Use Intensity)**

While the current district has an overall EUI in central Chicago of about 23 btu/ft², the reduction in energy use would allow for a great reduction. While it was never stated in the investigation what this reduction would be it could be assumed that over the entire district a 60 percent reduction in energy use would relate to at least a 45% to 50% drop in EUI. Meaning that the Central Chicago would have an EUI of about 13 btu/ft² making that a vast improvement over the existing District which would help greatly reduce the carbon emissions by the 2030 goal in the next section.

**CO2 Contribution**

The energy consumed per year in the existing district of central Chicago would create 3.90 MMTCO₂e. In this study, they were able to achieve a reduction of 3.12 MMTCO₂e which was composed of many categories, but the main ones being Energy Production, Building Efficiency, the Urban Matrix, Mobility or transportation, and a smart infrastructure. Each of them contributing varying but substantial amounts to the overall reduction of 3.12 MMTCO₂e. This was able to bring the district of central Chicago to the left-over portion of .780 MMTCO₂e in 2020 allowing of the completion of carbon Neutrality by 2030.

**Economics**

While this investigation’s main focus is not on the economic aspect, it is important to understand where funding for such aspects might come from. For this study of the Chicago Loop multiple options were discussed including federal, state, and privately funded options. While these options provide great incentives such as loans, tax breaks, and new developments what makes a comprehensive plan like this successful is the evaluation if buildings, this is an important tool in
understanding that not every building needs a complete renovation to help contribute to the carbon reduction. This is because sometimes enough can be done to contribute to the end goal without the complete renovation or new construction. With this understanding, the gap between financially possible and impossible begins to narrow.

Rochester

While the Central Chicago study is being used as an ideal scenario, Rochester is the city in which the proposed solution will be implemented. In order to see the full effects of the proposed solution, a baseline will first be established in the city as whole, with the assumption that the proposal district has the same baseline metrics.

Climate Information

As seen in figure 10, the Psychometric chart for Rochester, shows how Rochester is a predominately a cold climate with a moderate summer. This is determined, as discussed above, by looking at the clustering of the points. According to the Pacific Northwest National Laboratory & Oak Ridge National Laboratory in 2010, Monroe County is listed under a climate zone of cold, which corresponds to IECC or the International Energy Conservation Code Climate zone 5 as seen in figure 12 to the right [29]. A cold climate is defined as a region with between 5,400 and 9,000 heating degree-days. Degree-days refers not to 24-hour days, but rather the amount of days in the desired period multiplied by the average temperature below 65 degrees [30]. Knowing how many heating or cooling degree-days there are in a given year helps classify the region, by helping determine what the predominate system will be used to keep the building in a comfortable range.

![Figure 12: New York Climate Zones](image-url)
Where a Psychometric Chart becomes extremely valuable is when discussing comfort. These charts allow for the overlay of different systems and options to help maintain the comfort using sustainable systems. While these charts will not be used as an instrumental part of designing the proposed system the net zero or positive energy buildings plugged into this system would have used these charts to determine the best systems for their climate. For example, figure 14 depicts the Psychometric chart for Rochester with a typical set of systems that help maintain the comfort zone in a cold climate.

With all this information combined it allows this investigation to pick the best net zero and positive energy buildings for the climate, giving the best return on investment to the proposed district.

**Social**

**Surrounding Density & Diverse Uses**

Urbanization in Rochester has taken a couple different turns over the history of the city, Rochester began centralized around the Erie Canal when it was first developed as a manufacturing

![Figure 13: Example Design Strategies Psychometric Chart](image-url)
city. After this development, the city began to sprawl away from the urban core creating a small urban district and large suburban environment that can be seen in figure 14 below.

