

Carbon-Neutral Design Guidelines
for Medium Density Urban Areas
in Warm-Humid and Cool-Dry Climates

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ABSTRACT

This thesis combines Architecture 2030's carbon-neutral performance targets with the SmartCode transect-based development principles, to generate guidelines for design of medium-density carbon-neutral districts. The topic examines these guidelines in medium density planned and built sites (transect types T4, General Urban Zone, and T5, Urban Center Zone) in representative cities within a cool-dry climate (IECC climate zone 5B, Denver) and a warm-humid climate (IECC climate zone 3A, Atlanta). The thesis assumes that a carbon-neutral district is more effective and potentially easier to achieve than designing independent carbon-neutral urban buildings. Within an urban context, it is now possible to connect buildings to a renewable power source and design for lower energy requirements as a neighborhood/district. This strategy relies on intensive conservation and passive design strategies for each building in addition to providing access to on-site resources for the district as a whole.

The project approaches design thinking as a research method resulting in neighborhood/district, block and street, and building volume and massing strategies and guidelines. Two existing New Urbanist developments were selected in the IECC climate zone example cities for the U.S. Existing energy demand and Architecture 2030 targets were estimated from Energy Information Administration data based on building types and region. Problematic issues for each development were identified based on analyses of climate, solar access, daylight access, and ventilation patterns. A new design for each site outlines climatically driven urban design guidelines to promote access to solar energy, daylight, and ventilation resources for each block and building. Analysis of revised development patterns shows increased density is possible in both sites while achieving high site resource availability for passive design strategies. A simple method for estimating roof area required for photovoltaics under different fossil fuel reduction targets was developed and applied to each site. Finally, building-scale access to resources and block patterns of sun and shade are maximized through multiple design and analysis iterations of block types. New design guidelines are generated to promote carbon-neutral performance in each climate zone.

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CHAPTER I INTRODUCTION

Reducing and eliminating fossil fuel dependency from the building industry will alleviate smog, acid rain, and other side effects of pollution in major cities. At this time, power plants are burdened during peak hours, sometimes requiring the plant to expand to accommodate the users' needs. Peak hours are those in which the power plants experience their maximum demand during the day. Unless supplying a large consumer, peak hours tend to be those in which people are actively occupying their houses and apartments in the mornings and evenings, heating or cooling (based on season) demands from commercial buildings, and nighttime streetlight power. In some areas in which the power plants experience significant burden, the company may impose a peak period rate that is greater than the normal power rate. The Clean Air Act was a direct response to a realization of the harmful effects of pollution caused by fossil fuels. Carbon-neutral districts will reduce pollution by the use of renewable fuel, and alleviate peak loads. Cheaper energy could also be available within the district. Carbon reductions result in reduced greenhouse gasses that contribute to climate change.

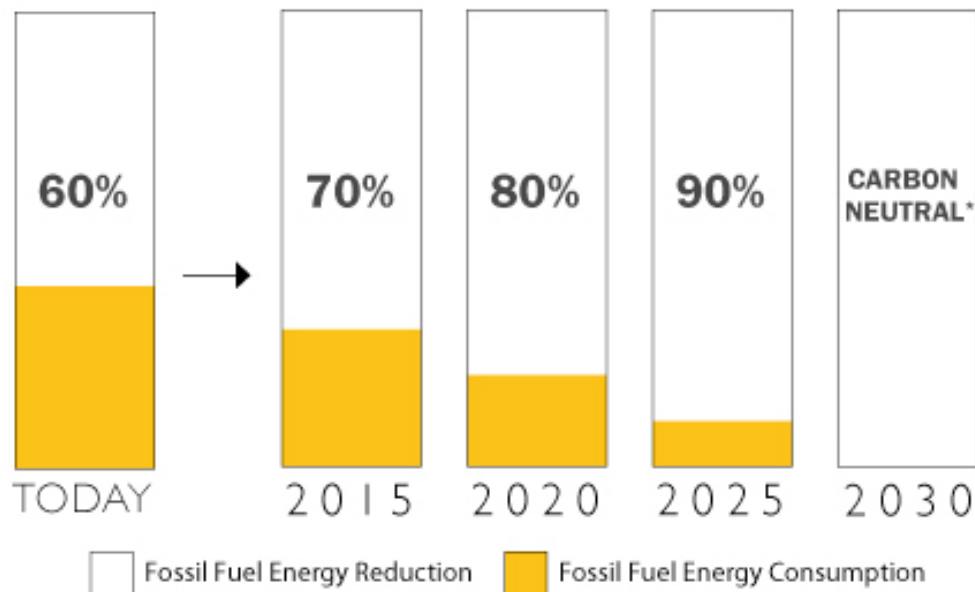
With increasing industry support for the Architecture 2030 Challenge and the widespread usage of the Leadership in Energy and Environmental Design program (LEED), the goal of carbon-neutral buildings is quickly gaining popularity. The Challenge, founded in 2002 by Edward Mazria, has since done much to compile statistics about the building industry's role in the United States' energy issues. The agenda of Architecture 2030 aims to gradually reduce the usage of fossil fuels in new and renovated buildings working toward a complete elimination of fossil fuel use by the year 2030 (Architecture 2030, 2013).

In 1963, Congress passed the Clean Air Act to begin to alleviate pollution that had become problematic in high-density areas (Environmental Protection Agency, 2013a). This initial act funded preliminary research and alleviation, and was amended in 1970 alongside the establishment of the Environmental Protection Agency. The amendments, which came shortly before the oil embargo in 1973, brought the need for clean air and alleviation of pollution to the forefront and created the first pollution regulations. Further amendments in 1977 created emissions standards to regulate air quality and pollution by means of the "Prevention of Significant Deterioration Program" so that pollution does not exceed a prescribed concentration limit (Environmental Protection Agency, 2013b).

Architecture 2030

Architecture 2030's carbon-neutral building standards are gaining support through use by the top firms both in the United States and internationally. The AIA administers a professional continuing education series that uses online and on site classes to address issues related to designing to reduce fossil fuel use. In the urban context, the 2030 District program and five cities (Seattle, Cleveland, Pittsburgh, Los Angeles, and Denver) are developing models for carbon-neutral districts. Each city does not require enrollment within district boundaries, but uses buildings enrolled in the program to record energy usage for information to authenticate the targets of the challenge, and energy efficiency and environmental benefits (2030 District, 2013).

Figure 1 shows the 2030 Challenge target reductions incrementally. This thesis will focus on the 2020 80% fossil fuel energy reduction and the 2030 carbon-neutral target (also referred to as the 100% fossil fuel energy reduction target). The Energy Star 25% fossil fuel energy reduction target is also used in this thesis for an additional comparison.



The 2030 Challenge

Source: ©2010 2030, Inc. / Architecture 2030. All Rights Reserved.
*Using no fossil fuel GHG-emitting energy to operate.

Figure 1. Architecture 2030 Challenge fossil fuel reduction targets (Architecture 2030, 2014).

Increased professional focus on the impacts of fossil fuels in the construction and operation of buildings calls for the formation of guidelines that aid in carbon-neutral building design and urban form. A widely used energy source, coal, contributes to the majority of the United States' sulfur dioxide pollution and can result in acid rain that contaminates water sources and erodes surfaces. Other fossil fuels, such as those utilized in transit, contribute to smog and poor air quality (Union of Concerned Scientists, 2002). These energy sources also contribute to increased global temperature in different ratios. The EPA estimates that the United States average temperatures could increase up to 11 degrees Fahrenheit by 2100 with increased rain in some areas and less snow overall. Additionally, a rise in sea level and increase in acidification will be detrimental for coastal areas (Environmental Protection Agency, 2013). For these reasons, it is necessary to lower fossil fuel usage during construction and material transportation and eliminate the use of fossil fuels in day-to-day building operations. Architecture 2030's approach is to involve the building industry in carbon reduction goals.

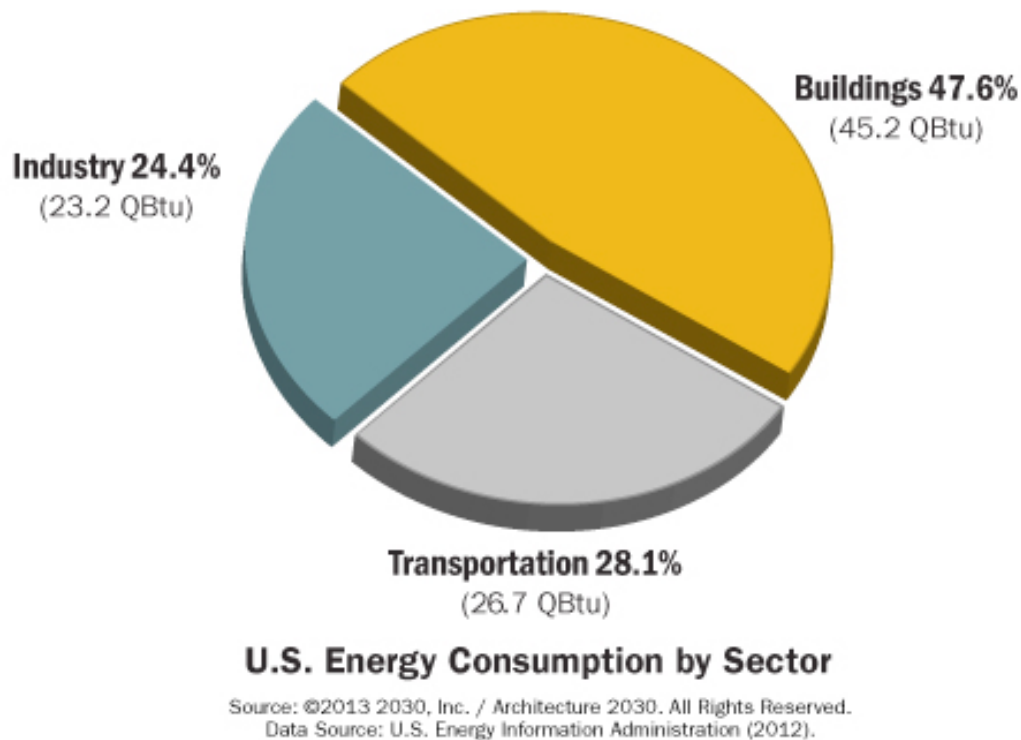


Figure 2. Architecture 2030 graphic for US energy consumption (Architecture 2030, 2014).

Form-Based Code

SmartCode is a transect-based code developed by the Center for Applied Transect Studies (CATS) and Duany Plater-Zyberk & Company that outlines the theoretically preferred changes in development patterns as settlement moves from the natural zone to the urban core. Transitions from one zone to another occur at the street and mid block with similar building forms adjacent to each other so that the line between zones is subtle. As a result, cities and counties that adopt a SmartCode-based code tend to have more blurred and mixed density patterns that do not necessarily resemble the distinct delineation in the transect diagram distributed by CATS (Figure 3). This thesis will explore medium density districts (T4 and T5 in Figure 3) rather than a particular transect density type to challenge the application of passive design. Medium density patterns outlined by SmartCode are those whose buildings are generally low rising and generously spaced with a variety of uses and styles. Street grids may or may not be strictly regular and green spaces may not be uniform. Building types in this density include single-family houses (SFH), townhouses, live-work units, mixed-use units, civic, office, and commercial buildings. Though many case studies show that complete or nearly complete passive design can be achieved in a single building, fewer cite intensive use across the entire district.



Figure 3. SmartCode's urban transect (Center for Applied Transect Studies, 2009).

This type of development regulation has been used in many cities and towns to integrate public transportation and livable urban character into new and existing neighborhoods. Cities that have suffered from sprawl are often governed by codes that do nothing to mitigate it. Sprawl results in car-reliant neighborhoods that tend to be very far from daily amenities so that residents are required to own and use a car to live in the area. Residential buildings in sprawl neighborhoods and districts are single-family detached units with few sidewalks. Why is this

bad? Without a mix of uses in a district, residents are forced to use a car as their primary form of transportation anywhere. In terms of sustainability, residents and businesses within these neighborhoods generally consider themselves individuals rather than members of a community. The “big box” department store sits across from single-family detached houses, separated by a large busy street. If members of a district consider themselves as contributors to the larger whole, they will be more attentive to their interactions and create guiding principles to guide the end result of the community at maximum capacity. These guiding principles or codes generally allocate streetscape, building heights, and setbacks from the street, and green space. For example, to create mixed-use neighborhoods, city planning offices generate a second alternative code, initiative, or plan that is idealized and goal-oriented to allow outside firms freedom to design outside the conventional sprawl-generating zoning code. Typically, once the sprawl-mitigation plan is generated, architecture and planning firms are contracted to design mixed-use neighborhoods.

Climate Selection Criteria

Climates for the study were selected based on generating significant variability in the design approach under different conditions. The International Energy Conservation Code (IECC) contains a map that divides the United States into climate regions (Figure 4) based on temperature and humidity (U.S. Department of Energy, 2013). The dry line down the central United States divides the country into dry and humid zones while the colors indicate temperature zones. To create a moderate variation between sites, two climates were chosen: cool-dry and warm-humid. As can be seen in the IECC Climate Region map, the warm-humid line divides climate zone 3A (the mixed/warm-humid climate) nearly in half. Climate zone 5B (cool-dry) will be represented by Denver, Colorado, and zone 3A (mixed/warm-humid) will be represented by Atlanta, Georgia. Due to its proximity to the warm-humid line in 3A, Atlanta will be considered a warm-humid climate rather than a mixed climate.

The IECC defines Atlanta’s climate as “a region that receives more than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis) or fewer, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.” (BCEP, 2009). The IECC additionally defines Lakewood’s climate as “a region with between 9,000 and 12,600 heating degree days (65°F basis).” (BCEP, 2009)

Site Selection Criteria

Site Selections for the study were based on the date that the district was completed, proximity to Atlanta and Denver, and adherence to New Urbanist principles. Adherence to New Urbanist principles was necessitated due to the SmartCode form-based code overlay. Site selection criteria are listed as follows:

1. At least 80% complete by October 2013.
2. Completed for no longer than 10 years.
3. Utilize New Urbanist principles in design.
4. Existing sustainable initiatives in place.
5. Near (within 10 miles of city boundary) or within IECC climate zone example cities.
6. IECC climate zone 3A and 5B.

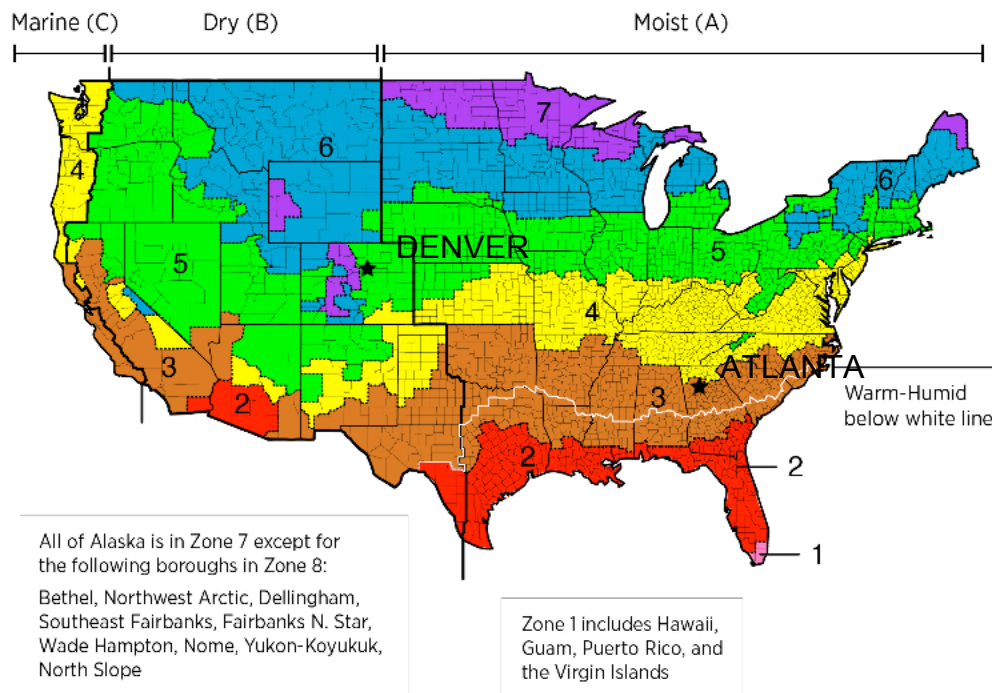


Figure 4. International Energy Conservation Code Climate Regions Map (BCEP, 2009).

Energy Targets

In comparison to typical buildings, Architecture 2030 outlines benchmark reductions in fossil fuel use by preset years. This project uses the Environmental Protection Agency's (EPA) Energy Star program, 2020, and 2030 years to calculate energy targets and generate design guidelines. The Energy Star program targets indicate a 25% reduction of fossil fuel energy use relative to a baseline building. In the year 2020, fossil fuel energy usage target reduced to 20% of total base building energy usage relative to base energy. The most ambitious target is that by 2030, buildings will operate completely independent of fossil fuels. This target is for all new buildings and major renovations.

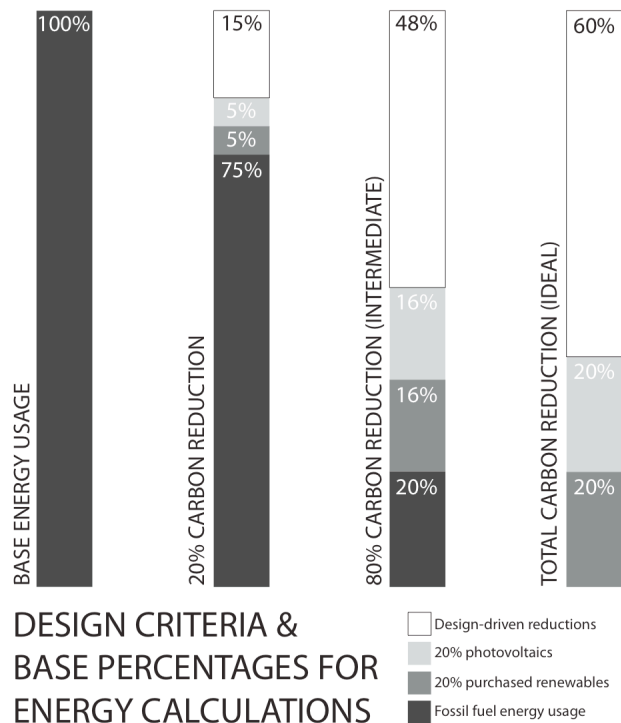


Figure 5. Energy Target Parameters.

As shown in Figure 5, an allowance of up to 20% of the fossil fuel reduction can be provided by purchased renewable energy credits under the 2030 program. This percentage would be purchased from off-site renewable energy sources through utility providers. To calculate this percentage of purchased energy, find 20% of the fossil fuel reduction target. For example, to calculate allowances for

80% fossil fuel reduction, first subtract the 20% allowance for fossil fuel supplied energy. From the remaining 80%, 20% may be purchased renewable energy.

$$(Baseline\ energy) - (fossil\ fuel\ allowance) = Fossil\ Fuel\ Reduction\ Target$$

Example for 80% fossil fuel reduction target: 100% base energy – 20% allowed fossil fuel use = 80% fossil fuel reduction target

$$Purchased\ renewable\ allowance = (0.2)(fossil\ fuel\ reduction\ target)$$

For urban planning purposes, this thesis recommends an additional target of 20% photovoltaic energy generation on the site. Note that photovoltaics is the method used in this thesis, but not the only on-site renewable resource option. This proportion allows a mirrored on-site/off-site renewable energy generation assumption. In other words, 20% of the fossil fuel energy reduction is being generated off-site, and the same amount is generated on-site through photovoltaics. See below for the calculations of these proportions.

$$On-site\ renewable\ energy\ allowance = (0.2)(fossil\ fuel\ reduction\ target)$$

Example for 80% fossil fuel reductions: (0.2)(80% fossil fuel reduction target) = 16% on-site renewables

The remaining energy demand will be met through design-driven reductions and include conservation, passive design, and climatic design. Final calculations according to this thesis for energy targets may be found below.

$$Design-driven\ reductions = (Fossil\ fuel\ reduction\ target) - (On-site\ renewable\ allowance) - (Purchased\ renewable\ allowance)$$

Example for 80% fossil fuel reductions: 80% reduction – 16% on-site renewables – 16% purchased renewables = 48% design driven reductions

CHAPTER II

ATLANTA DESIGN AND ANALYSIS

Glenwood Park is a 28-acre neighborhood 2 miles outside of downtown Atlanta. Planning was led by Dover, Kohl & Partners with numerous other contributors. The site, a former brownfield, is part of the Atlanta BeltLine, a 22-mile loop of green space and transit lines that follow a historic rail line. The BeltLine connects 45 neighborhoods and can be easily accessed within a half-mile radius. The BeltLine project seeks to create a more pedestrian friendly condition surrounding Atlanta, provide access to mass transit that travels to and from the city, encourage more consistent neighborhood character, and allocate green space for a continuous trail (Ecos Environmental Design et al., 2011). At maximum capacity, Glenwood Park is designed for 375 residential units, 48,000 square feet of retail space, and 20,000 square feet of office space with a program total of 750,000 square feet. Building types within the district include single-family houses (SFH), townhouses, live-work units, mixed-use units, and civic, commercial, and offices. Existing sustainable initiatives within the district include Southface Energy Institute Earthcraft house standards for all construction, some actions to reduce carbon dioxide, building with recycled materials, and high walkability. The district additionally follows United States Green Building Council (USGBC) building guidelines and Congress for the New Urbanism principles.

The Atlanta Regional Commission (ARC) has developed the Livable Centers Initiative (LCI) that encourages mixed-use, walkable cities in place of the car-reliant neighborhoods resultant of sprawl. Coupled with the improvement initiative for the Atlanta BeltLine, suburban and general urban neighborhoods of the Atlanta area have been undergoing revitalization and new construction in place of brownfields, strip malls, unused factories, and sprawl (non-historic) neighborhoods.

The Atlanta area is highly affected by its water supply, which has been in danger of changing in recent years. In fact, since the creation of the new approach to coding in the area in the 1990s, in 2006, the water sources, Lake Lanier and Lake Allatoona, have changed their operations to the detriment of the area. Since these changes, the code and planning has not changed or allowed for accommodation, a practice that could hinder success in the future (Atlanta Regional Commission, 2011, p. 6). Plan 2040 begins to address the need for sustainability combined with economic and social requirements of the region with various different programs to encourage a more sustainable region (Atlanta Regional Commission, 2011). Because the plan is relatively new, parameters and principles at times seem vague, but do emphasize regional issues such as water and air quality. While sulfur dioxide is a major pollutant caused by building operation energy from coal power plants, “the Atlanta region does not meet federal standards for both ground level ozone and fine particulate matter”



Figure 6. Glenwood Park with Context (image from USGS).