![Rochester Sprawl Diagram](image)

*Figure 14: Rochester, New York Sprawl Diagram*

The sprawl seen in the yellow is exactly what Timothy Beatly [12] was describing above. This expansion of low density created a large dependence on the automobile requiring an increase in infrastructure and less dependence on the public transportation system. In the end the downtown center, defined by the red area, was cut off by the Inner loop, a highway used to accommodate automobile traffic around the city, this forced the urban center to be cut off from pedestrian traffic making it a business only district. While this as plagued Rochester for many years today urbanization continues to take hold in the city of Rochester, Rochester is not only seeing a migration of natives but a migration of people from other cities around the state. This has caused a development of the suburban environments around the urban center of Rochester specifically the “South Wedge”. The “South Wedge” begins to correct this problem with its diversity of uses but still comes short in the density factor because the district is mostly single and duplex housing.
While the south wedge is a good start to the restoration of Rochester’s urban fabric, it is still in disrepair. With Rochester currently consisting of small single family and duplex residences, light and heavy industrial buildings, and commercial office buildings, it is a non-diverse environment that causes the need to travel for essential elements such as groceries. This is a common issue in Rochester as the city is commonly referred to as a “food desert” where no access or limited access is available to fresh groceries. This also affects the density of the area because without the required uses or services in the area the desire to live in the area stall the development of the city is caused. This does not mean that Rochester can’t have the density or can’t support the density, but in order to get both some changes will have to occur though out the city that will result in resiliency of uses and density though out the city districts.

Transportation

As discussed above transportation is essential to the health or quality of life that a city provides to its residents, but also directly relates to surrounding and diverse uses metric. These metrics are important in Rochester because while they supply a public transit system, a public transit system’s success is based upon how efficient, and how extensive the system is. Out of these two options the current Rochester public bus system is extensive, but tends to be inefficient. This is because of the distance between places and the location of places causes the need to transfer or sit on bus for longs period of times. This is mainly caused by the lack of uses in the immediate surrounding area, which is why all these metrics are tied so closely together.

Quality of Life

This brings about the final aspect in the social category Quality of life, Quality of life is an extremely qualitative measurement. But in this case, it will be measured by a comparison to the example city Central Chicago. When looking at the comparison between the two overall central Chicago seems to have a better quality of life, this is directly related to the categories above because
of the diverse uses and the transportation networks work together in order to provide easy of access which contributes to a better quality of life.

 Environmental  

 In Rochester, the electrical grid consists of some renewable sources such as hydro and solar power producing over 30 percent of our required electrical generation is from these sources. Therefore, Rochester’s region emits less CO₂ than the national average according to the US Environmental Protection Agency [31].

 District Energy Consumption:  

 While 30 percent is, a substantial amount of renewable energy the city of Rochester still consumes about 25.2 million MMBtu of energy annually. While 30% of that energy or 7.6 million MMBtu is considered renewable energy, mostly hydro power, how this efficiently this energy is being consumed throughout the city is the next step in understanding how that consumption can be reduce.

 District EUI (Energy Use Intensity)  

 To determine how efficiently the city uses it energy we look at Energy Use Intensity, specifically on a district level. As discussed above this is normally in units of kBtu/SQFT, the city of Rochester consuming about 99 kBtu/SQFT. This means that in comparison to the central Chicago study above Rochester consumes on average about 4 times more per SQFT on a normal day. While these numbers may seem hard to visually the effects of this are seen in CO₂ Contributions.

 CO₂ Contribution  

 Even with 30 percent of Rochester energy consumption being produced by renewable resources Rochester still produces 1.4 million metric tons according to the New York State Power Authority [32]. This is a large contribution considering that roughly a third of Rochester’s energy
is renewable and that Rochester produces about 40% of Chicago’s overall footprint. This amount of CO2 can be equated to over a 125,000 SUV’s driving 15,000 miles per year, that is half of Rochester drive around. While this gives a glimpse into how Rochester begins to fall in the metrics developed, where does Beechwood fall.

Existing Beechwood

As stated above the conditions throughout the city of Rochester are pretty consistent, which is why the evaluation of Rochester as a city will be used as the evaluation of the city district Beechwood, which is shown in figure 19 and 20 below. There are two things to note that will be different when discussing the Beechwood District. One is that Beechwood is a low-income neighborhood, and the second item is that the Energy and CO2 contributions will be adjusted as the districts number will be less than the overall number given for the city above.

Social

As mentioned above Rochester as a whole isn’t largely successful, but there is one more items to discuss in the Beechwood District, it is considered a low-income neighborhood. While the city of Rochester as a whole has a high poverty rate of about 40%; Beechwood has a poverty rate of 47% in 2014 according to the city of Rochester’s Neighborhood data map [33]. With the poverty
rate this high the it brings up the question of how far below the poverty rate most people are; in Beechwoods’ case that number is 50% according to the US census data [34]. That means a majority of the people in that 47% bring home about 50% of the united states poverty level; which makes it so that these people are living in extreme poverty. This makes Beechwood the ideal district or this study.

Environmental

To adjust these numbers as discussed above the census data collected from Rochester’s property data management tool will be used to help determine the amount of people located in the district. This number will then be multiplied by the MMBtu per person which was found above giving a total district energy consumption.

District Energy Consumption:

According to Rochester’s neighborhood data map [33], Beechwood consists of 6,288 Residents. Which when multiplied by the MMBtu per resident Beechwood consumes 213,980.64 MMBtu annually. This calculation can be seen in the formula below.

\[
\text{District Energy Consumption} = \left( \frac{\text{mmBTU}}{\text{Resident}} \right) \times (\text{Beechwood Residents})
\]

\[
\text{District Energy Consumption} = \left( \frac{34.03 \text{ mmBTU}}{1 \text{ Resident}} \right) \times 6,288 \text{ Residents}
\]

\[
\text{District Energy Consumption} = 213,980.64 \text{ mmBTU}
\]

In comparison to Rochester this is only a small portion of the consumption but helps illustrate the low density of Rochester fringe area.

District EUI

To determine a district EUI as stated above an estimated square footage will be determined and used to divide district consumption. To establish the square footage in the mostly residential neighborhood an average SQFT per home was developed using the united states census data.
According to this data the average home in the United States is 1054 SQFT. With 2,308 homes in the area as calculated using the Neighborhood Data tool provided by the city of Rochester [33]. Using these numbers above a base EUI can be established using the formula below.

\[ \text{District Energy Use Intensity} = (\text{District Energy Consumption}) \times (\text{District SQFT}) \]

\[ \text{District Energy Use Intensity} = (213,980.64 \text{ mmBTU}) \times (1054 \text{ SQFT} \times 2308 \text{ Homes}) \]

\[ \text{District Energy Use Intensity} = 88 \text{ kBTU/FT}^2 \]

While this number seems small it is in small units, this being stated it the neighborhood as discussed in majority house and thus has a smaller energy use intensity. One thing to remember is that this does not include the couple of warehouse and industrial buildings in the area as they their addition to the EUI would have been minimal.

**CO2 Contributions**

With the District energy consumption established above at 213,980.64 MMBtu, the CO2 contributions for the districts can also be established. With one kWh equivalent to \(7.03 \times 10^{-4}\) metric tons of CO2, the MMBtu figure above must first be converted to kWh which can be seen in the formula below, using this number a conversion will then be done to CO2 emissions.

\[ \text{kWh} = \frac{(213,980,640,000 \text{ BTU})}{(0.00029307107017 \text{ kWh})} \]

\[ \text{kWh} = 62,711,535 \]

\[ \text{CO2 Emissions} = (62,711,535) \times (7.03 \times 10^{-4}) \]

\[ \text{CO2 Emissions} = 44,086.21 \text{ Metric Tons} \]

While this 44,086.21 Metric Tons is only a fraction of the 1.4 million Metric tons the whole city consumes, it is a starting point that is ideal for measuring the effects of this proposal.

**Proposed Beechwood**

To complete this solution, the implementation of Positive Energy or Net Zero Building is essential. There for before showing the Implementation of the building and the location of them,
the uses and the buildings will be selected. Since this investigation is focused on the effects on a
district level and not the design of the buildings, these will be picked from already constructed or
planned projects.

From the research above it can be determined that the best way to establish a successful
district not only for this paper but in general is the idea of resiliency. This means that not only must
a district have diversified uses but these must also be redundant, to provide the rehabilitation of the
district as well as prevent the failure of the district.

Existing uses in Beechwood

While Rochester, as a whole, was discussed above, the district map for the proposed area
below, in figure 17, shows how the existing district severely lacks the uses necessary.

![Figure 17: Existing Beechwood Uses](image)

As the diagram shows most Beechwood consisting of residential use which can provides
one aspect of the district. But where Beechwood lacks is all the other uses, being that Beechwood
sits on the railroad tracks the out skits of the district are mainly industrial plants dealing with
manufacturing and distribution. While Industrial space is over powering retail, commercial or
office space is at a minimum providing little to no redundancy for the district which causes the
district to have no resiliency as a district.