(Atlanta Regional Commission, 2011, p. 24). This means that nitrogen oxides and volatile organic compounds are mixing in the sunlight to create ozone at the ground level, resulting in smog and haze that is detrimental to fragile organic matter and sensitive or outdoors-heavy people (Environmental Protection Agency, 2012). Particulate matter, on the other hand, is a result of either a reaction or actual construction or the like or both. These particles tend to be so fine that they can enter into the lungs and cause health problems; they may also be so dense in the air that they have been isolated as the primary source of haze in some areas (Environmental Protection Agency, 2013).

If the region maintains its activities as usual, walkability may be reduced due to poor air quality. Because factories, power plants, and construction contributes to the pollution problem in the Atlanta region, carbon-neutral guidelines can help to lighten the energy demand on coal power plants and encourage clean energy usage. If sensitivity is applied to the construction process, particulate matter may be reduced as well.

Programming

Single family houses (SFH) in Glenwood Park number 194. Although the energy demand for this program type is much lower than other building types on the site, the energy demand is a greater percentage of the total site energy demand due to their number. SFH are individual detached units that average 2,153 square feet per unit (Green Street Properties, 2013). They are currently located on the eastern half of Glenwood Park (in purple on Figure 7).

Townhouses in Glenwood Park number 117. Energy use for this building type in the Southeast is the same as the SFH above, however, because there are fewer units on site, the total demand will be lower. Townhouses are attached multi-story units that average 2,200 square feet per unit (Green Street Properties, 2013). They are spread throughout Glenwood Park (in blue on Figure 7).

Apartments in Glenwood Park number 114. Energy use for this building type is the lowest on site. Additionally, because there are fewer units, energy use will also be lower than any other residential program type. Apartments are multiple single-story units arranged in a multi-story building. They are primarily located in the center and western portion of Glenwood Park, typically above retail programming (in orange on Figure 7).

Retail space totals 48,000 square feet. Energy use for this building is nearly twice as high as residential requirements (see Table 1). Because the designed area is less than half of the residential requirement, energy remains proportional, even smaller than the residential requirements. Retail space is located on the eastern half of Glenwood park (in red on Figure 7).

Office space totals 20,000 square feet. Energy use for this building type is the highest on the site, however, because it is the smallest area, totals remain reasonable in proportion the residential program usage. Office programming is located solely on the southwestern corner of Glenwood Park (in green on Figure 7).

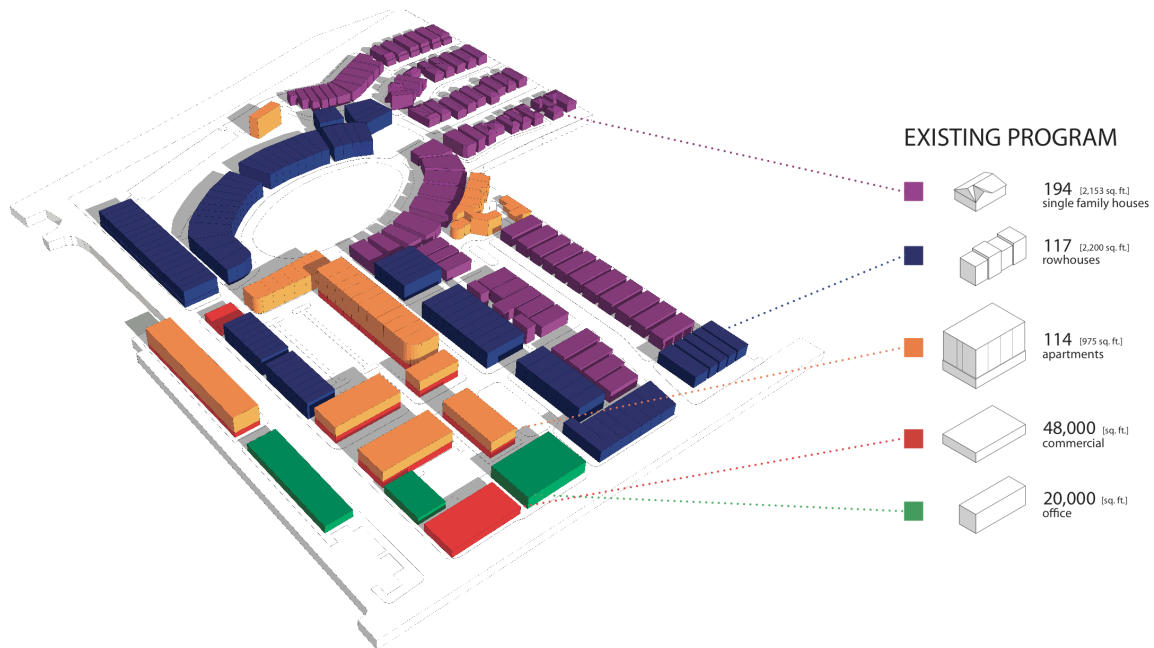


Figure 7. Glenwood Park Existing Program Distribution.

Calculation of energy requirements is based on the total area of each program on site. This calculation is seen below in Table 1.

Table 1. Glenwood Park Program.

<i>Program</i>	<i>Area Square feet</i>	<i>Quantity</i>	<i>Total Area Square feet</i>
SFH	2153	194	417,682
Townhouse	2200	117	257,400
Condominium	975	114	111,150
Retail	48,000	1	48,000
Office	20,000	1	20,000

The existing program requirements for Glenwood Park demand a large portion of energy from single family housing (SFH). Figure 8 (Glenwood Park existing program energy requirements and reductions) portrays Glenwood Park's energy demands with Architecture 2030's benchmark requirements. The energy demands are based on the typical energy use intensity (EUI) for each program type in its particular region. The EUI is based from the United States Energy Information Agency (EIA), and may not necessarily reflect actual energy consumption in Glenwood Park as currently built due to the mix of strategies employed by the current site. The use of typical site EUI allows for an equal comparison between the form of the existing and the form of the proposed designs. As outlined by the Architecture 2030 benchmarks, as efficiency increases, fossil fuel use decreases. Therefore, in this study, the EUI reflects this relationship inversely—a lower EUI assumes greater efficiency, better passive design, more on-site PV, increased purchased renewable energy, and lower fossil fuel usage. Table 2 shows each EUIs used for Glenwood Park.

Table 2. Glenwood Park Energy Use Intensities.

<i>Program</i>	<i>Base EUI</i> <i>kBTU/sqft/yr</i>	<i>25% EUI</i> <i>kBTU/sqft/yr</i>	<i>80% EUI</i> <i>kBTU/sqft/yr</i>	<i>100% EUI</i> <i>kBTU/sqft/yr</i>
SFH	40	30	14.4	8
Townhouse	40	30	14.4	8
Condominium	38	28.5	13.7	7.6
Retail	71	53.25	25.6	14.2
Office	84	63	30.2	16.8

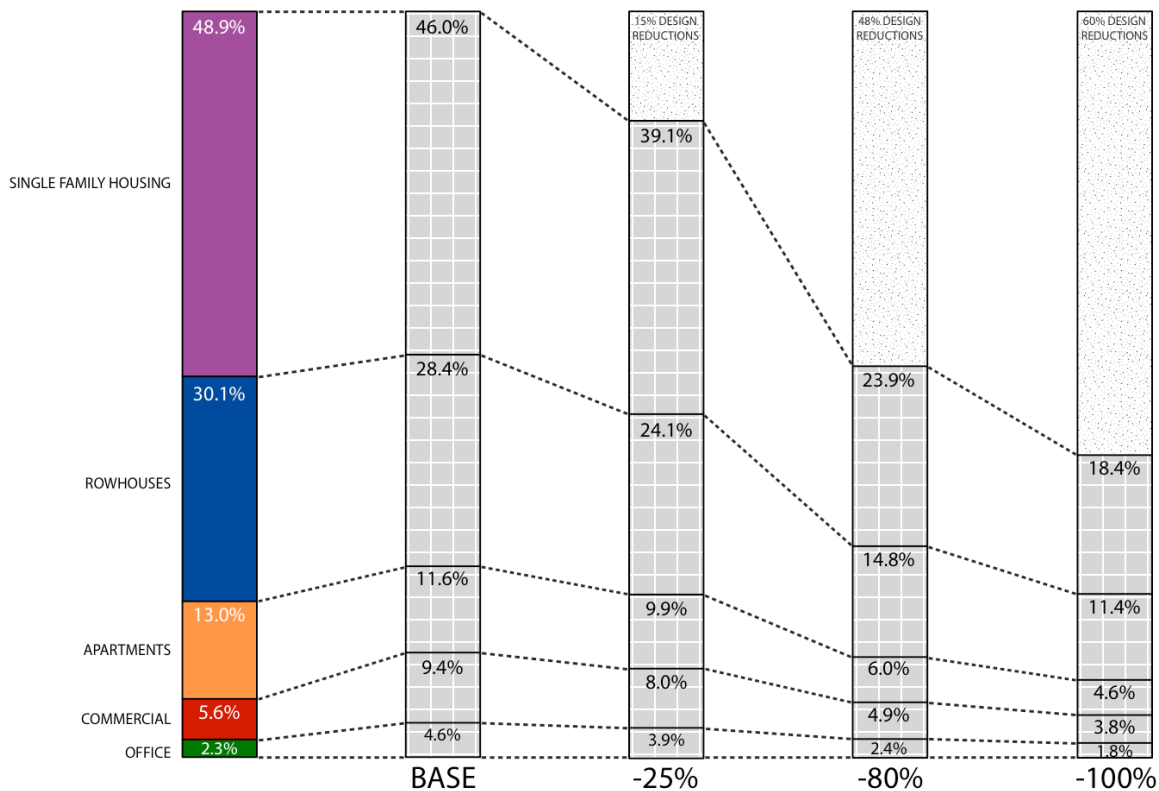


Figure 8. Glenwood Park existing program energy demands and reductions.

To calculate energy demands for each program type, the total square footage of the program is multiplied by the EUI and converted to the proper units (kilowatts per year, kWh/yr) by then multiplying by 0.000293 Wh/yr and 1000 Kilowatt. EUI selected reflects a target energy use desired for the site based on fossil fuel reductions. Table 1 indicates existing program area totals for Glenwood Park.

$$\text{Energy Demand} = \text{Area} * \text{EUI} * 1000 * 0.000293$$

$$\text{Units: kWh/yr} = \text{sq. ft} * \text{kBTU/sqft/yr} * 1000 * \text{Wh/yr}$$

To draw a comparison between targets and program type demands, program energy use totals are organized as a certain percentage of the whole site energy demand. The base comparison is based on 0% fossil fuel reductions. Energy Star targets (25% reduction) are based on a 25% fossil fuel reduction, in which case the whole is actually 75% of the base. The 2020 target (80% reduction) is based on an 80% reduction in fossil fuel energy use, in which case the whole is actually 20% of the base. Finally, the Architecture 2030 ideal target (100% reduction) is based on no fossil fuel usage and is 0% of the base. The remaining energy demand (Table 3) must be met through additional on-site energy generation and efficient design. (Architecture 2030, 2013).

Table 3. Glenwood Park Remaining Energy Demand.

<i>Program</i>	<i>Base Energy</i>	<i>25% Reduction</i>	<i>80% Reduction</i>	<i>100% Reduct.</i>
	<i>kWh/yr</i>	<i>kWh/yr</i>	<i>kWh/yr</i>	<i>kWh/yr</i>
SFH	0	2,937,139.82	1,409,827.12	783,237.286
Townhouse	0	1,810,036.8	868,817.664	482,676.48
Condominium	0	742,526.46	356,933.772	198,007.056
Retail	0	599,126.4	288,030.72	159,767.04
Office	0	295,344	141,577.6	78,758.4

Architecture 2030's 20% allowance for purchased off-site renewable energy increases the maximum energy demand relative to the same fossil fuel reduction target without off-site renewables. This 20% allowance is shown in Table 4 below (PV allowance and off-site renewable allowance are both the same for each target).

Table 4. Glenwood Park 20% Purchased Renewable Energy Allowance.

<i>Program</i>	<i>Base Energy</i>	<i>25% Reduction</i>	<i>80% Reduction</i>	<i>100% Reduct.</i>
	<i>kWh/yr</i>	<i>kWh/yr</i>	<i>kWh/yr</i>	<i>kWh/yr</i>
SFH	0	734,284.956	352,456.779	195,809.322
Townhouse	0	452,509.2	217,204.416	120,669.12
Condominium	0	185,631.615	89,233.443	49,501.764
Retail	0	149,781.6	72,007.68	39,941.76
Office	0	73,836	35,394.4	19,689.6

Next each building type's maximum energy use intensity is increased by 20% of the fossil fuel reduction. The additional 20% on-site photovoltaic allowance is also added to the fossil fuel reduction (for more explanation, see the Energy Targets section in Chapter 1).

Energy Star (25% fossil fuel reduction):

100% base – 25% fossil fuel reduction = 75% fossil fuel energy

*0.2 off-site renewable energy * 25% fossil fuel reduction = 5% off-site renewable*

*0.2 on-site PV energy * 25% fossil fuel reduction = 5% on-site PV*

25% fossil fuel reduction - 5% off-site renewable - 5% on-site PV = 15% design driven reductions

$$\text{Energy Star} = 0.85 * \text{Base Energy Demand}$$

2020 Target (80% fossil fuel reduction):

$$100\% \text{ base} - 80\% \text{ fossil fuel reduction} = 20\% \text{ fossil fuel energy}$$

$$0.2 \text{ off-site renewable energy} * 80\% \text{ fossil fuel reduction} = 16\% \text{ off-site renewable}$$

$$0.2 \text{ on-site PV energy} * 80\% \text{ fossil fuel reduction} = 16\% \text{ on-site PV}$$

$$80\% \text{ fossil fuel reduction} - 16\% \text{ off-site renewable} - 16\% \text{ on-site PV} = 48\% \text{ design driven}$$

$$2020 \text{ Target} = 0.52 * \text{Base Energy Demand}$$

2030 Target (100% fossil fuel reduction):

$$100\% \text{ base} - 100\% \text{ fossil fuel reduction} = 0\% \text{ fossil fuel energy}$$

$$.2 \text{ off-site renewable energy} * 100\% \text{ fossil fuel reduction} = 20\% \text{ off-site renewable}$$

$$.2 \text{ on-site PV energy} * 100\% \text{ fossil fuel reduction} = 20\% \text{ on-site PV}$$

$$100\% \text{ fossil fuel reduction} - 20\% \text{ off-site renewable} - 20\% \text{ on-site PV} = 60\% \text{ design driven}$$

$$2030 \text{ Target} = 0.40 * \text{Base Energy Demand}$$

Table 5 indicates energy demands based on the selected reductions.

Table 5. Glenwood Park Energy Demands.

Program	Base Energy kWh/yr	25% Reduction kWh/yr	80% Reduction kWh/yr	100% Reduct. kWh/yr
SFH	4,895,233.04	3,671,424.78	1,762,283.89	979,046.608
Townhouse	3,016,728	2,262,546	1,086,022.08	603,345.6
Condominium	1,237,544.1	928,158.075	446,167.215	247,508.82
Retail	998,544	748,908	360,038.4	199,708.8
Office	492,240	369,180	176,972	98,448

Some program types require more energy than others (see Table 2). Table 6 shows the relationship between energy required and program area in terms of percentage for Glenwood Park, assuming that all building types reduce their fossil fuel uses by equal proportions.

Table 6. Glenwood Park Program Distribution.

<i>Program</i>	<i>Total Area Square feet</i>	<i>Area % Percentage</i>	<i>Demand kWh/yr</i>	<i>Demand % program</i>
SFH	417,682	48.9	4,895,233.04	46
Townhouse	257,400	30.1	3,016,728	28.4
Condominium	111,150	13	1,237,544.1	11.6
Retail	48,000	5.6	998,544	9.4
Office	20,000	2.3	492,240	4.6
Total	854,232	100	10,640,289.1	100

Each target reflects a certain percentage requirement for program types on site. As can be seen in Figure 8, single family housing (SFH) and townhouses (or rowhouses) consume the most energy in Glenwood Park.

Existing Issues

Climatic analysis of Glenwood Park (explained later in this chapter) as built provides the basic premises on which the new design is based. Four problem areas are identified that decrease efficiency by not taking full advantage of passive strategies available for solar, daylight, and ventilation.

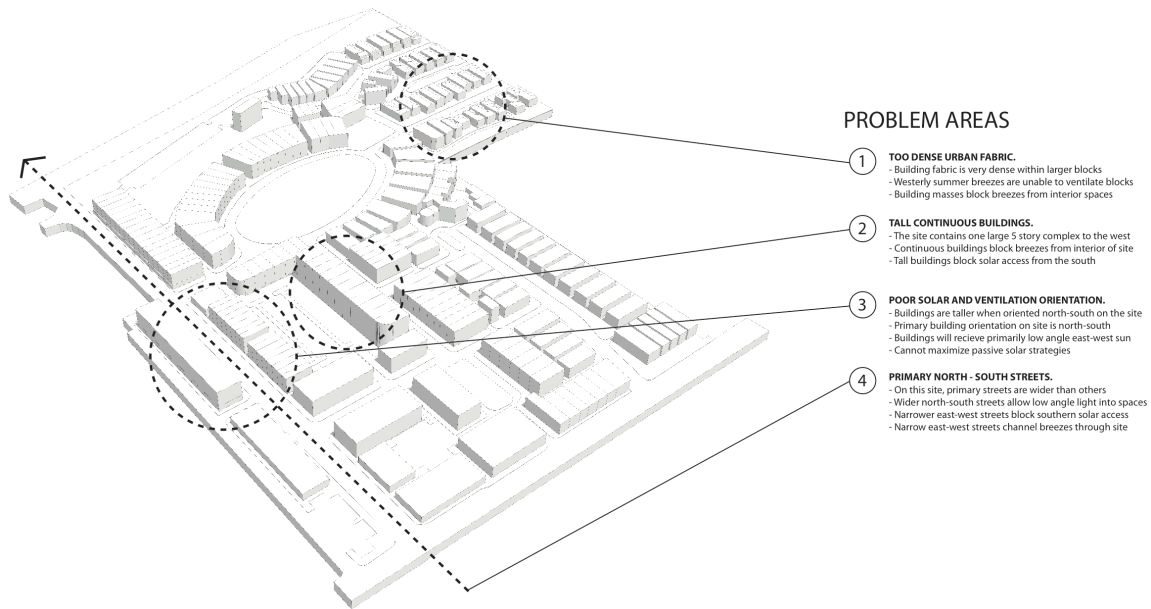


Figure 9. Glenwood Park Problem Areas.

1. *Too dense urban fabric.* The building fabric is very dense within the larger blocks. Westerly summer breezes are unable to ventilate blocks. Building masses block breezes from interior spaces.

2. *Tall continuous buildings.* The site contains one large five-story complex to the west. Other continuous buildings block breezes from the interior of the site. Tall buildings block solar access from the south.

3. *Poor solar and ventilation orientation.* Buildings are taller when oriented north-south on the site. Primary building orientation on the site is north-south. Buildings will receive primarily low angle east-west sun. Cannot maximize passive solar strategies.

4. *Primary north-south streets.* On this site, primary streets are wider than others. Wider north-south streets allow low angle light into spaces. Narrower east-west streets block southern solar access. Narrow east-west streets channel breezes through site.

Climatic Guidelines

The proposed climatic guidelines drive the form and organization of the new Glenwood Park site. They are the result of intensive climate studies to maximize solar, daylight, and ventilation use that will decrease energy use. Figure 10 highlights example areas for the application of each guideline.

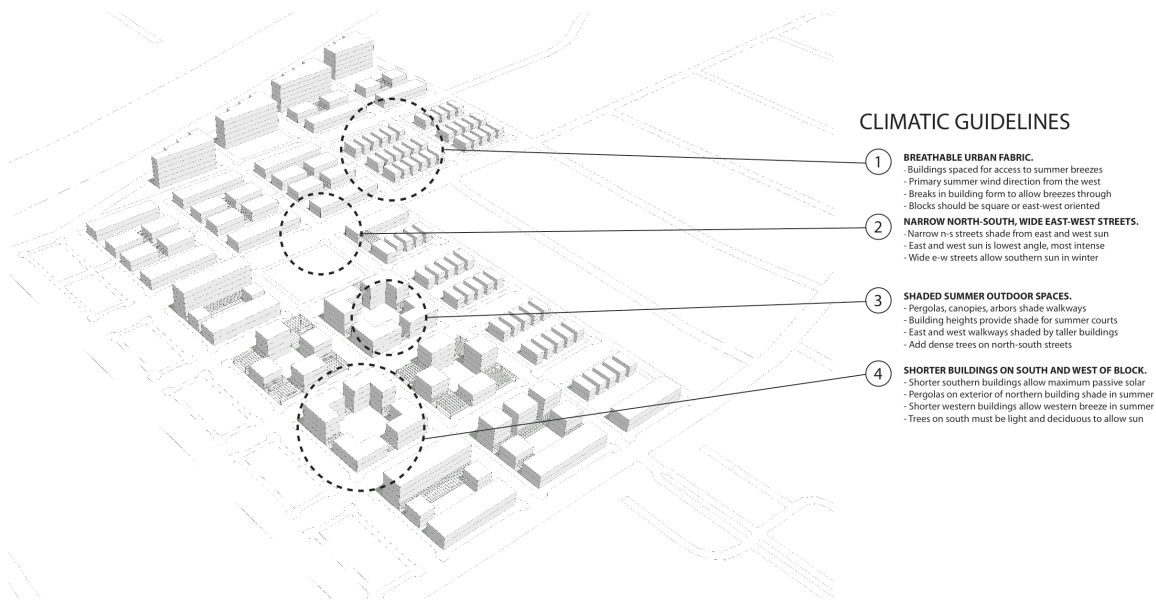


Figure 10. Glenwood Park Design Guidelines.

1. *Breathable urban fabric.* Space buildings for access to westerly summer breezes. Add breaks, punctures, and walkways through buildings to allow summer breezes through the site. Design square or east-west elongated blocks for maximum permeability (more streets mean more breaks in buildings, which results in more ventilation) and solar availability.

2. *Narrow north-south, wide east-west streets.* Design north-south streets to be narrow to provide shade from the low-angle, harsh east and west sun in the mornings and afternoons. Design wide east-west streets to allow for southern sun for the most efficient solar access and solar heat gain to south facades during the winter.

3. *Shaded summer outdoor spaces.* Shade pedestrian outdoor spaces (courtyards and walkways) with pergolas, canopies, and arbors. Use building heights to provide shade for summer courts and north-south oriented streets. Specify north-south street trees to be denser than trees planted on east-west streets.

4. *Shorter buildings on south and west of the block.* Keep buildings on the southern side of blocks shorter to allow maximum passive solar access. Add properly sized pergolas on the exterior of northern buildings to shade in summer while allowing solar heat gain in the winter. Keep buildings on the western side of the block to allow westerly summer breezes into the block. Specify trees on the south side of the block to be light and deciduous for maximum winter solar heat gain.

Additional urban strategies are employed as an overlay to the site design. Refer to Figures 11 and 12 for the remainder of this section. Open spaces with similar use as the existing site are provided to meet or exceed the amenities on the existing site. These spaces have been re-arranged to provide a green buffer-like zone between the five-story apartment complex to the west. This will allow breezes to come back down to ground level before entering the first built block. Building forms are staggered to diffuse the westerly summer breezes and filter them through the site. Tall apartment buildings to the north buffer sound from Interstate 20 (the southern boundary of the site) and do not block solar access due to their location. Pedestrian-friendly courtyards and walkways are made with pergolas, wide sidewalks, street trees, and vertical program organization. (DeKay and Brown, 2014).

New Program Distribution

The re-design uses the existing program as a criterion. After re-distribution based on the climatic guidelines (to be outlined in the following sections of this chapter) and analysis, program square footage is much higher than Glenwood Park as built. The new design allows for fewer SFH, but far more apartments to allow the minimum residential units on site. Office and retail programs are two- to three-times higher than the existing due to new requirements for solar and daylight access. The density changes slightly when adjusted to allow solar and daylight access into the center of the block (seen in the passive solar analysis section of this chapter).

Single Family houses number 62 on the new site. Similar to the existing program, each unit is 2,153 square feet. Because of the surrounding neighborhood to the east of the site, SFH remain located on the east half of Glenwood Park (in purple on Figure 13).

Townhouses number 85 on the new site. Consistent with the existing program, each unit is 2,200 square feet. Due to the new street organization of the new site, townhouses are primarily located on the northern portion of the site (in blue on Figure 13).

Apartments number 296 on the new site. Also consistent with the existing program, each unit is 995 square feet. This program element was increased due to site utilization efficiency (apartments allow for a higher floor area ratio than SFH or townhouses), and a lower EUI. This means that less energy would be required from more apartments than more SFH or townhouses. Apartments are spread throughout the site and generally above retail and office spaces (in orange on Figure 13).

SITE PLAN



Figure 11. Glenwood Park Plan.



Figure 12. Glenwood Park Plan larger scale.

Retail space totals 82,800 square feet on the new site. More space is gained through the use of more apartments and fewer SFH, in which case, more mixed-use buildings with retail and office below are possible. This space is nearly twice that of the existing built site. Retail space is primarily located in the south and southeastern portion of the site (in red on Figure 13).

Office space totals 65,300 square feet on the new site. Over three times the space is gained using the same strategies as those used for the retail space. It can be seen that office space primarily occurs above retail space due to the number of visitors to those spaces, hours of operation, and attraction to space (visitors are less likely to walk into an office and more likely to walk into a shop or restaurant without a reservation or appointment). Office space is primarily located in the south and southeastern portion of the site (in green on Figure 13).

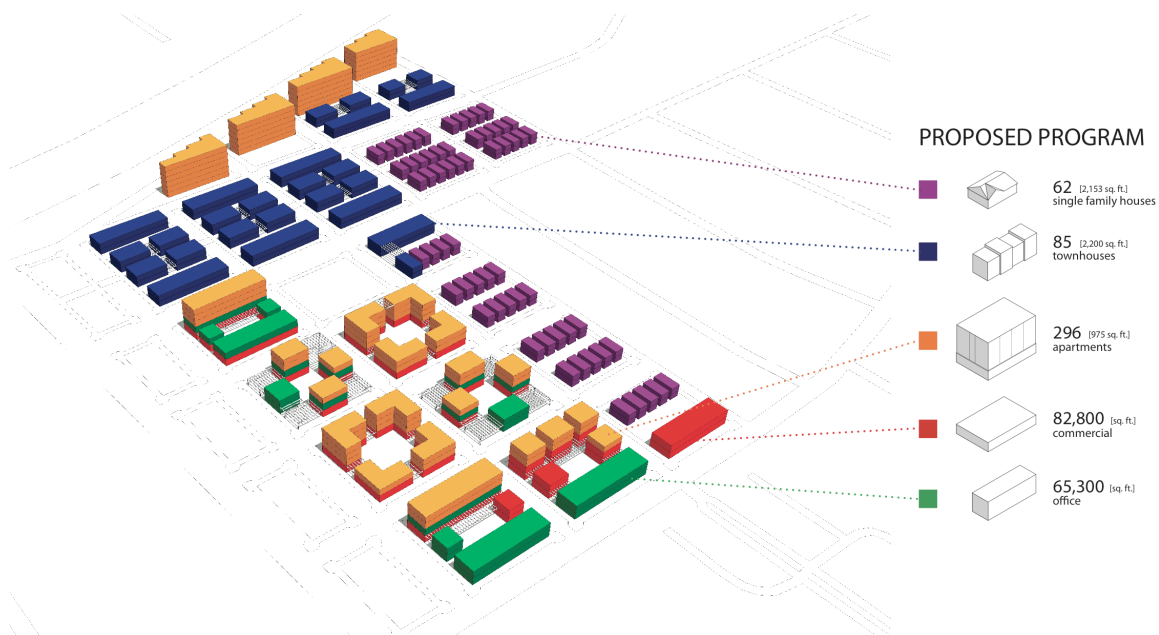


Figure 13. Glenwood Park Proposed Program Distribution.

Daylight and Shading Analysis

Closely spaced buildings along the north-south axis can achieve shading from harsh east and west sun. Building masses and plans are generated through the four climatic guidelines already listed, while building heights are regulated through the formation of a solar and daylight envelope. In select areas, buildings do not conform to the solar / daylight regulations for urban space creation, but the majority of the site is designed with this prescribed height to allow equal solar and daylight access to all block edges across the site. Refer to Figures 14-16 for the remainder of this paragraph. The solar and daylight envelopes are used to

allow solar and daylight access around the perimeter of each block. This ensures that every block has equal opportunity to utilize passive solar and daylight strategies and no other neighboring building casts a shadow on the south façade or creates a dark space that requires electric lighting. They are generated through the overlay of two different conditions based on orientation and sun position or sky view. Solar access is directional and most efficient on the southern side of buildings, while daylight access is ambient and available from every direction. Advantages of solar access include solar heat gain and efficient solar energy collection for PV and solar hot water systems (DeKay and Brown, 2014). Maximum daylight access reduces demand for artificial lighting and (in some cases) cooling demand from large quantities of lighting fixtures (DeKay and Brown, 2014). To find the daylight envelope, a sky exposure plane is extruded at a 50° angle from the lowest base of a window to receive daylight access. This angle represents a low-medium minimum spacing angle that is chosen to generously accommodate the medium density across the neighborhood development. This will allow a daylight factor of 2.0 (with some assumptions made in regard to the materials and openings in facades). The solar envelope is derived by a building height maximum of 0.59 times the street width to allow solar access across the entire southern façade of every building. This number is the mean recommended solar spacing factor for 34N latitude during the summer hours. Both the 50° sky exposure plane and .59 solar spacing factor are based off Atlanta's 34N latitude (DeKay and Brown, 2014).

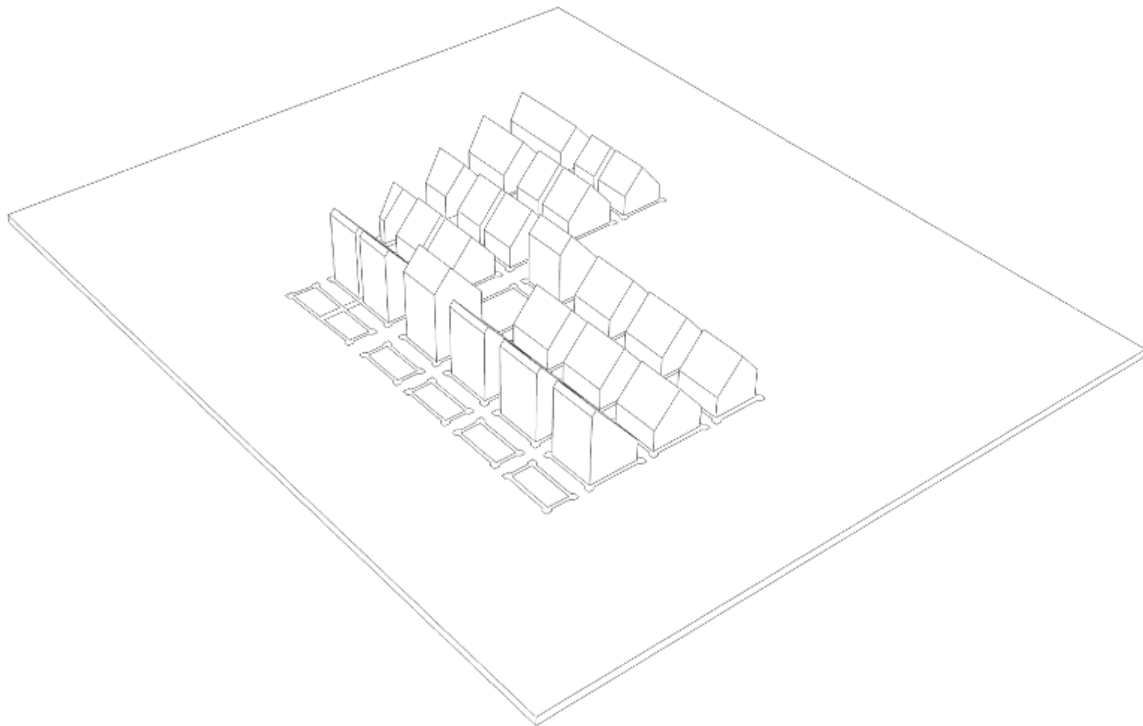


Figure 14. Forms created by sky exposure plane for east and west facades.

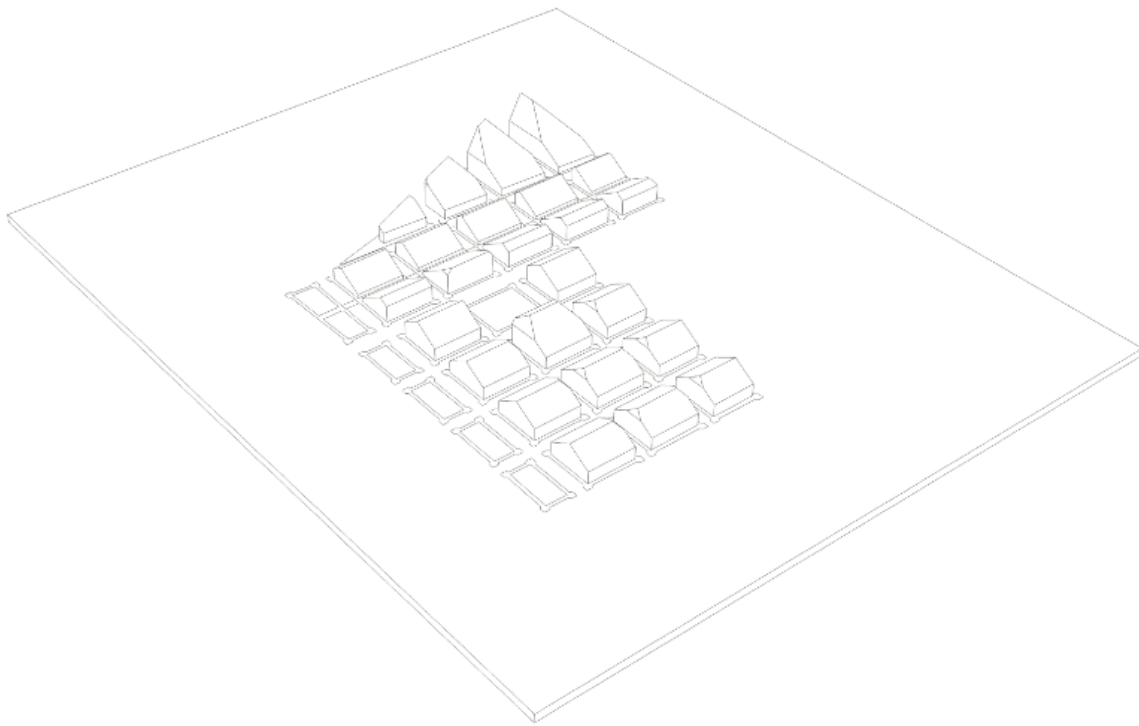


Figure 15. Forms created by solar spacing angle for south facades on east-west streets.

Sectional implications of the solar and daylight envelope are indicated below in Figure 17. Street, sidewalk, and planting widths are derived from the SmartCode template (Center for Applied Transect Studies, 2009). The matrix is based on orientation and type (use) indicates street types for Glenwood Park. Each type also contains a vertical program organization based on New Urbanist principles that promote retail and office on lower levels with residential above (Center for Applied Transect Studies, 2009), and energy use gradients that promote spaces with the least heat generation above where access to solar heat gain will be greater.

Passive zone areas are the spaces within the building that are most affected by solar, daylight, and ventilation access. This space is 20 feet from the façade of the building, with some generalizations made concerning window size and spacing (DeKay and Brown, 2014). For this reason, buildings are generally no more than 40 feet thick. The northern apartment buildings are thicker, but will also have circulation and utility cores that will occupy part of the central space outside the passive zone.



Figure 16. Forms created by sky exposure plane and solar spacing angle.

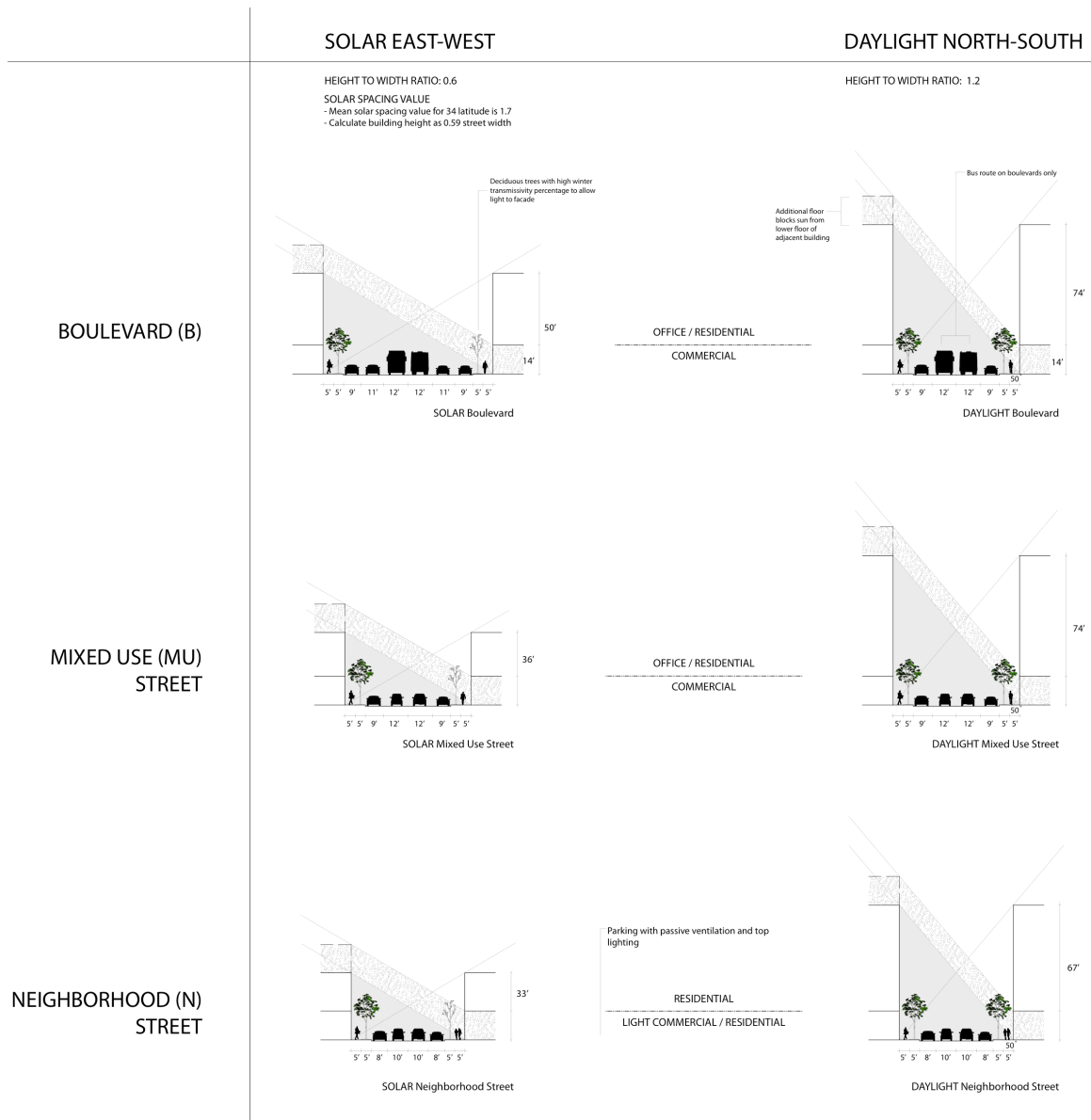


Figure 17. Glenwood Park Street Sections.



Figure 18. Passive zones.

Shading and Passive Solar Analysis

Atlanta's climate calls for shading as a major design driver for both buildings and outdoor space. On average, temperatures in Atlanta remain above freezing.

Over half of the year, temperatures are between 32-68 degrees. Late Spring through early Fall accounts for the warmest time of the year with temperatures rising to 68-79 degrees during the day time in the first and last part of the warm season. The warmest months are June, July, and August with temperatures between 79-100 degrees during the daytime hours, dropping concurrently with the sunset. For Atlanta, cooling will be needed for much of the year as the daytime (and some nighttime temperatures) can reach far above the comfort zone. Dehumidification is also important as the entire year experiences at least 40% humidity. Summer mornings and evenings experience the greatest humidity, while winter days experience the least. On a daily cycle, humidity and temperature are inversely related to one another. Monthly temperatures are generally warm, with seven months of the year reaching design highs above the 79-degree summer comfort zone recommendation. Summertime design lows are in the mid-to-upper 50s. The mean temperature (white space within temperature ranges) during these months sits within the 68-79 degree comfort zone.

February, March, and November experience design highs that lie within the comfort zone. The remaining months and design lows experience temperatures that are below the comfort zone. This includes: design lows and means for February, March, and November; and the entire months of January and December. It is necessary to account for the design low temperatures during the months of January, February, and December. These months experience temperatures between 12-16 degrees (F). Additionally, these months experience the fewest hours of sunlight. For buildings, this means that solar heat gain is most important for the months of January, February, and December to reduce the active heating load as much as possible. For outdoor spaces, these months should have the most solar access and least shading to allow warm occupiable spaces. Summer months should still be shaded for comfort and some amount of shading (although less than during the summer months) will exist during the transition seasons of fall and spring.

Upper levels of each building typically have maximum solar access. Although all levels will have access to solar benefits, the upper levels will have unobstructed solar access. For this reason, program types with the least internal heat gain have been located on the upper levels of each building.

Trees can also be used for shading, however, the types used in the re-design differ based on orientation. Deciduous tree species with a high winter transmissivity percentage (high solar coefficient) will allow the most light through during the winter and are used in front of the southern façade if trees are to be planted. North, east, and west facades do not require specific trees due to the

ambient quality of the light from each direction. They may be selected for shade in summer, but winter transmissivity percentage is less critical.

Additionally, trees can be selected based on height. In Figures 19 and 20, sections show taller trees in large green spaces while shorter trees line sidewalks. This strategy allows more light into the upper levels and creates a shorter canopy for each sidewalk to shade people. Large open spaces are provided with taller trees that create a taller canopy with more shade on the ground because the scale of the open space is larger than that of the street section.

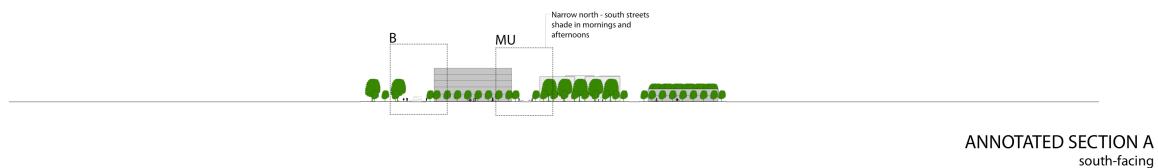


Figure 19. Glenwood Park Annotated Section A.

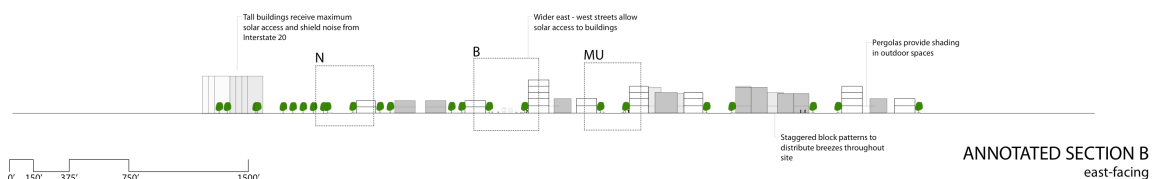


Figure 20. Glenwood Park Annotated Section B.

Summer shading is needed on south, east, and west facades. Southern shading is achieved through properly sized architectural shading devices so that solar heat gain is accessible during the winter. North – south streets are narrow to take advantage of shadows cast by the buildings, while east – west streets are wide to allow solar access (see Figure 21). Street widths are not primarily driven by use, but by orientation; though lane width is calculated by expected traffic volume and program type (Center for Applied Transect Studies, 2009). As previously stated, pergolas on lower levels provide summer shading for pedestrian walkways and outdoor spaces (see Figure 22).

Urban and building form was generated from the climatic guidelines then modified by the solar and daylight envelope (see Figure 16 in the daylighting section of this chapter) that were then fine-tuned based on the need to allow solar, daylight, and ventilation access into the center of the block or as needed for all buildings that compose the block on July 21. Shading studies aided to increase pedestrian activity on the sidewalk and center of the block. For these studies, each block has been assigned a name based on building form and program type. They were then shown without shading devices added to allow for a base of comparison. Finally, initial shading strategies were added with notes



Figure 21. Narrow North-South, Wide East-West Streets.



Figure 22. Shaded Summer Outdoor Spaces.

for more efficient strategies after analysis. To read the following section, the base study is presented followed by the initial shading strategy and an assessment for further efficiency.

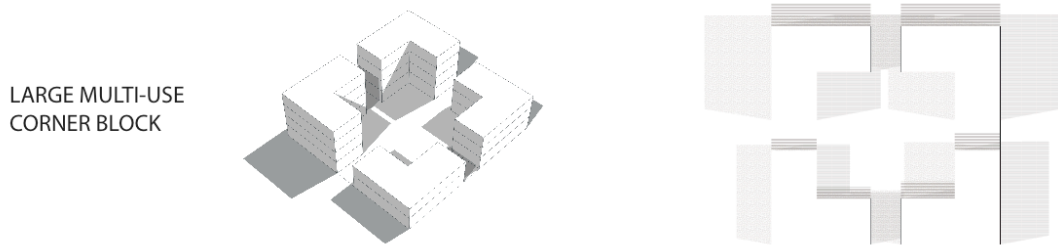


Figure 23. Glenwood Park Mixed Use Block 1 Study.