**Planned Uses and Locations:**

This analysis of the existing uses that currently exist in the district of Beechwood allows
for the determination of what uses would best revitalize the area. Again, as the research above
dictates; Multiple uses, walkable environments or transportation to essential area, access to
essential elements such as food and groceries, and entertainment are paramount in revitalization.
But what about the possibility of making these new additional uses self-sufficient allowing for
funds usually marked for operation cost to be cut allowing for reinvestment. This is where the
implementing Net Zero and Positive energy buildings can help accomplish this. To help establish
how much can be saved and reinvested, accurate numbers in terms of energy use and budget need
to be used. For this reason, examples were chosen from buildings that have already been built or
designed. Below their uses and why their important will be listed out before showing where they
will be implemented in the district to help revitalize it.

**Net Zero and Positive Energy Examples:**

**Walgreens: Evanston, IL**

This was chosen to bring essential items with in the district, so that the need for vehicular
transit could be greatly reduced, for everyday items. Walgreens was chosen because it not only is
a drug store but also a grocery store creating a mixed-use retail environment. One of the challenges
they faced in this project was the use itself, since retail spaces must draw people in using transparent
façade’s and Net Zero buildings are usually super insulated boxes with no windows. Per High
Performance Building, they combatted this issue with many different systems and solutions
including solar panels, natural ventilation, High R-value building envelope, and high efficiency
heating and cooling systems [35]. Integrating these solutions with in the design allowed them to
achieve a carbon footprint of 226.2 MTCO₂ per year, an EUI of 18.6 Kbtu/ft² per year, and building
that is net zero 10 out of the 12 months in a calendar year [35]. While most of these number above seem high for an annual consumption they are equal to a two-month total of a normal Walgreens store.

Omega Center for Sustainable Living: Rhineback, NY

A community center that helps spread the idea of sustainable living is essential in an urban environment such as beechwood for multiple reasons. One being that with the education on how to live sustainably it makes the urban environment less costly environmentally as well as economically. As many of the building is this section the building uses bioclimatic design to help reach its goal. This building in particular uses many different systems to reach net zero the most influential of them passive daylighting and natural ventilation. These systems in combination bring the net EUI to -8 annually according to the American Institute of Architects [36].
While some office buildings do exist in the district already part of rebuilding a district is providing not only diverse uses for people to use but diverse people as well. By having diverse people and uses you establish an ecosystem with the district. To help accomplish this diversity high efficiency office buildings will be placed throughout the district. According to Sunrise Solar,
this building produces all the electricity it requires making it truly a net zero structure, creating 960,000 kWh of clean energy [37].

**Bright' n Green “Sandy Resistant” Mixed Use Project: Brooklyn, NY**

The adaptability of this project was the reason it was chosen as a necessity to the district. It not only begins to provide extra density by providing housing it also provides a community or retail center on the first floor which helps to create a resiliency. This building maintains a net zero energy use with the addition of solar panels, but prides itself on the efficiency of HVAC system. This efficiency is accomplished by preheating the air using geothermal wells, and using heat recovery units on the exhausted air. This allows for an almost 90% efficient system creating the ability for the solar to cover the remaining energy use [38].

*Figure 21: Picture of Bright N Green Mixed Use Facility*
Delta Building: Brooklyn, NY

The Delta building will be an important building in this solution as it helps with providing housing and creating a higher density in the area. While still providing no energy cost energy and contributing to carbon neutrality. This building while similar to Bright N Green accomplishes its energy goals by being super insulated and efficient rather than using state of the art heating and cooling systems [39].

Uphill House: Cambridge, NY

The Cambridge house was selected because it is close in size to the average house used above to determine the EUI of the area. It also matched our climate zone therefore providing accurate number for the consumption and production of energy. Located in Cambridge, NY this home has been net positive in energy use since 2012, suppling over 8,400 kWh in that time frame.
of clean energy. This is an impressive feat and when deployed in the Beechwood District should prove to be extremely useful in offsetting energy use and supporting carbon neutrality. All information curiosity of Net plus Design [40].