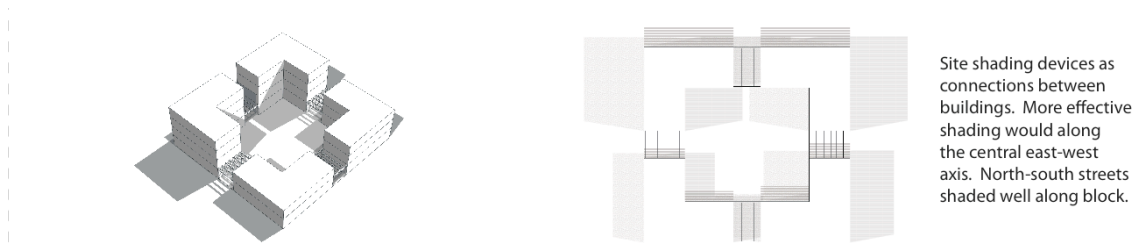


Figure 24. Glenwood Park Mixed Use Block 1 Improvement.

A more efficient iteration would remove shading devices as connections on the north and south sides of the block as the spacing of the buildings is close enough to provide shading for the majority of the day. More effective shading would be provided along the central east – west axis. For this block, north – south streets are well-shaded from the existing buildings, due to the building forms.

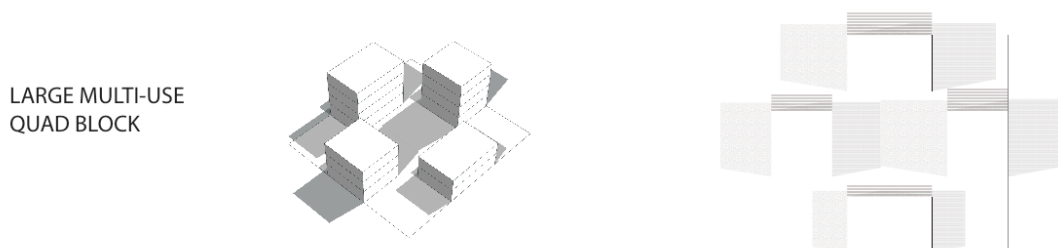


Figure 25. Glenwood Park Mixed Use Block 2 Study.

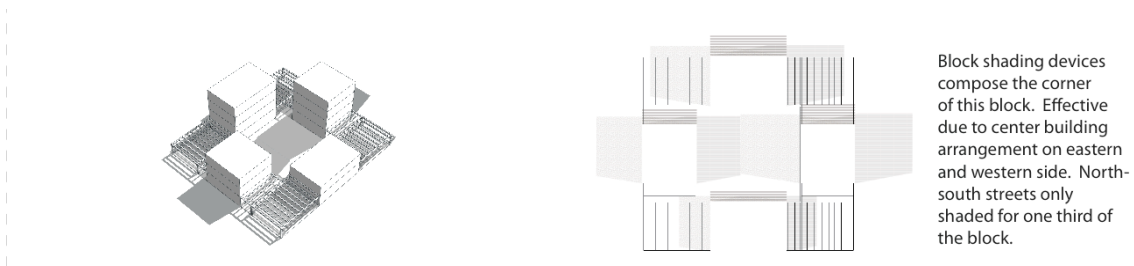


Figure 26. Glenwood Park Mixed Use Block 2 Improvement.

Corner shading devices within the large multi-use quad block are effective due to the center building arrangement of the eastern and western sides of the block. Extending these shading devices over the sidewalk would increase the shading area over these spaces due to the absence of buildings at these points.

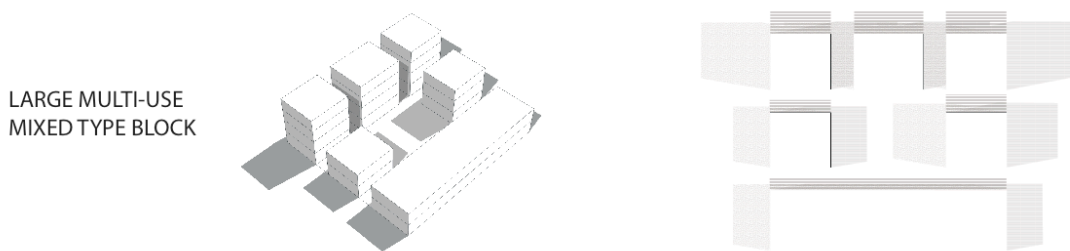


Figure 27. Glenwood Park Mixed Use Block 3 Study.

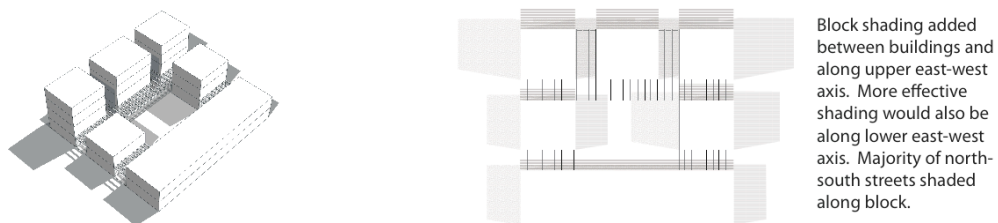


Figure 28. Glenwood Park Mixed Use Block 3 Improvement.

The large multi-use mixed type block increases shading to the southern façade while still providing shading between the building connections. It can be seen again that due to the spacing of the buildings on the east – west axis, shading devices are not needed on the northern side of the block. More effective shading would also follow the lower east – west axis. Shading from the building forms covers the majority of the north and south sidewalks.

LARGE MULTI-USE
LINEAR BLOCK

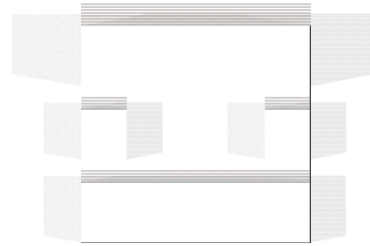
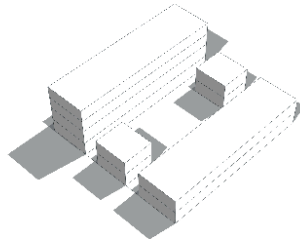
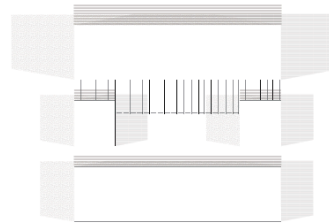
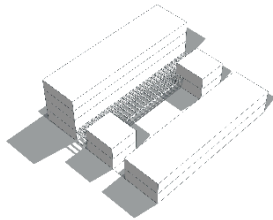


Figure 29. Glenwood Park Mixed Use Block 4 Study.



Block shading added between buildings and along upper east-west axis. More effective shading would also be along lower east-west axis. Majority of north-south streets shaded along block.

Figure 30. Glenwood Park Mixed Use Block 4 Improvement.

Block shading in the large multi-use linear block is added between buildings and along the upper east-west axis. This is a strategy that most of the other blocks can employ whether or not the north and south buildings are continuous or separated. More effective shading would also be located along the lower east – west axis. The majority of the street on the east and west edges of the block is shaded.

LINEAR RESIDENTIAL
BLOCK

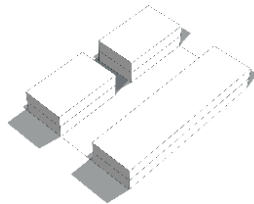


Figure 31. Glenwood Park Residential Block 5 Study.



Figure 32. Glenwood Park Residential Block 5 Improvement.

The linear residential block provides shading only between the building connections on the northern side of the block. This shading strategy is ineffective due to shading already existing due to the building spacing. Most effective shading would be across the east – west access on the southern façade. Due to the building form, north – south streets are well-shaded along the length of the block.

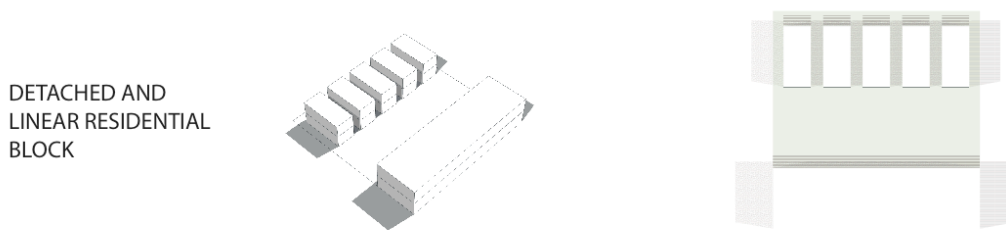


Figure 33. Glenwood Park Residential Block 6 Study.

The detached and linear residential block contains no shading study due to the single family houses present (individuals are given opportunity to shade as desired) and trees suggested for the center of the block.

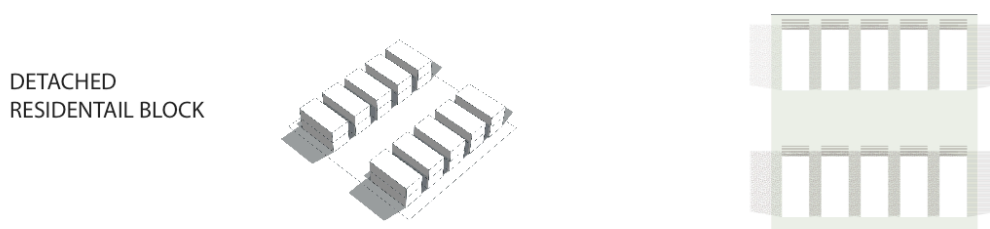


Figure 34. Glenwood Park Residential Block 7 Study.

The detached residential block contains no shading study due to the single family houses present and trees suggested for the center of the block. Trees suggested will provide shading from summer sun, while allowing solar access in the winter. Because the SFH forms are only two stories, trees will shade the majority of the buildings (see Figures 11 and 12, site plan).

Photovoltaic Requirement

The existing plan allows for a maximum of 418,732 square feet of roof space for photovoltaics. The new plan for Glenwood Park allows for a maximum of 253,984 square feet of roof space for photovoltaics. This is considered the gross roof area and does not account for daylighting, walkways, stairway access, or other building utilities that typically exist on the roof. The new plan contains less roof area due to a greater mix of uses with fewer single family houses whose roofs are not ideal or efficient for photovoltaic use. Larger buildings with multiple tenants are more conducive to easy utility and maintenance access.

This project adopts additions to the Architecture 2030 targets suggesting that 20% of fossil fuel energy reductions are generated from on-site PV. This calculation can be found in the programming section of this chapter.

To estimate the required PV area, energy production from PV is calculated in relation to the average yearly incident solar radiation of 6.4 kWh/sq m/day (Marion and Wilcox, 1994). An additional 15% is added to the total to account for loss in conversion and transmission of power from the PV array to the user. This allotment is then sized based on a selected 1-axis tracking 255-Watt monocrystalline panel with an efficiency of 15% (AIBC International, 2014) with an area of 21.39 square feet (Mississippi State University Center for Sustainable Design, 2014).

$$\text{Daily energy demand (kWh/day)} = \text{Yearly demand (kWh/year)} / 365 \text{ days}$$

$$\text{Production size (kW)} = \text{Daily demand (kWh/day)} / 6.4 \text{ kWh/sq m/day}$$

$$\text{Panels needed} = ((\text{Production size [kW]} * 1000) * 1.15 \text{ loss}) / 255 \text{ W per panel}$$

$$\text{Net collector area needed (Square feet)} = \text{panels needed} * 21.39 \text{ square feet per panel}$$

Maximum area required for photovoltaics to power the entire site is seen below in Table 7.

Table 7. Maximum Photovoltaic Area Required from Selected Panel System.

<i>Program</i>	<i>Base PV area Square feet</i>	<i>25% PV area Square feet</i>	<i>80% PV area Square feet</i>	<i>100% PV area Square feet</i>
SFH	202,147.78	151,610.84	72,773.20	40,429.56
Townhouse	124,575.25	93,431.44	44,847.09	24,915.05
Condominium	51,104.16	38,328.12	18,424.40	10,220.83
Retail	41,234.70	30,926.02	14,867.72	8,246.94
Office	20,326.96	15,245.22	7,308.03	4,065.39
TOTAL	439,388.85	329,541.64	158,220.44	87,877.77

Table 8 shows the percentage of the maximum photovoltaics needed that can be placed on roof area in the proposed Glenwood Park site compared to the site as built. One important discovery is the ability to power the entire site through photovoltaics nearly two to three times over at the 2020 target (80% reduction) and 2030 target (100% reduction). Due to the high efficiency of the PV panels used, the high excess energy production potential in the 2020 and 2030 target districts could be fed back into the electric grid and bought by the utility company. This large potential excess allows for the district to be powered given normal roof conditions (stair access, building systems, daylighting, walkways that typically occupy the roof). Additionally, the calculation does not take south-facing facades into account, which add more area available for PV use. The calculation also does not account for spacing to allow solar access during the winter (the lower sun angle during the winter months will cast a longer shadow from one panel to another). These goals are possible with a less efficient PV system (to a minimum capacity of about 160 Watts for the same size panel). The following table shows that for the base (no fossil fuel reduction) and Energy Star targets, there is not enough roof area to meet the power demand in its entirety. This, however, is a calculation to find the absolute maximum area needed for photovoltaics for each site. Because it is more common to use some combination of strategies, this maximum area is most likely far greater than the actual area that would be used.

Table 8. On-Site Photovoltaics Percent of Demand Met Using Gross Roof Area.

<i>Program</i>	<i>Base PV area percent</i>	<i>25% PV area percent</i>	<i>80% PV area percent</i>	<i>100% PV area percent</i>
Existing site	66%	94%	188%	310%
New site	58%	77%	161%	289%

The project uses a target of a minimum of 20% of fossil fuel reductions provided through on-site photovoltaics. Table 9 below provides areas found under this recommendation. Percent allowed refers to the percent of the total energy requirement allowed to go toward on-site photovoltaic production as part of this project (for this calculation, see the energy target parameter section of the first chapter). The 20% area refers to the square foot area of panel surface needed to meet the stated 20% on-site photovoltaic power generation requirement. Due to the program EUIs, the 20% on-site photovoltaic area does not consistently decreasing across. If EUI is kept constant while reductions increase, the PV area decreases at a consistent rate.

Table 9. Area Required for 20% On-Site Photovoltaics.

<i>Program</i>	<i>Base PV area Square feet</i>	<i>25% PV area Square feet</i>	<i>80% PV area Square feet</i>	<i>100% PV area Square feet</i>
Percent allowed	0	5%	16%	20%
20% area	0	65,908.30	31,644.10	17,576

Remaining roof space in the proposed plan after the 20% photovoltaic recommendation is subtracted from the gross roof area and shown below in Table 10. This remaining roof space can be used for solar hot water, daylight apertures, mechanical equipment, and any further PV used to exceed the targets.

Table 10. Excess Roof Area.

<i>Program</i>	<i>Base PV area Square feet</i>	<i>25% PV area Square feet</i>	<i>80% PV area Square feet</i>	<i>100% PV area Square feet</i>
Remaining area	0	188,075.67	222,339.91	236,408.45

Passive Ventilation Analysis

The seasonal Atlanta wind roses indicate that on average, the primary wind generally comes from the east and northeast. A strong secondary wind typically comes from the west. While both winds carry at least 30% relative humidity, the secondary wind tends to carry more humidity with an average of over 70%. Seasonally, fall (September - November) experiences the most winds with the

primary and secondary being more equally distributed in relation to time. The remaining seasons see fairly calm and consistent winds throughout. Winds tend to stay above freezing, even in the winter. Those coming from the primary direction tend to be cooler (possibly due to the lesser humidity or non-coastal orientation). Monthly, winds tend to be fairly constant with a slight increase in March and April, and a more drastic increase in December. Though the record winds are much higher, average high speeds do not exceed 18 mph while the mean generally falls between 7 and 11 mph. Daily wind patterns tend to be light. For the majority of the year, winds stay between 5-10 mph throughout the entire day. In the spring and early summer, the winds increase to between 10-20 mph during the daytime hours, dropping back to 5-10mph after sunset. This is important to aid in the ventilation of the neighborhood district. Because these winds are somewhat light, more attention should be paid to allow them to filter through the site and provide equal access to ventilation. December experiences the most consistently strong winds with 10-20 mph winds throughout the entire day.

Blocks and buildings are oriented in such a way to allow westerly summer breezes throughout the site. Tall, mixed-use buildings are located on the perimeter of the block to give each building access to ventilation. Buildings on the west of the block are typically shorter so that breezes are able to come back down to the ground before reaching the next building. Block patterns are mixed so that breezes come through the center of one block and through the edges of the following one. This diffuses the wind so that it does not become concentrated in a single line, while the rest of the site remains stagnant.

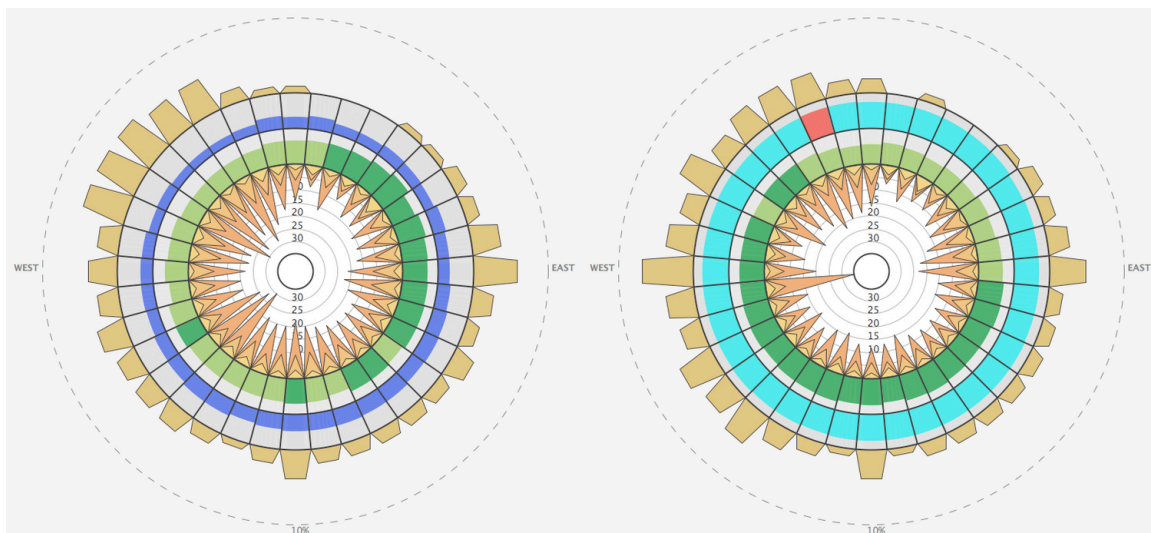


Figure 35. Atlanta winter and summer wind rose studies (climate consultant).

CHAPTER III

DENVER DESIGN AND ANALYSIS

Belmar is a former brownfield in Lakewood, Colorado, an extension of Denver. The site originally was the Villa Italia shopping mall built in 1966 and abandoned about 30 years later. Construction was funded by an EPA loan as part of the Brownfields Program and adheres to Colorado's renewable portfolio standard. Because the site qualified as a brownfield, contaminated soil, water, and materials from dry cleaners located on the site were removed prior to construction. Continuum Partners, LLC, Van Meter Williams Pollack, LLC, and the Colorado Coalition managed the project (Environmental Protection Agency, 2009). The Colorado Coalition primarily assists the homeless in the state to acquire jobs, housing, and other necessities in addition to supporting affordable, green, and/or carbon-reducing developments and programs in the state.

The state also has an extensive energy program, Recharge Colorado, through the Governor's Energy Office. This program includes a new energy standard that aims to achieve 30% renewable energy in Colorado. Distributed Generation (DG), supported by Colorado's department of energy, provides a framework for additional energy sources to be added to the existing energy grid so that additional lines are not needed. This means that it is most economical and effective to offer incentives for consumers to implement their own renewable energy technology (usually solar) such as adding photovoltaic panels to rooftops. Because the energy generated by the panels feeds to the consumer, additional transmission lines are not needed, while the percentage of renewable energy within the grid increases (Governor's Energy Office, 2010).

The site contains a combination of medium density and special district areas to allot space for chain department stores and large parking garages that support the greater Lakewood-Denver area. Additionally, because the site contains a relatively high number of residential units (Single family house, rowhouses, apartments), commercial and office program and parking requirements are high. This means that buildings may occupy the majority of the site to meet program requirements. Within the center of the district, where the density is highest and space is tightest, apartments and retail surround large program units that either do not require natural light (a 75,000 square foot, 16 screen cinema), and buildings that only require daylighting, but no views (chain department stores such as Best Buy, Whole Foods, Dick's Sporting Goods, and Target). Parking structures are lined on at least one side with small commercial units and topped with PV panels for power generation for the district. These panels provide necessary energy to maintain their respective parking garages (accounting for 5% of the total energy used on site) (Environmental Protection Agency, 2009). Other parking structures fill interior block spaces or are attached to their supporting programs (Target provides its own parking structure attached to the



Figure 36. Belmar with Context (image from USGS).

building). Finally, surface and on-street parking fill the remaining portion of the parking requirement.

Housing within the district consists of a wide variety including: SFH, rowhouses, apartments, and condominiums. A small SFH neighborhood accounts for an entire block in the southern portion of the site. A six-story parking structure is surrounded by 4- to 5-story apartment buildings within three blocks that serve as a southern boundary to the Belmar square park. These structures link the site to its southern surroundings (3- and 5-story apartment buildings). Within the center of the district, apartment buildings moderate density and spatial differences between periphery row housing and central mid-rise mixed-use areas.

Programming

Single family houses (SFH) in Belmar number 30. Due to the smaller energy demand generated from the SFH than most other building types on site, energy use is small relative to the whole site energy demand. SFH are individual detached units that average 2,500 square feet per unit (Miller, 2005). They are currently located in a single block on the central southern portion of Belmar (in purple on Figure 37).

Townhouses in Belmar number 318. Energy use for this building type in the West is the same as the SFH above, however, because significantly more townhouses are present on site, the proportion of energy consumed will be much greater. Townhouses are attached multi-story units that average 1,876 square feet per unit (Miller, 2005). They are primarily located in the southeastern portion of Belmar (in blue on Figure 37).

Apartments in Belmar number 956. Energy use for this building type is the lowest on site, making this the most efficient housing type. This efficiency takes advantage of a low area to energy use ratio. Apartments are multiple single-story units arranged in a multi-story building. Each unit averages 998 square feet (Miller, 2005). They are located throughout Belmar (in orange on Figure 37).

Commercial space area totals 1,200,000 square feet. Commercial and office space accounts for over half of the entire site demands. This is due to its high energy use and high square footage on site (see Table 11). Commercial space is distributed throughout Belmar (in red on Figure 37).

Office space area totals 800,000 square feet. As stated for the commercial space, both office and commercial space account for over half of site energy demands. Office space is located on the central northern portion and southwestern corner of Belmar (in green on Figure 37).

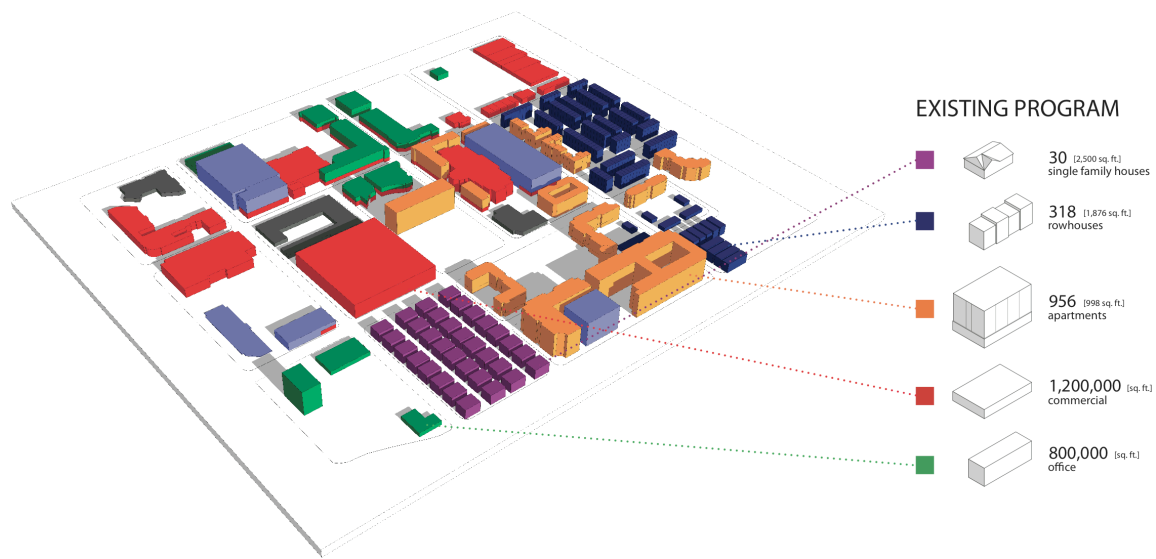


Figure 37. Belmar Existing Program Distribution.

Calculation of energy requirements is based on the total area of each program on site. This calculation is seen below in Table 11.

Table 11. Belmar Program.

<i>Program</i>	<i>Area Square feet</i>	<i>Quantity</i>	<i>Total Area Square feet</i>
SFH	2,500	30	75,000
Townhouse	1,876	318	596,568
Condominium	998	956	954,088
Retail	800,000	1	800,000
Office	1,200,000	1	1,200,000

The existing program requirements for Belmar demand a large portion of energy from commercial and office space. Figure 38 (Belmar existing program energy requirements and reductions) portrays Belmar's energy demands with Architecture 2030's benchmark requirements. The energy demands are based on the typical energy use intensity (EUI) for each program type in its particular region. The EUI is based from the United States Energy Information Agency (EIA), and may not necessarily reflect actual energy consumption in Belmar as currently built due to the mix of strategies employed by the current site. The use of typical site EUI allows for an equal comparison between the form of the

existing and the form of the proposed designs. As directed by the Architecture 2030 benchmarks reduce fossil fuel use and increase building efficiency, fossil fuel use decreases. Therefore in this study, the EUI reflects this relationship inversely—a lower EUI assumes greater efficiency, better passive design, more on-site PV, increased purchased renewable energy, and lower fossil fuel usage. Table 12 shows each EUI's used for Belmar.

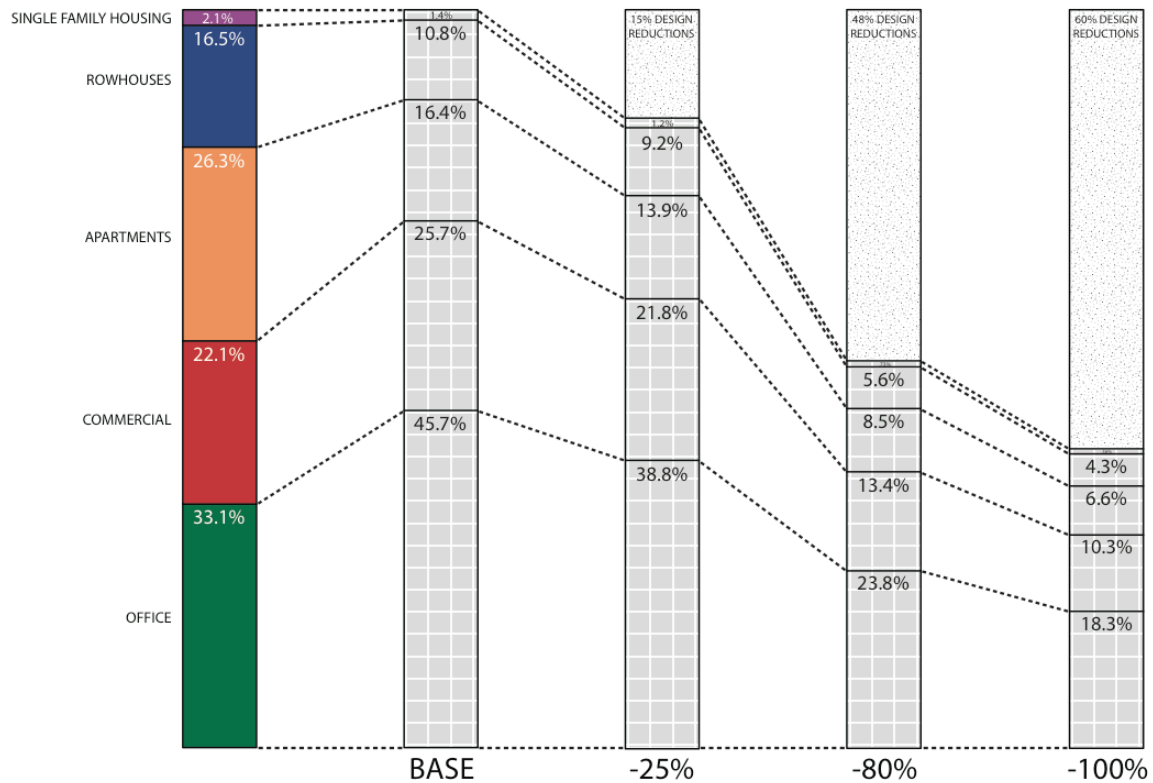


Figure 38. Belmar existing program energy demands and reductions.

Table 12. Belmar Energy Use Intensities.

<i>Program</i>	<i>Base EUI</i> <i>kBTU/sqft/yr</i>	<i>25% EUI</i> <i>kBTU/sqft/yr</i>	<i>80% EUI</i> <i>kBTU/sqft/yr</i>	<i>100% EUI</i> <i>kBTU/sqft/yr</i>
SFH	40	31.5	15.1	8.4
Townhouse	40	32.25	15.5	8.6
Condominium	38	30.75	14.8	8.2
Retail	71	67.5	32.4	18
Office	84	59.25	28.4	15.8

To calculate energy demands for each program type, the total square footage of the program is multiplied by the EUI and converted to the proper units (kilowatts per year, kWh/yr) by then multiplying by 0.000293 Wh/yr and 1000 Kilowatts. EUI selected reflects a target energy use desired for the site based on fossil fuel reductions. Table 13 indicates existing program area totals for Belmar.

$$\text{Energy Demand} = \text{Area} * \text{EUI} * 1000 * 0.000293$$

$$\text{kWh/yr} = \text{sq. ft} * \text{kBTU/sqft/yr} * 1000 * \text{Wh/yr}$$

To draw a comparison between targets and program type demands, program energy use totals are organized as a certain percentage of the whole site energy demand. The base comparison is based on 0% fossil fuel reductions. Energy Star targets (25% reduction) are based on a 25% fossil fuel reduction, in which case the whole is actually 75% of the base. The 2020 target (80% reduction) is based on an 80% reduction in fossil fuel energy use, in which case the whole is actually 20% of the base. Finally, the Architecture 2030 ideal target (100% reduction) is based on no fossil fuel usage and is 0% of the base. The remaining energy demand (Table 13) must be met through additional on-site energy generation and efficient design. (Architecture 2030, 2013).

Table 13. Belmar Remaining Energy Demand.

Program	Base Energy kWh/yr	25% Reduction kWh/yr	80% Reduction kWh/yr	100% Reduct. kWh/yr
SFH	0	553,770	265,458	147,672
Townhouse	0	4,509,696.14	2,167,450.86	1,202,585.64
Condominium	0	6,876,875.49	3,309,845.76	1,833,833.46
Retail	0	12,657,600	6,075,648	3,375,360
Office	0	16,665,840	7,988,352	4,444,224

Architecture 2030's 20% allowance for purchased off-site renewable energy increases the maximum energy demand relative to the same fossil fuel reduction target without off-site renewables. This 20% allowance is shown in Table 14 below (PV allowance and off-site renewable allowance are both the same for each target).

Table 14. Belmar 20% Purchased Renewable Energy Allowance.

<i>Program</i>	<i>Base Energy kWh/yr</i>	<i>25% Reduction kWh/yr</i>	<i>80% Reduction kWh/yr</i>	<i>100% Reduct. kWh/yr</i>
SFH	0	138,442.5	66,364.5	36,918
Townhouse	0	1,127,424.03	541,862.714	300,646.409
Condominium	0	1,719,218.87	827,461.441	458,458.366
Retail	0	3,164,400	1,518,912	843,840
Office	0	4,166,460	1,997,088	1,111,056

Next each building type's maximum energy use intensity is increased by 20% of the fossil fuel reduction. The additional 20% on-site photovoltaic allowance is also added to the fossil fuel reduction (for more explanation, see the Energy Targets section in Chapter 1).

Energy Star (25% fossil fuel reduction):

$$100\% \text{ base} - 25\% \text{ fossil fuel reduction} = 75\% \text{ fossil fuel energy}$$

$$0.2 \text{ off-site renewable energy} * 25\% \text{ fossil fuel reduction} = 5\% \text{ off-site renewable}$$

$$0.2 \text{ on-site PV energy} * 25\% \text{ fossil fuel reduction} = 5\% \text{ on-site PV}$$

$$25\% \text{ fossil fuel reduction} - 5\% \text{ off-site renewable} - 5\% \text{ on-site PV} = 15\% \text{ design driven reductions}$$

$$\text{Energy Star} = 0.85 * \text{Base Energy Demand}$$

2020 Target (80% fossil fuel reduction):

$$100\% \text{ base} - 80\% \text{ fossil fuel reduction} = 20\% \text{ fossil fuel energy}$$

$$0.2 \text{ off-site renewable energy} * 80\% \text{ fossil fuel reduction} = 16\% \text{ off-site renewable}$$

$$0.2 \text{ on-site PV energy} * 80\% \text{ fossil fuel reduction} = 16\% \text{ on-site PV}$$

$$80\% \text{ fossil fuel reduction} - 16\% \text{ off-site renewable} - 16\% \text{ on-site PV} = 48\% \text{ design driven}$$

$$2020 \text{ Target} = 0.52 * \text{Base Energy Demand}$$

2030 Target (100% fossil fuel reduction):

100% base – 100% fossil fuel reduction = 0% fossil fuel energy

*.2 off-site renewable energy * 100% fossil fuel reduction = 20% off-site renewable*

*.2 on-site PV energy * 100% fossil fuel reduction = 20% on-site PV*

*100% fossil fuel reduction - 20% off-site renewable - 20% on-site PV = 60%
design driven*

*2030 Target = 0.40 * Base Energy Demand*

Table 15 indicates energy demands based on the selected reductions.

Table 15. Belmar Energy Demands.

<i>Program</i>	<i>Base Energy kWh/yr</i>	<i>25% Reduction kWh/yr</i>	<i>80% Reduction kWh/yr</i>	<i>100% Reduct. kWh/yr</i>
SFH	879,000	692,212.5	331,822.5	184,590
Townhouse	6,991,776.96	5,637,120.17	2,709,313.57	1,503,232.05
Condominium	10,622,815.8	8,596,094.36	4,137,307.2	2,292,291.83
Retail	16,642,400	15,822,000	7,594,560	4,219,200
Office	29,534,400	20,832,300	9,985,440	5,555,280

Some program types require more energy than others (see Table 12) Table 16 below shows the relationship between energy required and program area in terms of percentage for Belmar.

Table 16. Belmar Program Distribution.

<i>Program</i>	<i>Total Area Square feet</i>	<i>Area % percent</i>	<i>Demand kWh/yr</i>	<i>Demand % percent</i>
SFH	75,000	2.1	879,000	1.4
Townhouse	596,568	16.5	6,991,776.96	10.8
Condominium	954,088	26.3	10,622,815.8	16.4
Retail	800,000	22.1	16,642,400	25.7
Office	1,200,000	33.1	29,534,400	45.7
Total	3,625,656	100	64,670,392.8	100

Each target reflects a certain percentage requirement for program types on site. As can be seen in Figure 38, commercial and office space consume the most energy in Belmar, assuming that all building types reduce their fossil fuel uses by equal proportions.

Existing Issues

Climatic analysis of Belmar (explained later in this chapter) as built provides the basic premises on which the new design is based. Four problem areas are identified that decrease efficiency by not taking full advantage of passive strategies available for solar, daylight, and ventilation.

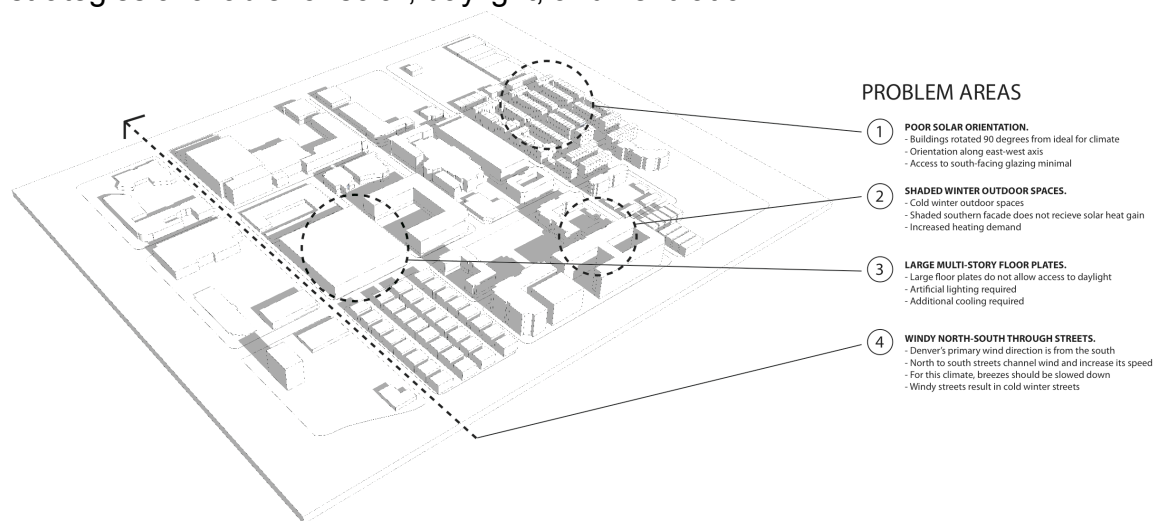


Figure 39. Belmar Existing Problem Areas.

1. *Poor solar orientation.* In some areas, on site, solar orientation is rotated 90 degrees from desired for a cool, dry climate. The majority of the rowhouses in the circled area will not be able to take advantage of solar heat gain from south-facing windows.

2. *Shaded winter outdoor spaces.* These spaces are undesirable to occupy in the winter. In addition, shaded areas of the southern façade receive daylight but not solar heat gain, resulting in an increased heating demand.

3. *Large multi-story floor plates.* Spaces that do not have adequate access to daylight require electric lighting to account for the remaining demand. Extra-large multiple story buildings will not only require artificial lighting but also cooling throughout the year to account for heat generated from the lighting.

4. *Windy north-south through streets.* Denver's primary wind direction in the summer and winter is from the south. Through streets that run north to south will channel the wind and increase its speed, making spaces feel colder in the winter.

Climatic Guidelines

The proposed climatic guidelines drive the form and organization of the new Belmar site. They are the result of climate studies to maximize solar, daylight, and ventilation use that will decrease energy use. Figure 40 highlights example areas for the application of each guideline.

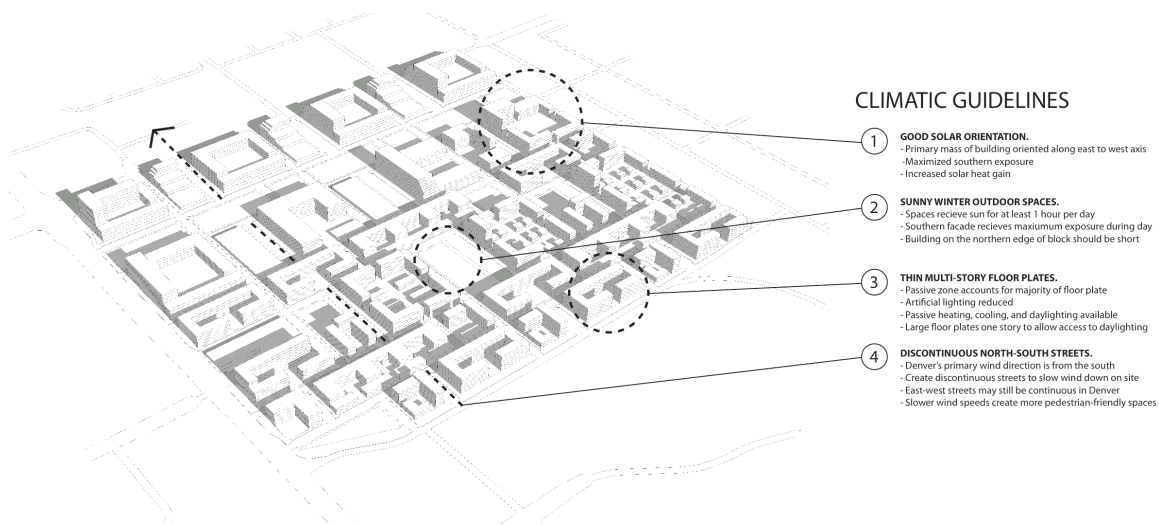


Figure 40. Belmar Design Guidelines.

1. *Good solar orientation.* Locate the primary mass of the building along the east-west axis to allow for maximum southern exposure. Concentrate the tallest buildings on the northern side of the block to collect the most solar heat gain. Keep southern buildings shorter so that solar access is available to the northern side of the block.

2. *Sunny winter outdoor spaces.* Design outdoor spaces to receive sun for at least one hour per day based on December 21 solar patterns. Design blocks so that the southern façade receives exposure during the day for at least 4 hours. Maximize solar access to the southern façade to increase solar heat gains.

3. *Thin multi-story floor plates.* Keep building floor plans thin to increase passive zone area within the floor plan to maximize passive heating, cooling, and lighting. Decrease artificial lighting demands by increasing daylight access. Restrict large floor plates to one story to allow access to daylight and minimize artificial lighting demand.

4. *Discontinuous north-south streets.* Because Denver's primary wind direction is from the south, create discontinuous north-south streets to slow the cold southerly winter wind down on site and increase walkability across the entire site. Orient through streets east-west so that access to surrounding neighborhoods is available but do not allow strong, cold winds to sweep through and decrease pedestrian use.

Additional urban strategies are employed as an overlay to the site design. Refer to Figure 41 for the remainder of this section. Open spaces with similar use as the existing site are provided to meet or exceed the amenities on the existing site. These spaces have been re-arranged to provide a green parkway on the main boulevards so that buildings along these streets (which are the highest volume pedestrian walkways), are taller than the rest of the site. This green zone also allows breezes to diffuse within the main pedestrian space so that it remains useable throughout the year. Small parks dispersed throughout the southern portion of the site in a fashion similar to Savannah, Georgia. This allows residents in the area to have parks and recreation areas within walking distance to their houses, townhouses, and apartments. (DeKay and Brown, 2014)

New Program Distribution

The re-design uses the existing program as a criterion. After re-distribution based on the climatic guidelines (to follow later in this chapter) and analysis, program square footage is higher than Belmar as built. The new design allows for fewer SFH, but far more townhouses, and nearly three times more apartments. Because daylight and solar analysis indicate that buildings could be significantly taller than the existing plan has built while still allowing winter sun, the resulting program area is much higher than the original. Office and commercial programs are only slightly higher as they were restricted due to their high energy use.

Single family houses number 26 on the new site. Similar to the existing program, each unit is 2,500 square feet in size. These units are spread throughout the southern portion of the site (in purple on Figure 42).

Townhouses number 532 on the new site. Consistent with the existing program, each unit is 1,876 square feet. Because the existing design organizes a primary street on the northern half of the site, the proposed design maintains that condition, which in turn allows townhouses to be spread across the northern half of Belmar (in blue on Figure 42).