Proposed Uses:

As we can see from above many of these buildings could be helpful if implemented into the Beechwood district. Figure 18 shows these uses mapped out across the district, in a fashion that supports the current district. For the addition of mixed use many of the buildings have been added to main corridors or centers to help those areas expand at a natural pace rather than artificially inducing these uses to purely residential areas. To maintain the history of the district many of the warehousing and distribution facilities are remaining for both the economic stability and the population they bring to the area. While the district already had a great amount of housing it was a majority single family homes, to preserve this character positive energy homes were scattered throughout the district, while also placing Higher density housing such as multifamily buildings
near the industrial areas to help minimize the impact on the surrounding properties. Lastly a sustainable living community was implemented in the district to help with addressing and teaching the aspects of living sustainably.

Social

Surrounding Density and Diverse Uses:

When comparing the two maps above in figures 21 and 22 the spread of uses using mixed use facilities and the existing retail spaces beings to create clear main corridors in this district. Providing traffic for uses that never existed in the district including supplying groceries and other necessities. While the addition of these uses to help develop the main corridor is important the addition of housing in the area is important as well as it continues to create resiliency. Once a single-family residence district now a diverse district containing a multitude of housing styles from studio to two bedroom apartments now appeals to much of the population. Lastly every district has its own character, and while the architectural style of the building examples is irrelevant it was important to consider the current uses in the neighborhood and building upon them not replace
them. Therefore, a lot of the warehousing and industrial building were left with their current use. They bring a history to the district and since they have been around for such a length of time they help to stabilize the financial side of the district by supplying jobs while the newer business proposed establish themselves.

Transportation

As discussed above in Chicago the success of a district is not only based upon the diversity of uses but the transportation required to get there. If the only way to get fresh food is to drive not everyone will have access to that amenity. Therefore, in the proposed plan one can see that the uses were laid out close enough to each other that all the uses would be within walking distance for the district. This allows the entire district to have access to all the amenities without the use of a car.

Quality of Life

Since the relationship between Transportation and surrounding density and diverse uses was established as quality of life. It can be assumed that if an improvement is seen in the transportation metrics and surrounding diverse uses and density that an improvement in quality of life will be seen as well. While the Social category is a qualitative measure it can be clearly stated and seen that an improvement in the district would be noticeable in the proposed plan.

Environmental

District Energy Consumption:

Since this plan has implemented additional buildings to this district additional power consumption for the district would be expected. But because these buildings are net Zero or positive energy buildings their effects on energy consumption are non-existent. While this may be true it is important to determine how much energy would be offset by these new additions to the neighborhood. By looking at the adjustments each building would be bringing to the district it was seem that the total energy consumption was reduced to 192,582 MMBtu that is about a ten percent reduction.
Since our energy consumption did show some effect to the limited amount of buildings that were placed throughout the neighborhood this adjustment might also be visible in District EUI as well.

**District EUI**

Since there was a noticeable reduction in the amount of energy consumed it can be assumed that there should be a slight reduction in EUI as well. In order to determine how much of a reduction as estimation was calculated based upon the correlation between EUI and energy consumption. This can be accomplished because the only buildings that would adjust the district EUI are the newly implemented Buildings. Therefore, since about 10 percent was reduced in energy consumption and a comparable 13 percent can be accomplished since the relationship between EUI and Energy consumption requires the EUI reduction to be greater than energy consumption reduction. This 13 percent reduction allows for the EUI to drop for 88kBtu/SQFT to 76 kBtu/SQFT a modest reduction that not only helped reduced energy consumption but should help reduce the CO₂ contributions as well.

**CO₂ Contributions**

To see what this study has reduced the districts CO₂ contributions by the reduction was multiplied by the CO₂ coefficient used above.

\[
\text{\textit{CO₂ Emissions}} = (6,271,153) \times (7.03 \times 10^{-4})
\]

\[
\text{\textit{CO₂ Emissions}} = 4408.62 \text{ Metric Tons}
\]

This means that the overall district contribution can be reduced from 44,086 metric tons to 39,678 metric tons. This means that the district has successfully lowered its carbon footprint using NetZero and Positive Energy Buildings.
Economics

Total Cost:

When determining total cost for a project of this scale in the board sense that this investigation looks at it can be very difficult. This is because building construction is region specific therefore as well as project specific. Since most of these projects did not disclose the final cost of the buildings an estimation was created. To create the estimation the final amount of sqft implemented was multiplied by a sqft estimator from RS means.