Apartments number 2,660 on the new site. The new area per unit is 1,500 square feet. Because apartments are located above the majority of retail and office space, program area is increased while maintaining efficiency due to the low energy use generated by the program type. Apartments are spread

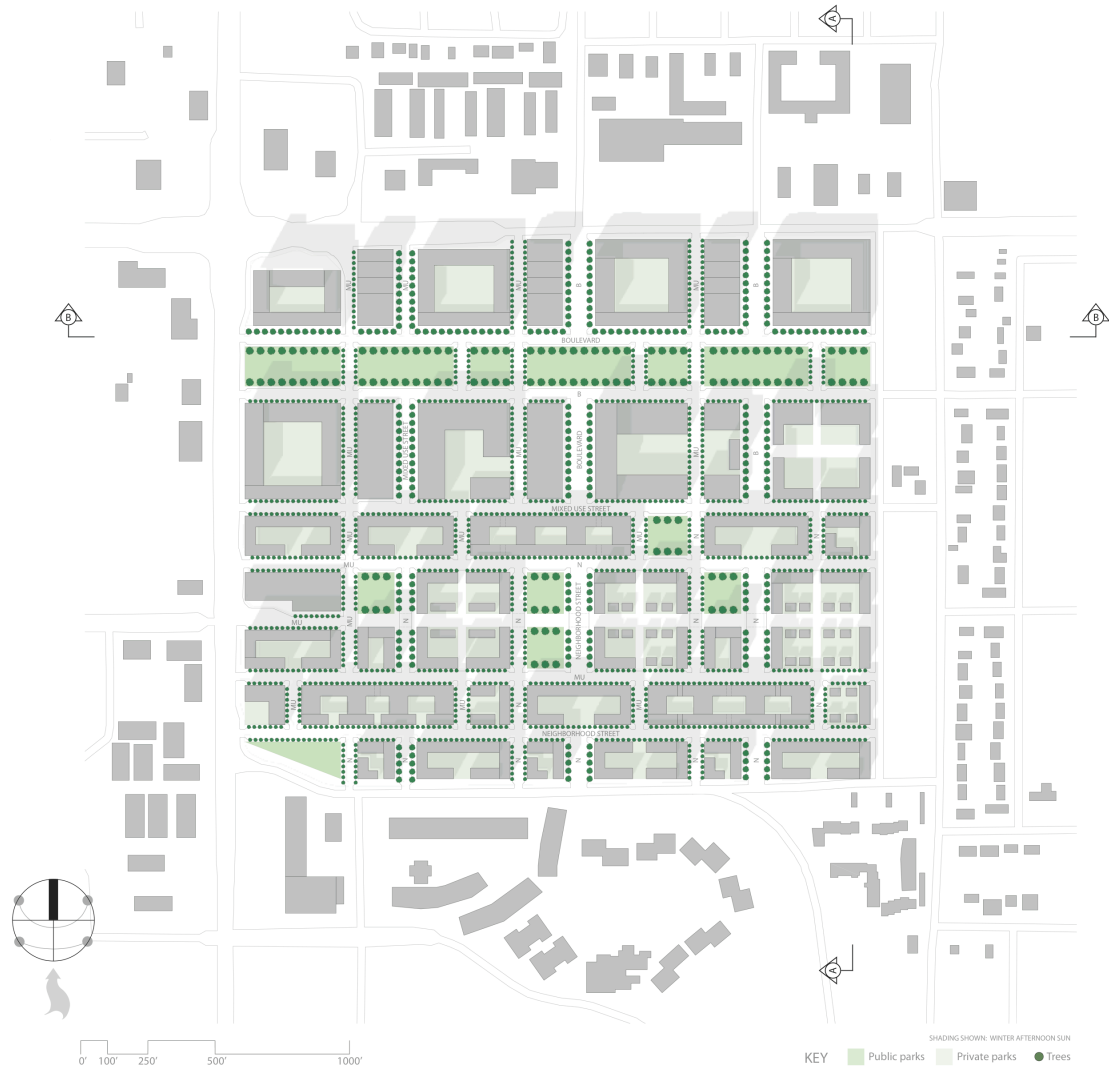


Figure 41. Belmar Plan.

throughout the site and always above retail or office spaces (in orange on Figure 42).

Commercial space totals 1,280,700 square feet on the new site. The total commercial space is kept close to the original allotment due to the high energy use required. This program type is dispersed throughout the site primarily as part of mixed-use buildings with apartments on upper levels (in red on Figure 42). Any “big box” type requirements occur in single story large floor plate buildings that do not require large amounts of artificial lighting due to access to daylight.

Office space totals 800,000 on the new site. The total office space is kept the same as the original program requirements. The program type is spread throughout the site with a high density along the northern main boulevard (in green on Figure 42).

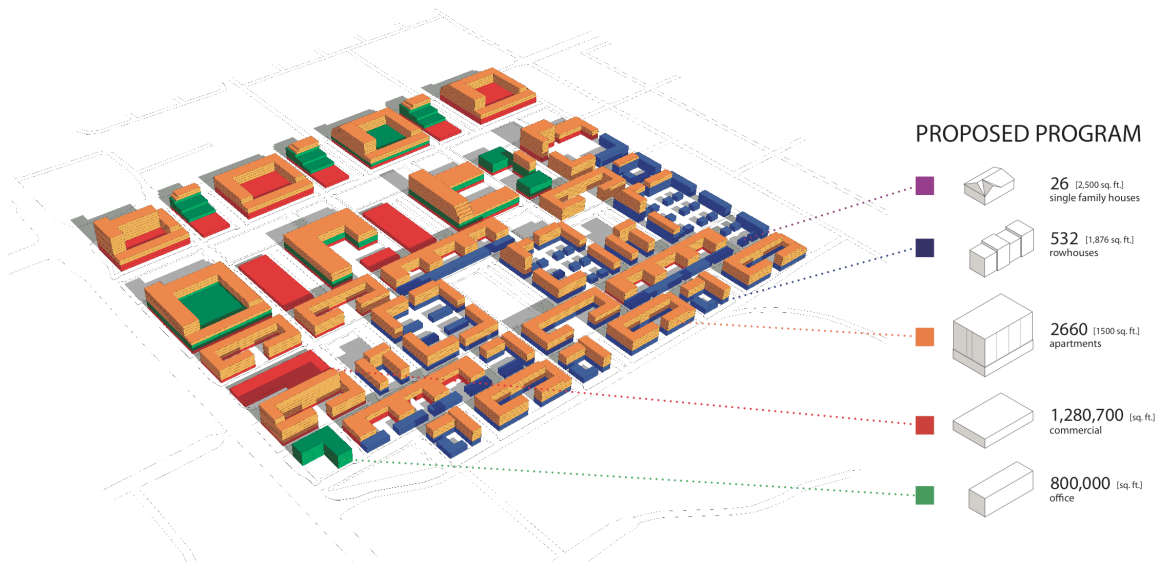


Figure 42. Belmar Proposed Program Distribution.

Daylight Analysis

Daylight access is crucial to reduce artificial lighting demands. Building masses are generated through the four climatic guidelines already listed, while building heights are regulated through the formation of a combined solar and daylight envelope. All buildings on site conform to the prescribed height regulations to allow equal solar and daylight access to all block edges across the site. Refer to Figure 43 for the remainder of this paragraph. The solar and daylight envelope is generated through the overlay of two different conditions based on orientation. Solar access is directional and most efficient on the south side of buildings, while

daylight access is ambient and available from every direction. Advantages of solar access include solar heat gain and effective solar energy collection for PV and solar hot water systems (DeKay and Brown, 2014). Maximum daylight access reduces demand for artificial lighting and (in some cases) cooling demand from large quantities of lighting fixtures (DeKay and Brown, 2014). To find the daylight envelope, a plan is extruded at a 40 or 45° angle (higher for north – south and lower angle for east – west) from the lowest base of a window to receive daylight access. This angle is derived from the medium-low density to correspond with the medium density in the proposed design. The solar envelope is developed by a building height maximum of half the street width (DeKay and Brown, 2014).

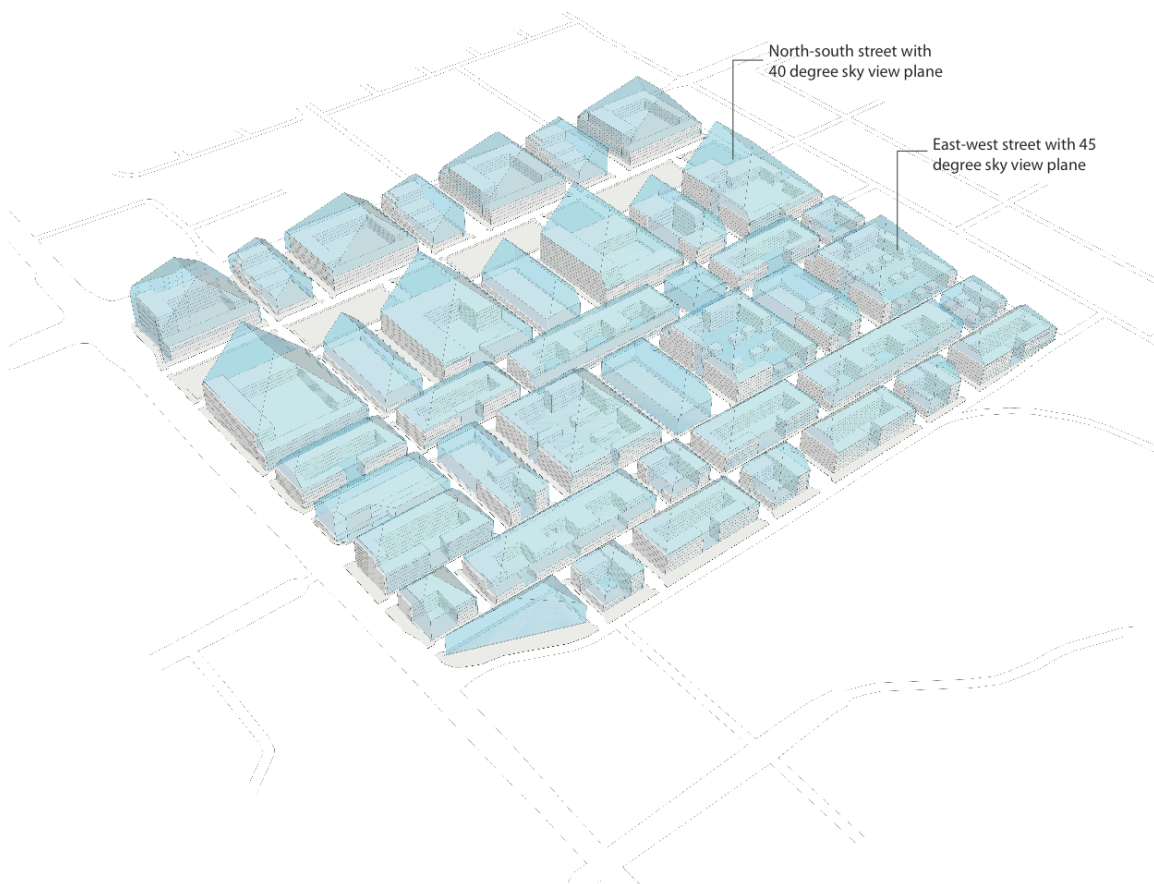


Figure 43. Sunny Winter Outdoor Spaces.

Sectional implications of the solar and daylight envelope are indicated below in Figure 44. Street, sidewalk, and planting widths are derived from the SmartCode template (Center for Applied Transect Studies, 2009). The matrix is based on orientation and pedestrian use determines street types for Belmar. Each type also contains a vertical use organization based on New Urbanist principles that

promote retail and office on lower levels with residential above (Center for Applied Transect Studies, 2009), and energy use gradients that promote spaces with the least heat generation above, where access to solar heat gain will be greater.

Passive zone areas are the spaces within the building that are most affected by and make use of solar, daylight, and ventilation access. The analysis method employed sets the passive zone at 20 feet from the façade (with some generalizations made concerning window size and spacing) (DeKay and Brown, 2014). For this reason, many buildings are generally no more than 40 feet thick. Wider buildings allow circulation and service spaces on the interior of the building with a small non-passive zone occupiable area, and the majority of occupiable space remains passive.

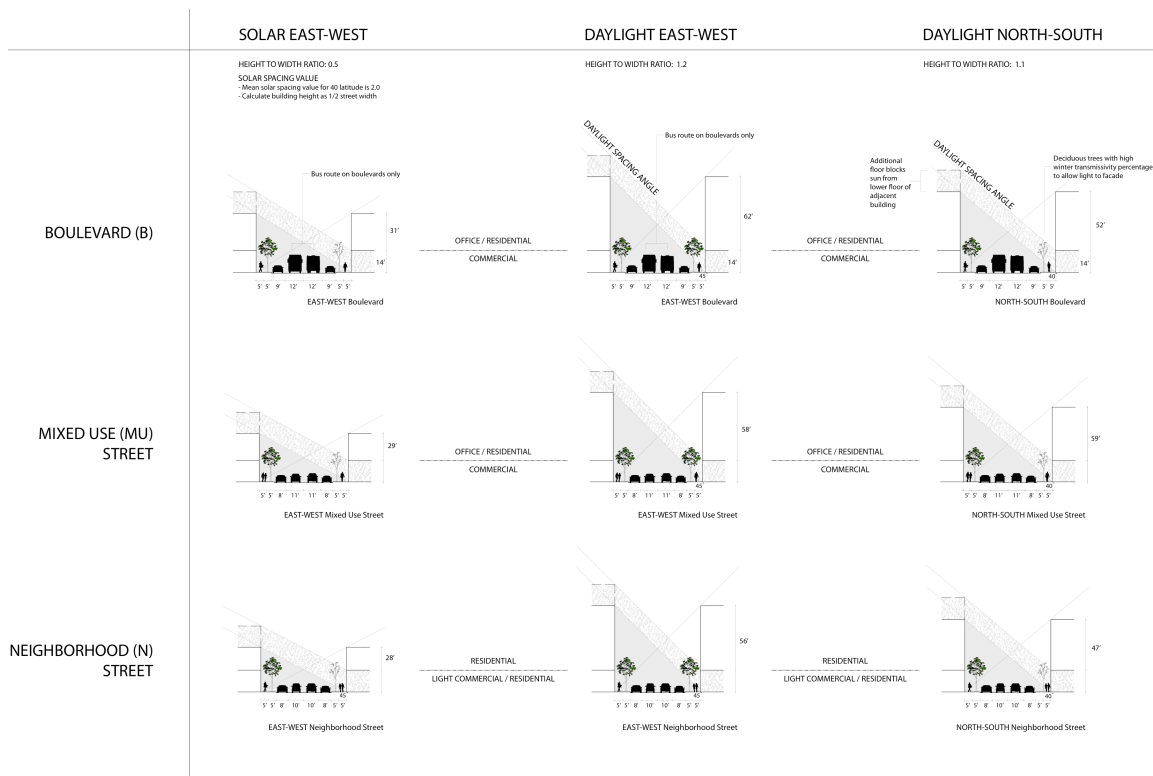


Figure 44. Belmar Street Sections.

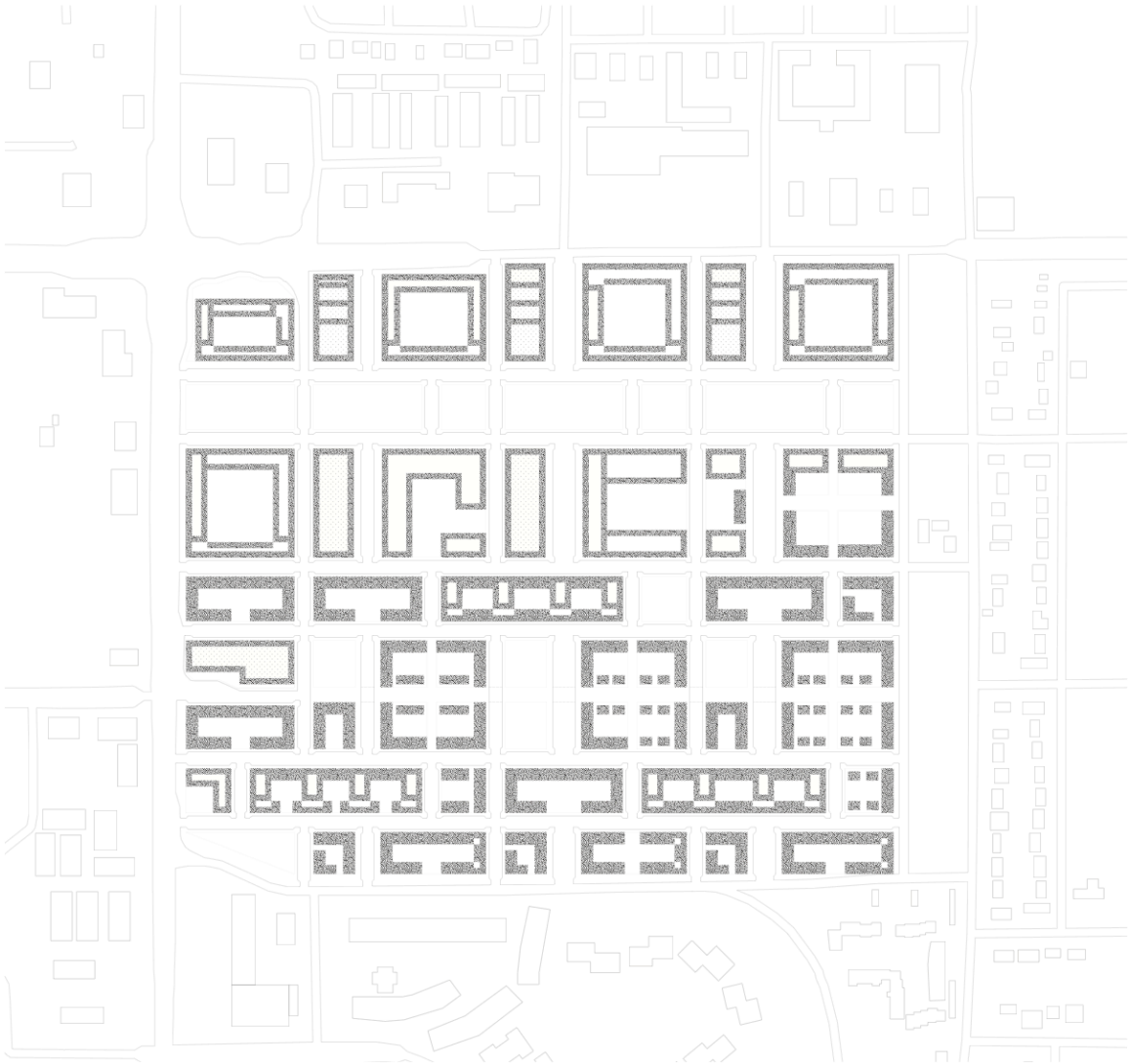


Figure 45. Passive zones.

Passive Solar Analysis

The dry bulb temperature describes the ambient air temperature for the location. In Denver, the dry bulb temperature stays generally cool, with the warmest months being July and August. During these months, the temperatures peak around 4pm and begin dropping significantly after sunset. The remainder of the year experiences temperatures between 32-68 degrees F during the day. In the winter and early spring (December-March), below-freezing temperatures begin shortly after sunset through the night to shortly after sunrise. Humidity is inversely related to temperature. As the day progresses, humidity in the air dissipates to somewhere between 20-40% humidity, and then rises back for the nighttime hours when temperatures are cooler. This pattern is consistent all year. Monthly temperatures tend to fall below the 68-78°F comfort zone except for the average highs for July and August. Design highs for May-September tend to be above the comfort zone. During these months, access to cooling, whether passive or active, is necessary. The remaining months, which account for the majority of the year, October-April, require some heating whether throughout the day or during the nighttime hours.

Based on analysis of sun shading charts, it is primarily necessary to heat for the majority of the winter and spring seasons throughout the day. Towards the latter part of June, this need wanes but maintains a continued possibility of cooler than comfort temperatures in the morning hours. Primary shading for this part of the year is needed on the southwestern facade. During the summer, some sun shading is needed on the southern facade of the building, but the primary shading remains the southwestern portion.

In light of the above studies, it is clear that parts of May, June, July, August, and September require cooling during at least part of the day. April and October are typically comfortable during the day with heating needed during some nighttime and morning hours. All months require some heating or (account for cooler nighttime temperatures in the summer).

Though trees may be used for shading during the summer, they cannot be dense, so as to allow maximum sun during the winter. Additionally, the tree type should differ based on orientation. Deciduous tree species with high winter transmissivity percentage allow the most light through during the winter and are used in front of the southern façades if trees are to be planted. North, east, and west facades do not require specific trees due to the ambient quality of the light from each of these directions. In the summertime, trees may be used for shading on east and west facades due to the low-angle high heat gain of the sun from those directions. North light is used for daylight only and does not need shading or specific trees at this latitude.

In large open spaces, trees line the area, allowing solar access to the center of the space for pedestrian comfort during the winter. For scale, tall trees are planted along the edges of open spaces while shorter trees line the sidewalks. A short, light canopy is created for walkways and minimal summer shading.

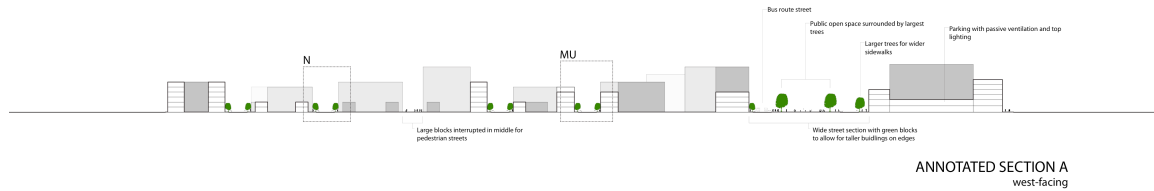


Figure 46. Belmar Annotated Section A.

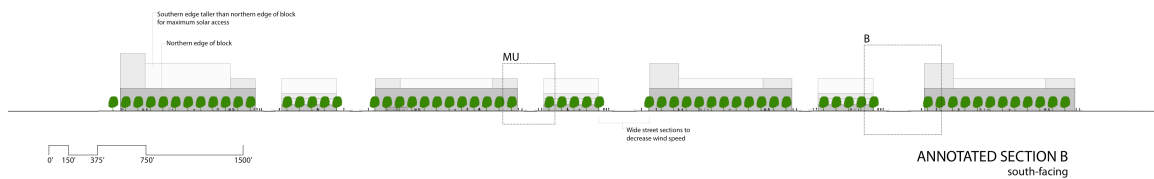


Figure 47. Belmar Annotated Section B.

Block design and analysis in Belmar maximizes the opportunity for daylighting and solar heat gain within the interior of the site. In this method, each block is named based on its shape, features, and program type. Shade areas of the central outdoor space are located, as well as a pattern of solar access on the northern building's south façade. Improved studies are then generated based on forms that cast the most problematic shadows.

Ten different block types are identified in the new Belmar site. To read the following figures, find the name and initial study in the first figure (for example, Belmar Mixed Use Block 1 Study) followed by an improved study (for example, Belmar Mixed Use Block 1 Improvement) and recommendations for further improvements based on increase in percentages. These percentages are based on sun exposure to the courtyard and southern façade of the interior of the block.

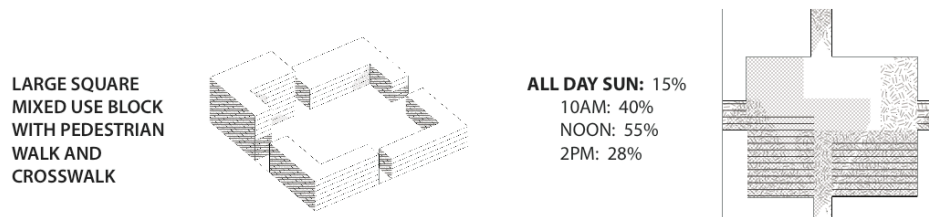


Figure 48. Belmar Mixed Use Block 1 Study.

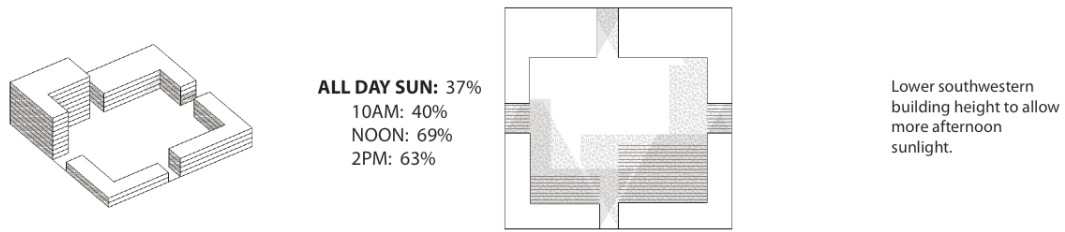


Figure 49. Belmar Mixed Use Block 1 Improvement.

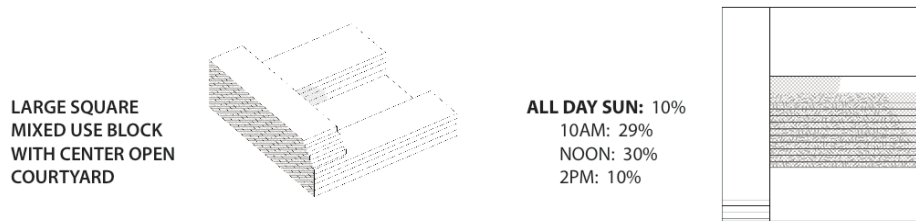


Figure 50. Belmar Mixed Use Block 2 Study.

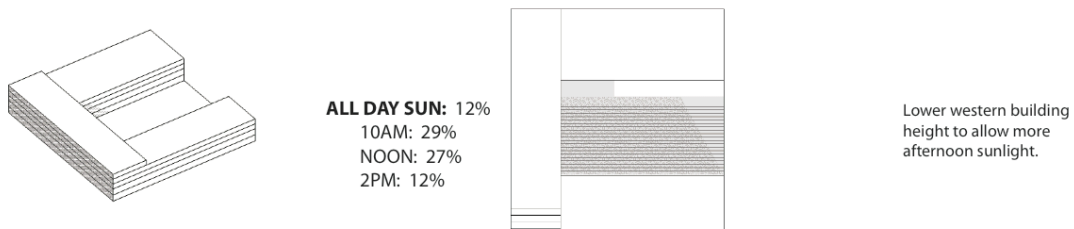


Figure 51. Belmar Mixed Use Block 2 Improvement.

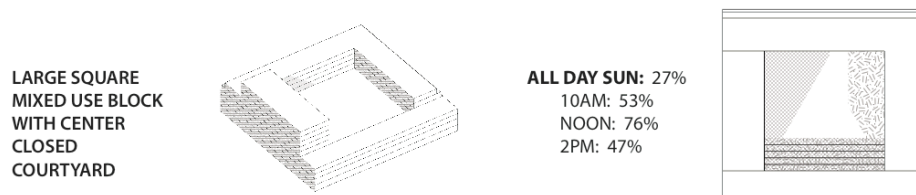


Figure 52. Belmar Mixed Use Block 3 Study.

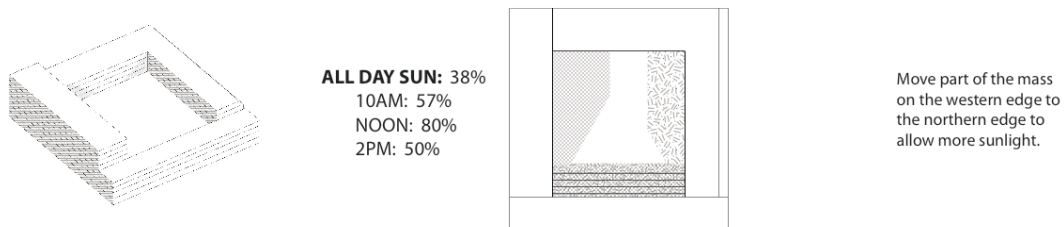


Figure 53. Belmar Mixed Use Block 3 Improvement.

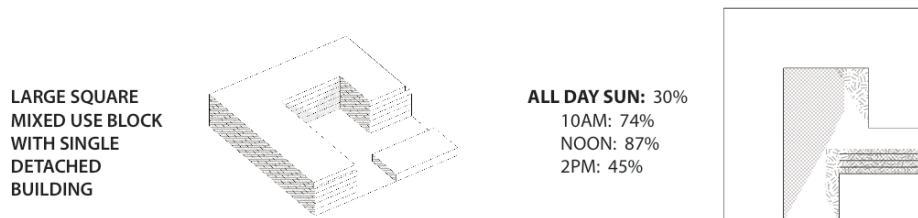


Figure 54. Belmar Mixed Use Block 4 Study.

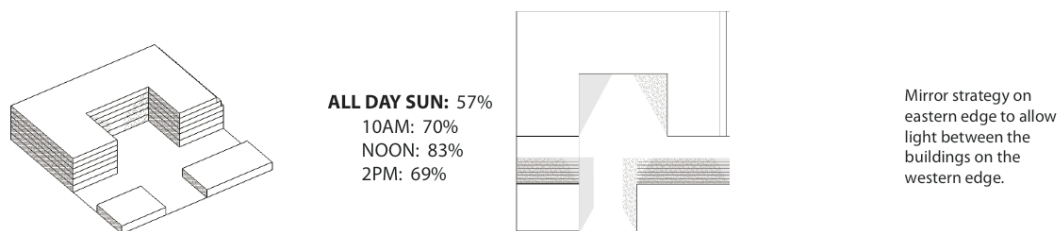


Figure 55. Belmar Mixed Use Block 4 Improvement.

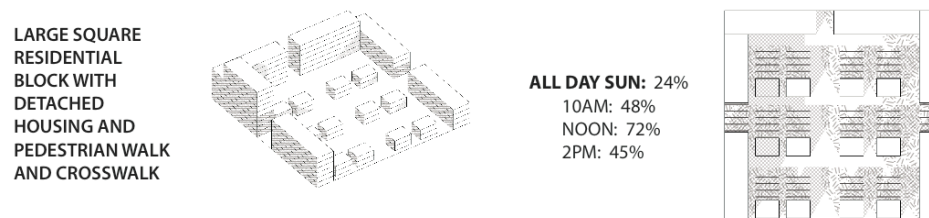
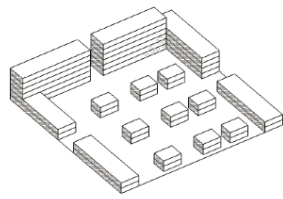
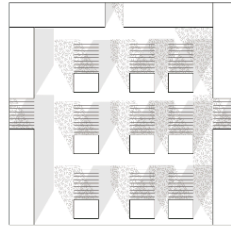


Figure 56. Belmar Residential Block 5 Study.



ALL DAY SUN: 28%
 10AM: 52%
 NOON: 75%
 2PM: 53%



Lower all surrounding building heights and decrease the number of single family houses in the center (the northern edge may stay at maximum height if desired).

Figure 57. Belmar Residential Block 5 Improvement.

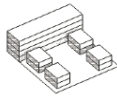
SMALL SQUARE
 RESIDENTIAL
 BLOCK WITH
 DETACHED
 HOUSING



ALL DAY SUN: 15%
 10AM: 38%
 NOON: 75%
 2PM: 25%



Figure 58. Belmar Residential Block 6 Study.



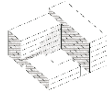
ALL DAY SUN: 32%
 10AM: 61%
 NOON: 86%
 2PM: 61%



Rotate the orientation 90 degrees so that rowhouses occupy northern edge of the block.

Figure 59. Belmar Residential Block 6 Improvement.

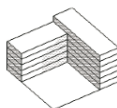
SMALL SQUARE
 RESIDENTIAL
 BLOCK WITH
 DETACHED
 BUILDING



ALL DAY SUN: 5%
 10AM: 9%
 NOON: 55%
 2PM: 9%



Figure 60. Belmar Residential Block 7 Study.



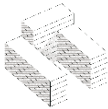
ALL DAY SUN: 71%
 10AM: 71%
 NOON: 100%
 2PM: 100%



Remove small southwestern building.

Figure 61. Belmar Residential Block 7 Improvement.

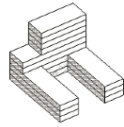
SMALL SQUARE
 RESIDENTIAL
 BLOCK WITH OPEN
 COURTYARD



ALL DAY SUN: 20%
 10AM: 47%
 NOON: 100%
 2PM: 47%



Figure 62. Belmar Residential Block 8 Study.



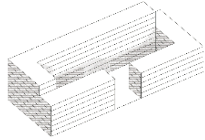
ALL DAY SUN: 20%
10AM: 47%
NOON: 100%
2PM: 47%



Increase northern building height, decrease building height on eastern and western sides of the block.

Figure 63. Belmar Residential Block 8 Improvement.

NARROW
RESIDENTIAL
BLOCK WITH
SEMI-CLOSED
COURTYARD



ALL DAY SUN: 9%
10AM: 22%
NOON: 31%
2PM: 22%

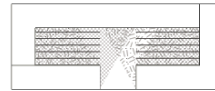
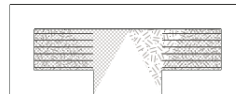


Figure 64. Belmar Residential Block 9 Study.



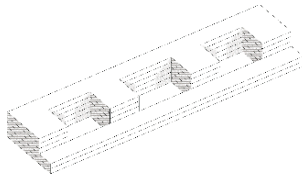
ALL DAY SUN: 23%
10AM: 40%
NOON: 49%
2PM: 40%



Increase space between building edges on the southern side of the block.

Figure 65. Belmar Residential Block 9 Improvement.

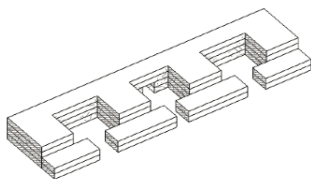
NARROW
RESIDENTIAL
BLOCK WITH
CLOSED
COURTYARD



ALL DAY SUN: 6%
10AM: 12%
NOON: 29%
2PM: 12%



Figure 66. Belmar Residential Block 10 Study.



ALL DAY SUN: 13%
10AM: 39%
NOON: 65%
2PM: 39%



Add breaks in the southern building to allow light into interior courtyards.

Figure 67. Belmar Residential Block 10 Improvement.

Photovoltaic Requirement

The existing Belmar plan allows for a maximum of 1,709,412 square feet of roof space for photovoltaics (PV). The new plan for Belmar allows for a maximum of 1,552,096 square feet of roof space for PV. This is the gross roof area and does

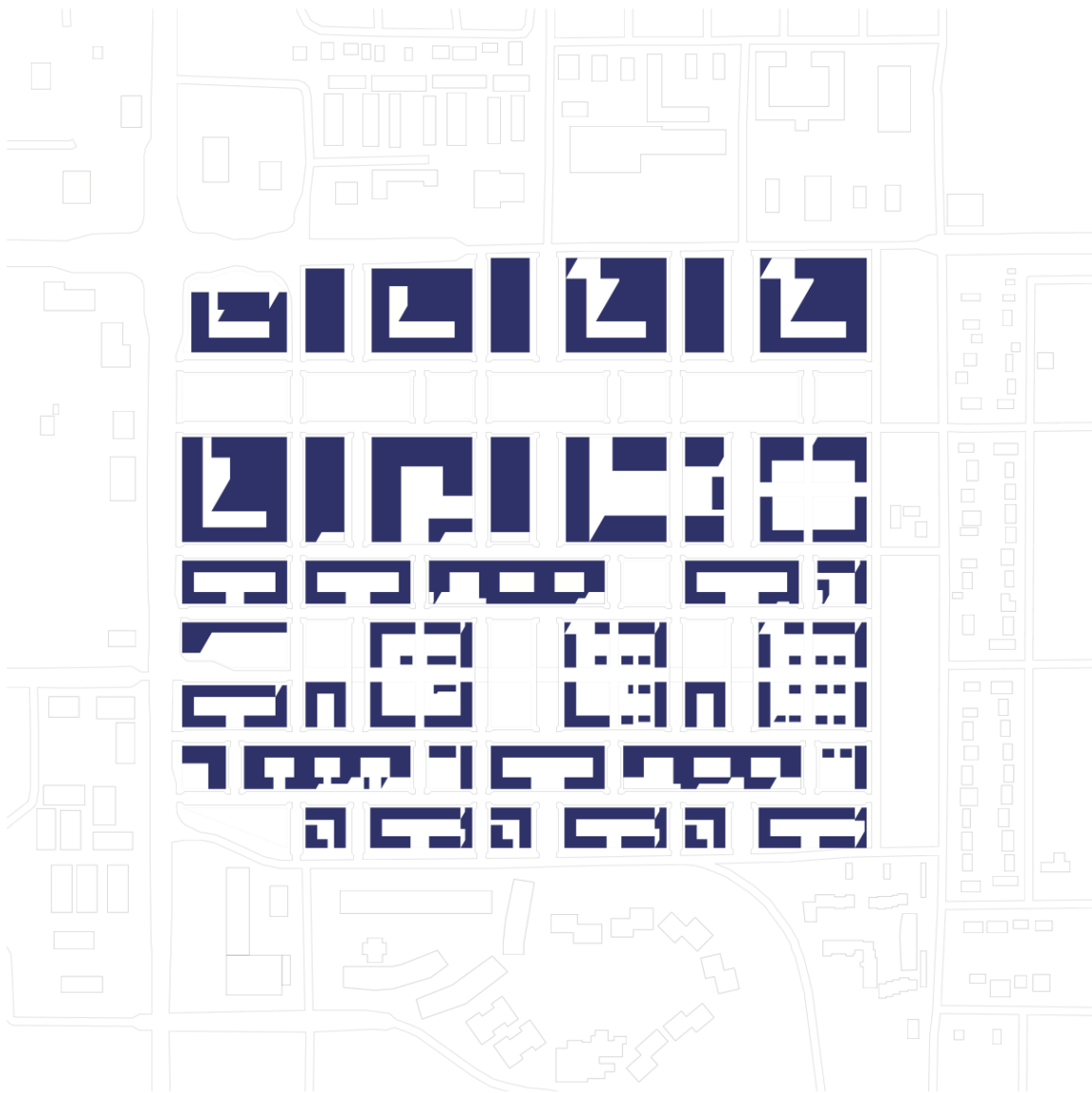


Figure 68. Roof area available for photovoltaics.

not account for daylighting aperture, walkways, stairway access, or other building utilities that typically exist on the roof. Figure 68 shows the roof area available for PV.

This project adopts additions to the Architecture 2030 targets suggesting that 20% of fossil fuel energy reductions are generated from on-site PV. This calculation can be found in the programming section of this chapter.

To estimate required PV area, energy production from PV is calculated in relation to the average yearly incident solar radiation of 6.4 kWh/sq m/day (Marion and Wilcox, 1994). An additional 15% is added to the total to account for loss in conversion and transmission (Mississippi State University Center for Sustainable Design, 2014) from the PV array to the user. This allotment is then sized based on a selected 1-axis tracking 255-Watt monocrystalline panel with efficiency of 15% (AIBC International, 2014) with an area of 21.39 square feet (Mississippi State University Center for Sustainable Design, 2014).

$$\text{Daily energy demand (kWh/day)} = \text{Yearly demand (kWh/year)} / 365 \text{ days}$$

$$\text{Production size (kW)} = \text{Daily demand (kWh/day)} / 6.4 \text{ kWh/sq m/day}$$

$$\text{Panels needed} = ((\text{Production size [kW]} * 1000) * 1.15 \text{ loss}) / 255 \text{ W per panel}$$

$$\text{Net area needed (Square feet)} = \text{panels needed} * 21.39 \text{ square feet per panel}$$

Maximum area required for photovoltaics to power the entire site is seen below in Table 17.

Table 17. Maximum Photovoltaic Area Required from Selected Panel System.

<i>Program</i>	<i>Base PV area Square feet</i>	<i>25% PV area Square feet</i>	<i>80% PV area Square feet</i>	<i>100% PV area Square feet</i>
SFH	32,265.02	25,408.70	12,180.05	6,775.65
Townhouse	256,643.72	206,919.00	99,449.44	55,178.40
Condominium	389,926.48	315,532.62	151,866.10	84,142.03
Retail	610,884.41	580,770.39	278,769.79	154,872.10
Office	1,084,104.72	764,681.01	366,530.64	203,914.94
TOTAL	2,373,824.36	1,893,311.72	908,796.02	504,883.13

Table 18 shows the percentage of the maximum photovoltaics needed that can be placed on roof area in the proposed Belmar site compared to the site as built. One important discovery is the ability to power the entire site through photovoltaics nearly two to three times over at the 2020 target (80% reduction) and 2030 target (100% reduction). Due to the solar energy collection of the PV panels used, the high excess energy in the 2020 and 2030 target districts could be fed back into the electric grid and bought by the utility company. This large potential excess allows for the district to be powered given normal roof conditions (stair access, building systems, daylighting, walkways that typically occupy the roof). Additionally, the calculation does not take south-facing facades into account, which add more area available for PV use. The calculation also does not account for spacing to allow solar access during the winter (the lower sun angle during the winter months will cast a longer shadow from one panel to another). These goals are possible with a less efficient PV system (to a minimum capacity of about 140 Watts for the same size panel). The following table shows that for the base (no fossil fuel reduction) and Energy Star targets, there is not enough roof area to meet the power demand in its entirety. This, however, is a calculation to find the absolute maximum area needed for photovoltaics for each site. Because it is more common to use some combination of strategies, this maximum area is most likely far greater than the actual area that would be used.

Table 18. Maximum Coverage of On-Site Photovoltaics.

<i>Program</i>	<i>Base PV area percent</i>	<i>25% PV area percent</i>	<i>80% PV area percent</i>	<i>100% PV area percent</i>
Existing site	72%	90%	188%	339%
New site	74%	92%	192%	346%

The project uses a target of a minimum of 20% of fossil fuel reductions provided through on-site photovoltaics. Table 19 below provides areas found under this recommendation. The percentage allowed refers to the percent of the total energy requirement allowed to go toward on-site photovoltaic production as part of this project (for this calculation, see the energy target parameter section of the first chapter). The 20% area refers to the square foot area of panel surface needed to meet the stated 20% on-site photovoltaic power generation requirement. Due to the program EUIs, the 20% on-site photovoltaic area does not consistently decrease across. If EUI is kept constant while reductions increase, the PV area decreases at a consistent rate.

Table 19. 20% On-Site Photovoltaics.

<i>Program</i>	<i>Base PV area Square feet</i>	<i>25% PV area Square feet</i>	<i>80% PV area Square feet</i>	<i>100% PV area Square feet</i>
Percent allowed	0	5%	16%	20%
20% area	0	378,662.30	181,759.20	100,976.60

Remaining roof space in the proposed plan after the 20% photovoltaic recommendation is subtracted from the gross roof area and shown below in Table 20. This remaining roof space can be used for solar hot water, daylight apertures, mechanical equipment, and any further PV used to exceed the targets.

Table 20. Remaining Roof Area.

<i>Program</i>	<i>Base PV area Square feet</i>	<i>25% PV area Square feet</i>	<i>80% PV area Square feet</i>	<i>100% PV area Square feet</i>
Remaining area	0	1,368,162.00	1,565,065.00	1,645,847.00

Passive Ventilation Analysis

The seasonal Denver-Stapleton wind roses (Figure 69) indicate that on average, the primary wind generally comes from the south, sometimes secondarily northeast. A secondary wind typically comes from the north. Although there is some very slight variation throughout the year, typically it carries about a 50% relative humidity. Seasonally, spring (March - May) experiences the least winds, but they are generally stronger from the north, west, and south. Summer, fall, and winter experience the most consistently southern winds of the year. Secondary northern winds tend to occur much less frequently than the primary southerly wind. Winter is the only season that sees winds below freezing (as indicated by the dark blue in the outer portion of the petal in Figure 69). In other months, winds are generally around 60-68°F. Air moving from both the primary and secondary directions tends to be slightly cooler than other breezes. Except for the spring, these account for the significant majority of time. Monthly, wind tends to be fairly constant with a slight increase during the beginning of the summer. Though the record winds are much higher, average high wind speeds do not exceed 19 mph while the mean generally falls between 7 and 11 mph. Daily wind averages fall into the patterns shown below. Throughout the year, the

strongest winds occur in the afternoons and tend to fade off as the sun sets. January through June accounts for the strongest winds (10-20 mph) during the majority of the day while July through December experience only small breezes of 5-10 mph throughout the day. January and June are the only months that experience stronger than average winds during the nighttime hours.

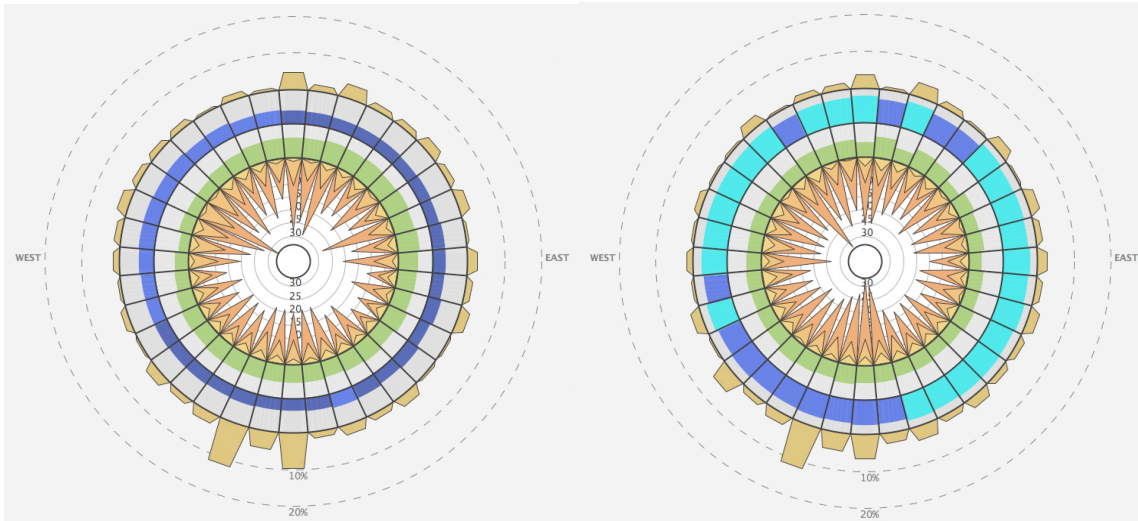


Figure 69. Denver summer and winter wind rose.

Denver experiences a primary wind from the south and secondary wind from the north. In the colder Winter months: protect outdoor spaces from the southern wind, allow light into indoor and outdoor spaces, and stagger streets to slow wind speeds. In the warmer summer months: Denver experiences a short, mild summer season that only briefly climbs above the comfort zone during the day. Residential units may be designed to remove the need for air conditioning completely. Some large, special district areas within the neighborhood will retain the need for air conditioning, possibly throughout the year. Solar access for daylighting in the large footprint commercial buildings will help to reduce cooling and lighting need (during the day), although this will reduce the amount of roof space for photovoltaics.