To determine an average per sqft a mixed-use coefficient was developed by taking the average uses and averaging them together to get a total sqft cost of $273/Sqft. Now to determine total cost the amount of carbon neutral sqft is multiplied by the coefficient, therefore the total cost for this project comes in at $715,250,000. To determine the feasibility of this number the payback period will be calculated next.

Payback Period:

To help determine the estimated payback period for this investigation it is known that each building will have a different payback period depending on systems used and overall cost of the project therefore the longest payback period was taken. This was done for multiple reasons but the biggest being that it is worst case scenario. This is because each property has a fixed project payback period and the longest would be the determining factor on if investors or developers were interested. This is important to understand because while that number above is the total cost for the district one developer or investor could not sustain the project long enough. This is why the payback period of 45 years was chosen as it would take the Walgreens Net Zero Example above to achieve its breakeven point according to High Performance Building [35].
CONCLUSION/DISCUSSION

In this section, the results above will be discussed leading to the overall decision of whether the investigation is in fact successful. It will be broken down into the three metric categories with the final section being the final verdict on the overall investigation.

Environmental

In figure 25 above the results from the above section are illustrated with a blue line as the proposed solution and the black line as the existing, and an improvement can be seen in all categories. While marginal at about 10 percent across all categories the investigation in the environmental category is success it has successfully driven down consumption, EUI and Emissions all on the district level. This is important to recognize because this was without any physical improvement to the surrounding neighborhood it was purely the implementation of new buildings to supplement the existing fabric as is. This creates the first successful category for this investigation before the social category is investigated.

Figure 25: Environmental Results
Like the environmental metrics above the Social metric results shown in figure 26 above also show a similar result with improvements in all categories. Surrounding and diverse uses allows for an improvement because the new faculties create more uses and a higher density to help support the new uses. To help support these uses and density transportation had to be addressed as well and the improvement is based upon the fact that the community starts to be a walkable community. Therefore, because the transportation system itself is not updated the improvement is minimal on the scale of improvement. Lastly is quality of life which is the last metric in the social category because the improvement is the average of the two categories before it. Meaning that quality of life will also be improved by supplying new uses, higher density, and increased walkability. Creating the success for the overall Social category. Which now bring the question of is this economically feasible.
Economics

The results above are obvious there is an immense cost to this project resulting in an overcost of 715 million dollars. While this cost is large and the effects are minimal as discussed above the cost will not one person’s responsibility each building could in theory fall upon individual investors resulting in a much lower individual investment. And since this project is looked in a total cost the payback period was taken to be worst case scenario. For this to happen the longest payback period had to be used hence why the Walgreens payback period was chosen. Resulting in an average payback period of about 52 years according to High Performance Buildings. This means that while the project is expensive and can be considered to have minimal return it is economically feasible.

Overall Feasibility

Overall this investigation is marginally successful; it revitalizes a low-income community and it supports carbon neutrality, while it may do minimally according to some I would say that is it successful. But I would like to raise a couple of points and clarify how greater improvements could be made to achieve the original goal of a carbon neutral district. This study only looked at if this district were to be supported as is. This means that all of the surrounding buildings maintain their current efficiency. But what if you not only produce the carbon neutral building but also improved the surrounding building’s efficiency. This could be something as simple as replacing the light bulbs to all LED, or replacing the windows in order to reduce heating and cooling loads. It would be interesting to see if this would have greater effect then just the ten percent that carbon
neutral building can establish. It might even be the solution to achieving the image below figure 28 where the district begins to supply its own energy. This is because like creating Net Zero and Positive Energy buildings efficiency is key.

Future Research

While this investigation was successful at revitalizing communities the technologies are still too expensive, but future research opportunities still exist. A couple of ideas on how to expand upon this research could be how does efficiency play a role; if the efficiency of each property in the district was improved would the possibility of carbon neutral districts become a reality as discussed above. But what kind of role will the rebound effect play on this goal of upgrade efficiency. While this is only one expansion of the idea it could very well lead not only to a solution but also the expansion of the idea of creating a carbon neutral power grid.

Figure 28: Beechwood Energy Map
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