The existing configuration creates strong southern winds down the main N-S streets with little to no ventilation across the E-W axis. Such an effect creates cold, windy streets in the Winter and mild, windy streets in the summer, however, because the climate is cool and dry, the area lies generally cooler than comfort for the majority of the year--indicating a need for slower winds and sunny outdoor spaces. Sun and ventilation analysis diagrams show spaces in need of more sun, ventilation, or slower winds. These diagrams, combined with existing green and public spaces, are used to create a hierarchy of passively designed spaces within the site.

Figures 70 and 71 compare the existing with the proposed sites' wind patterns entering the site. Figure 72 highlights areas where the north–south streets are discontinuous to slow southerly winter winds as they make their way across the site. Streets are discontinued in these instances to divert and deflect wind throughout the rest of the site. The slower winds allow them to feel less cold in winter.

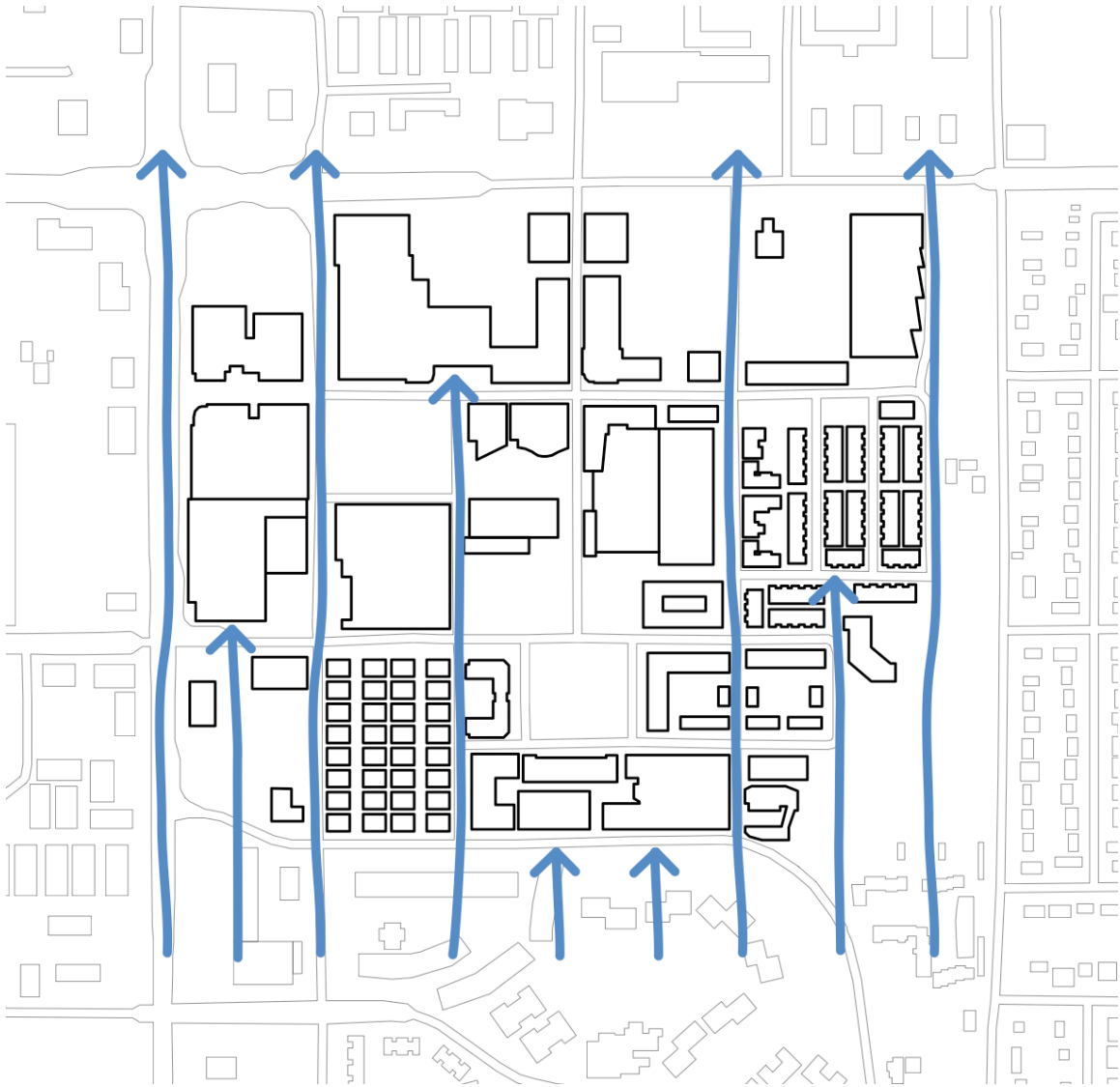


Figure 70. Existing Belmar plan wind patterns.



Figure 71. Proposed Belmar plan wind patterns.

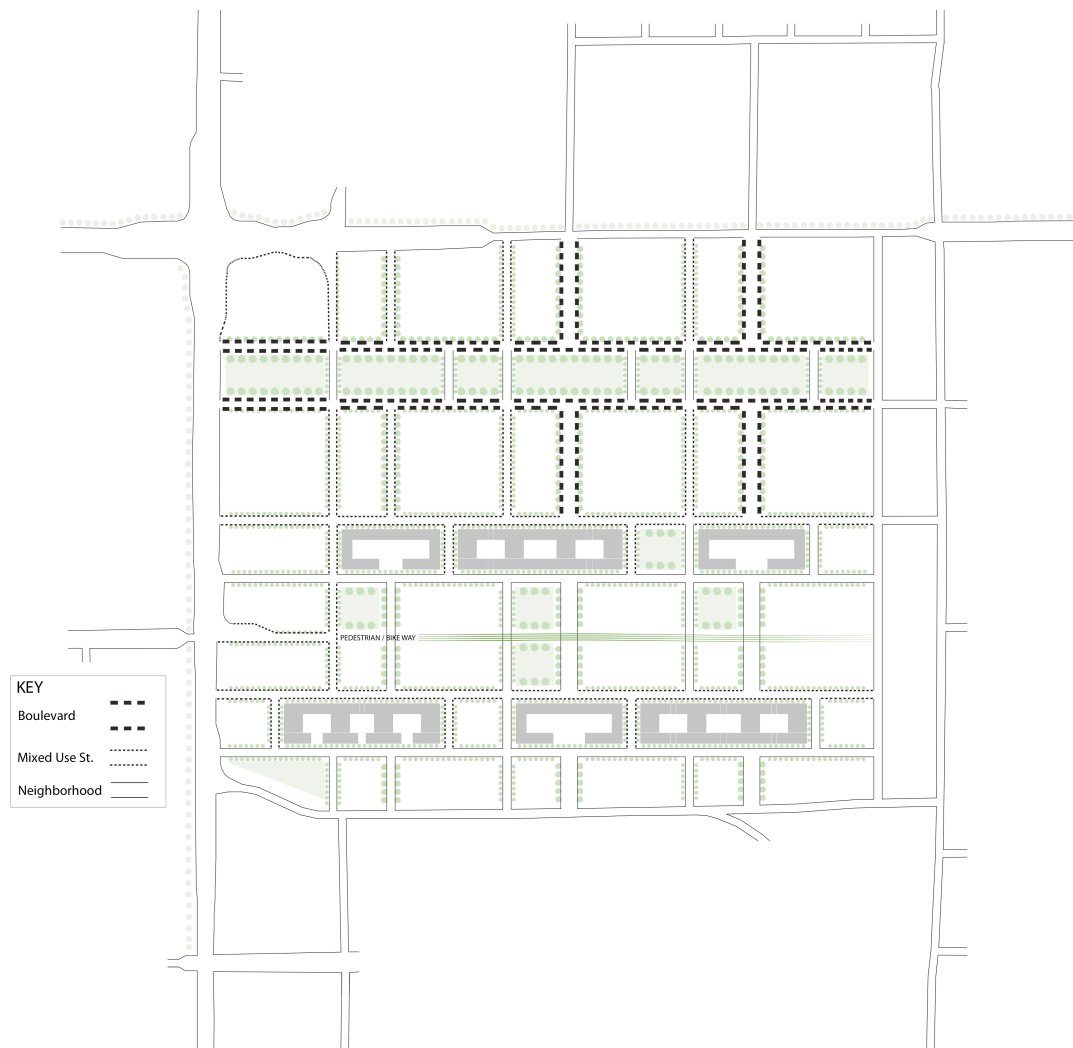


Figure 72. Discontinuous North-South Streets.

CHAPTER IV

GUIDELINES AND DISCUSSION

The following design guidelines integrate climatic design and New Urbanist principles in an urban district. The guidelines are basic enough to use at multiple scales, as shown in the solar and shading studies. On the district level, the guidelines can be used to regulate the orientation and form of the urban fabric: how the streets are arranged and the blocks are shaped (square, narrow, small, large, etc.). On a smaller scale, the guidelines are used to generate the form of the blocks and heights of each building based on its relationship to blocks that surround them and solar, daylight, and ventilation access to the interior of the block.

In Glenwood Park, Atlanta, Georgia:

1. *Create a breathable urban fabric.*
 - Space buildings for access to westerly summer breezes.
 - Add breaks, punctures, and walkways through buildings to allow summer breezes through the site.
 - Design blocks to be square or better east-west elongated for maximum permeability.
 - Maximize breaks in buildings to allow more ventilation and solar availability.
2. *Make narrow north–south, wide east–west streets.*
 - Keep north-south oriented streets narrow to shade from low-angle, harsh east and west sun in the mornings and afternoons.
 - Keep east-west streets wide to allow for solar availability and solar heat gain to the south sides of buildings during the winter.
3. *Shade summer outdoor spaces.*
 - Shade pedestrian outdoor spaces (courtyards and walkways) with pergolas, canopies, arbors, and trees.
 - Use building taller buildings along north-south oriented streets to shade summer courts and sidewalks.
 - Specify denser trees for north-south streets than east-west streets (trees in front of southern facades are least dense).
 - Specify deciduous trees in front of south facades.
4. *Limit building heights on south and west of the block.*
 - Keep buildings on the southern portion of the block shorter for more solar access.
 - Add properly sized pergolas on the south side of buildings to provide shade in the summer and allow solar heat gain in the winter.

- Keep buildings on the western sides of blocks shorter and discontinuous to allow westerly summer breezes into the block.

The proposed design is not a specific proposal for the rebuilding of the neighborhood development, but yields design recommendations for how the district can be designed to make use of climatic forces to reduce energy use. The primary climatic design objectives for Atlanta are to create a breathable, ventilated, shaded urban fabric while still allowing maximum solar exposure to roofs and south facades.

Final analysis for photovoltaic capacity on site reveals (see photovoltaic analysis in Chapter II) that space is available on roofs for complete dependence on PV for 2020 and 2030 targets (80% and 100% fossil fuel reductions). While the existing Glenwood Park plan contains more roof area, both existing and proposed schemes completely allow the same 2020 and 2030 targets to be met (see Figure 73). Though utility space is not taken into account in the calculations, the over-abundance of space remaining after the 20% allowable PV recommendation is put in place, and the abundance of available excess roof area beyond the net required array area in the 2020 and 2030 districts allow these methods to be easily employed. In Figure 73, the area above the line indicates PV area needed that is not available on site with roof area only. All space below the line indicates area available for PV on the proposed site.

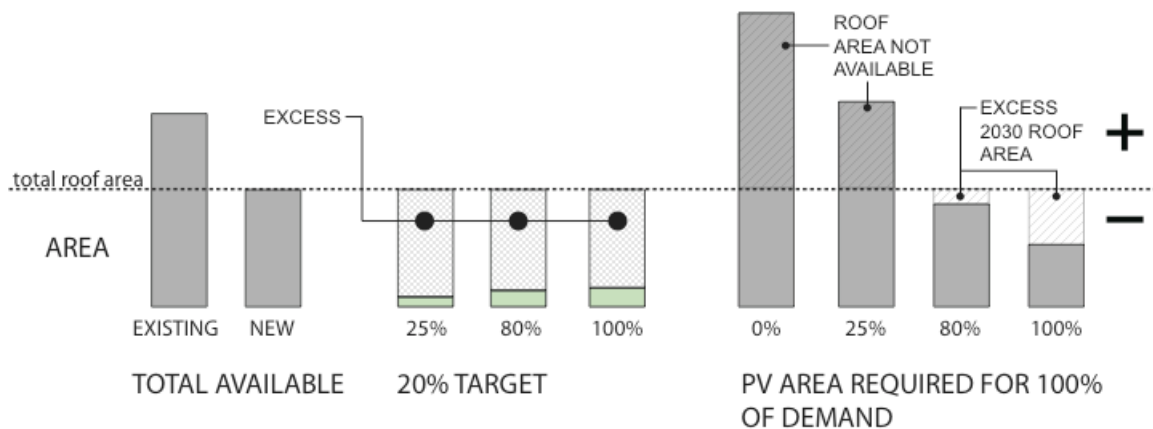


Figure 73. Glenwood Park photovoltaic target analysis.

In Belmar, Lakewood, Colorado:

1. *Orient for good solar orientation.*

- Arrange most of the building mass along the east-west axis to allow for the most southern exposure.

- Keep the tallest buildings on the northern portion of the block to collect the most solar heat gain from the south.
 - Ensure that buildings on the south side of the block are shorter so that solar access is available to the north side of the block.
2. *Create sunny winter outdoor spaces.*
 - Design outdoor spaces to receive sun for at least one hour per day based on December 21 solar patterns.
 - Place importance on solar access to the southern façade to increase solar heat gains.
 - Arrange buildings inside blocks so that the southern façade receives at least 4 hours of sun exposure per day between 10 am and 2 pm.
 3. *Use thin multi-story floor plates.*
 - Design building forms so that most occupied space is within the passive zone (nearly all space inside the building is within 20 feet of a window).
 - Increase daylight access through thin floor plans to reduce artificial lighting demands.
 - Provide passive heating, cooling, and lighting within the passive zone on the interior portion of the building.
 - Limit large floor plates to one story to use roofs to admit sunlight and daylight from above and minimize artificial lighting and cooling.
 4. *Design discontinuous north-south streets.*
 - Create discontinuous north-south streets to slow the cold southerly winter wind down on site and increase walkability across the entire site.
 - Allow through streets along the east-west axis so that access to surrounding neighborhoods is available without compromising walkability due to cold, windy winter conditions.

The proposed design is not a specific proposal for the rebuilding of the neighborhood development, but a design test of recommendations for how the district can be designed to make use of climatic forces to reduce energy use. The primary climatic design objectives for Denver are to create a sunny, diffused wind fabric.

Final analysis for photovoltaic capacity on site reveals (see photovoltaic analysis in Chapter III) that space is available on roofs for complete dependence on PV for 2020 and 2030 targets (80% and 100% fossil fuel reductions). In fact, the existing Belmar plan contains slightly more roof area than the existing, so that both plans can be viewed similarly and completely allow the same 2020 and 2030 targets to be met (see Figure 74). Though utility space is not taken into account in the calculations, the abundance of space remaining after the 20% allowable PV recommendation is put in place, and the abundance of available excess roof area beyond the net required array area in the 2020 and 2030

districts allow these methods to be easily employed. In Figure 74, the area above the line indicates PV area needed that is not available on site with roof area only. All space below the line indicates area available for PV on the proposed site.

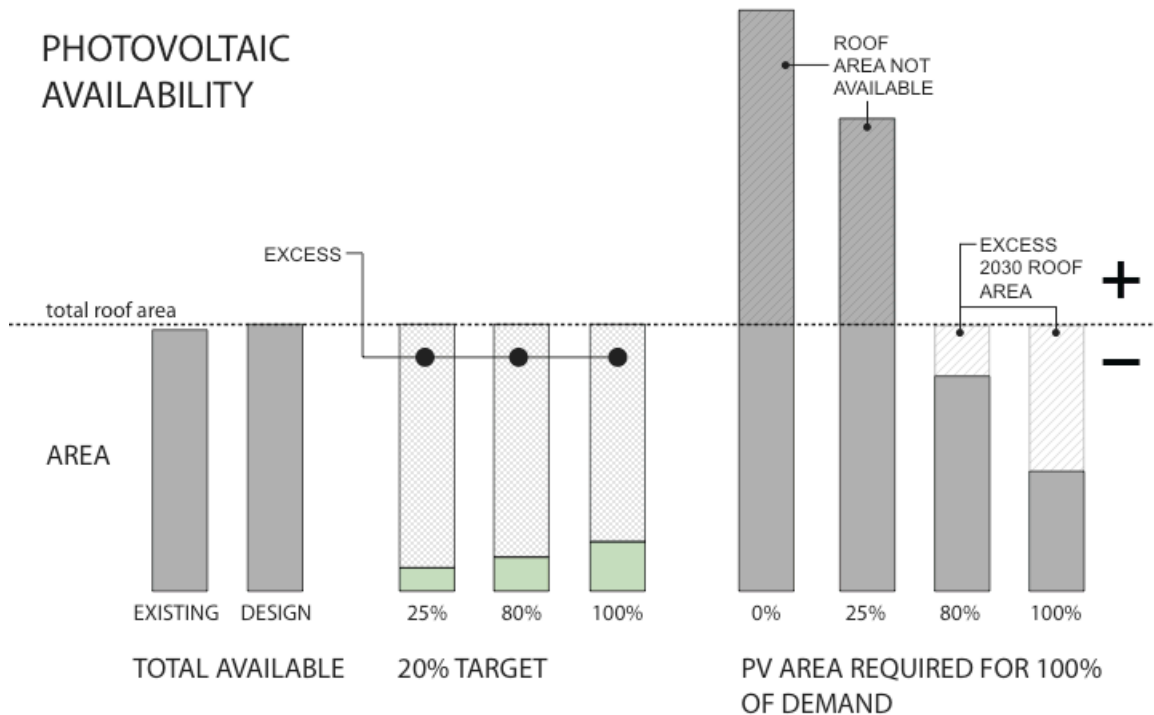


Figure 74. Belmar Photovoltaic Analysis.

The studies above outline some urban design approaches that help to meet the Architecture 2030 targets on a district scale and could help to eliminate the building industry's dependence on fossil fuels to generate power. Elements from the study, such as the promising photovoltaic analysis, provide initial indication that the goal is attainable. Integration of climatic design into the urban fabric is integral to the success of the plan, so that passive strategies are available and on-site renewable resources are abundant to use throughout the site. While also employing New Urbanist principles, the forms generated meet all goals and amenities available on the existing site, plus adds a climatic and energy production overlay. Additionally, the modulation of street sections by orientation and use can regulate development while achieving social, economic, and energy goals.

CHAPTER V

QUESTIONS FOR FURTHER RESEARCH

Questions generated from the project include inquiries into the potential next stages of design for each proposed site. Each decrease in scale allows for further refinement of the guidelines and further climatic integration. The following are questions and topics for further study generated by this thesis:

1. *Can the street sections be revised further to derive very basic design strategies from them?* The street sections for both sites are developed in a grid based on a single orientation and a specific set of uses. Vehicular lane widths are based on traffic, but street widths are based on orientation and necessary building spacing. More revision of the street sections would allow for examples of different solar, daylight, and ventilation strategies to appear, but also will allow the sections to begin to inform differences between the new climatic form and existing code requirements. The differences could then be categorized into a climatic overlay or simple revisions to the existing code that improve efficiency and access to solar, daylight, and ventilation on site.
2. *What is the maximum percentage of photovoltaics allowed on site with other roof uses taken into account?* Initial studies indicate that 2020 and 2030 targets are possible for both Glenwood Park and Belmar. In fact, they are both possible for the existing sites as built today, assuming the existing buildings have the efficiency needed for the energy reductions (unlikely), but the goal of this thesis is not to retrofit existing sites. The initial photovoltaic studies are very positive and require further analysis to prove or disprove the first hypothesis that photovoltaics, when calculated as a whole neighborhood development, could be an integral part to the success of each fossil fuel reduction target.
3. *What supply side strategies would help toward bringing the sites to carbon-neutral?* In its current form, the study provides primarily passive strategies to reduce dependence on fossil fuels. These strategies involve site design to allow every building to become more efficient and able to use passive technology and climatic elements available for the region. Photovoltaic analysis is a beginning step towards sizing on-site renewable power generation to reduce fossil fuel demand. Natural gas (though not completely carbon-neutral) is a viable option for all targets up to the carbon-neutral target. Building cladding systems, fuel cells, co-generation, and active systems are further areas of future study to supply a carbon-neutral district.
4. *Can a method be developed to calculate the effects of the passive energy strategies employed?* It is known that the passive strategies employed in the new site designs will reduce energy demand, but further analysis could include estimates of energy demand reduction and carbon reduction from urban and

building strategies employed in the guidelines and the next layers of technology and design on the site.

5. *Where is it most effective to make energy reductions within the district?* This thesis assumes district-wide energy reductions. In a district with multiple uses, it may be most cost-effective to make reductions in some specific areas, while others may not be most cost-efficient for reductions.

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VITA

Jennifer Delane Stewart was born in Athens, Georgia, on May 11, 1990. After graduating high school in 2008, Jennifer was accepted to the architecture program at the University of North Carolina at Charlotte. Travel was an integral part of studies at UNC Charlotte. Jennifer was given the opportunity to travel to Washington, D.C.; Charlottesville, Virginia; Chicago, Illinois; London, England; Rome, Italy; and multiple cities in Spain and Portugal. Also during this time, a love of climbing, mountain biking, hiking, and camping was further developed through involvement with UNC Charlotte's outdoors program, Venture, and the attendance of Exercise Science classes in wilderness trip leading, challenge course activities, and rock climbing. In architecture, focus toward sustainability and model-making guided studio and elective classes. Jennifer is also responsible for much of the formation of the EcoReps program through the Office of Student Life and Facilities Management at UNC Charlotte.

In 2012, Jennifer graduated Cum Laude with her Bachelor's of Arts in Architecture. She was accepted to the graduate architecture programs at the University of Florida, Georgia Institute of Technology, University of North Carolina at Charlotte, and University of Tennessee, Knoxville, the latter in which she enrolled immediately after completion of her Bachelor's in Charlotte. At the University of Tennessee, Jennifer traveled to Nashville, Tennessee; and Asheville, North Carolina, as part of studio projects for a transit-oriented district and urban brewery respectively. Other work at the University of Tennessee has included two additions to the Haiti project including the healthy housing handbook and Eben-Ezer medical clinic addition.

Thesis work titled "Carbon-Neutral Design Guidelines for Medium Density Urban Sites in Warm, Humid and Cool, Dry Climates" won honorable mention for the Church Memorial Thesis Prize in April of 2014 and will be included in the Honors Exhibition of 2014. This thesis work sited in Denver, Colorado, and Atlanta, Georgia, encompassed the design and analysis of two medium density urban neighborhoods. The result of the design was the guidelines generated from the designs.

Jennifer graduated with a Master of Architecture and concentrations in Sustainable Design and Urban Design in 2014.