Architectural strategies in reducing heat gain in the sub-tropical urban heat island

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Architectural Strategies in Reducing Heat Gain
in the Sub-Tropical Urban Heat Island

by

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A thesis submitted in partial fulfillment of the requirements for the degree of
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This thesis is dedicated to my Dad and Mom, Gary and Karen Blazer. Without their love and support who knows how things may have turned out.
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ARCHITECTURAL STRATEGIES IN REDUCING HEAT GAIN IN THE SUB-TROPICAL URBAN HEAT ISLAND

Mark A. Blazer

ABSTRACT

Most scientists agree that the earth’s temperature continues to rise. The heat gain is more pronounced in urban areas due to a phenomenon known as the urban heat island effect. The urban heat island effect is a seemingly inevitable result of urban development, which has far reaching consequences. With energy costs skyrocketing and the destruction of the environment at risk, urban structures and buildings must do more to make our urban settings more environmentally friendly.

So far, there are two well known ways to combat these effects. First, the heat island can be slightly be negated by adding well-watered vegetation to a site. Second, is to use building materials and systems that reflect the light, thus increasing the overall albedo of an urban area. Albedo is the ratio of the light energy is reflected compared that of which is absorbed. The combinations of these two practices are some of the components in green architecture.
To Date, the United States has been slow to adopt policies that reduce the urban heat gain. Likewise, developers have been hesitant to construct these buildings due to implied cost and lack of knowledge. The intent of this project is to show that there are many strategies and design features that can be implemented to combat the urban heat island effect, even in the most challenging locations. The project will also employ green architecture methods in a commercial sector that has yet to fully grasp the potential to reduce heat gain and lower the urban heat island effects.

To aid in the research, this project will detail buildings that are already addressing the urban heat island. The document will identify the most effective and inexpensive ways to solve this problem. It will also describe what can be done to reduce heat waste generated by lighting and cooling. In doing so, the information garnered should lead to design strategies that new buildings can utilize to reduce the urban heat island effect.
CHAPTER 1 – URBAN HEAT ISLAND EFFECT

Introduction

An urban heat island is a built-up area which is significantly warmer than its surroundings. In such an area, typically the temperature difference is usually greater at night than during the day and is greater in the winter than in the summer. The main cause of an urban heat island is the modification of the land's surface by development. Waste heat, generated by energy usage, is a common secondary contributor. Growing urban centers tend to modify greater areas of land and have a corresponding increase in average temperatures (see Figure 1.1). In addition, these same urban areas will see monthly rainfall increase twenty to forty miles downwind when compared to upwind. The rainfall is the result of hot currents rising, which then move downwind to clash with the cooler suburban air. Rain clouds will then tend to form with more frequency.¹ By knowing how a heat island is caused, strategies may be implemented to help mitigate or reduce its negative effects. Failing to confront this problem may result in irreversible damage to the surrounding environment and have a negative effect on the economy.
Components

There are many causes that contribute to an urban heat island. One example is the presence of more dark surfaces when compared to the rural surrounding landscape. Dark roofs are very common in urban centers. Dark roofs contribute to the heat island by absorbing a high percentage of light energy striking the roof’s surface, rather than reflecting light energy away. The ability to reflect heat, termed albedo, is low among dark surfaces (see Figure 1.2). The petroleum based roof for instance, while great for water proofing, is poor at reflecting light energy away. Another poor reflector is street pavement, especially asphalt. Not only does asphalt pavement absorb more light energy, it stores it for long periods of time. Pavement is one of the leading causes for the night time urban heat island.
Another leading cause for the heat Island effect is the absence or total loss of sufficiently watered vegetation. The loss of vegetation in the urban setting is often an unavoidable circumstance. Sparse vegetation can eliminate two important cooling mechanisms, shade and evapotranspiration. Shade cools the air by blocking solar radiation from hitting low albedo surfaces. The reduced thermal energy prevents the surface and ambient temperatures from becoming unnaturally inflated. Evapotranspiration, on the other hand, is the result of both evaporation and plant transpiration. According to the Heat Island Group, “a single mature, properly watered tree with a crown of thirty feet can evapotranspire up to forty gallons of water in a day, which is like removing all the heat produced in four hours by a small electric space heater.”2
Other causes for urban heat island include the canyon effect and building/vehicular energy consumption. The canyon effect is a geometric problem commonly associated with cities that have a concentration of skyscrapers. When light energy enters an urban core it bounces off either a building roof or building facade. In urban cores this light energy is more likely to bounce off several surfaces when compared to rural and smaller scale urban areas (see Figure 1.3). Making matters worse is the notion that building facades in downtown areas usually have large spans of surface area made of glass and other reflective surfaces. Therefore, light energy is bounced around and reflected many times, giving the energy more time to be absorbed into the urban fabric. Buildings and vehicles also add to the heat island by generating waste heat produced by their mechanical functions. Urban areas are more adversely affected by waste heat gain when compared to their rural counterparts because of the presence of more mechanical processes and because of the canyon effect.

Figure 1.3 light energy reflection in the various settings (University of Arizona)
Consequences

Urban heat islands have numerous impacts on the cities in which they occur. They affect the city’s climate, inhabitants, surrounding ecosystems and economy. The most noticeable of these affects is the daily increase in temperature. According to the EPA, some city temperatures are increased as much as 10°F when compared to a nearby rural area. In conjunction with the increase in temperature, the rate of ozone formation rises. Elevated concentrations of low altitude ozone has a significant effect on a city’s air quality. The ozone increase is the main contributor to city smog. The increased amount of ozone can also result in a variety of human health concerns. The ozone also affects the health of vegetation and can tarnish its visual appearance. The air quality is further effected by the release of additional emissions and greenhouse gases through an increase use of air conditioning and other mechanical systems. Finally, there is an effect to the economy through the increase use of energy. Air conditioning is a sizable expense for the operation budget of a business. Since the buildings within in the urban heat island need more cooling, their energy consumption and operational expenses will be increased.

Conclusion

The urban heat island is having major impacts on American cities. As cities grow, they pave new roads, cut down trees, and consume additional
energy resources. All of these factors lead to an increase in the urban heat island effects. These effects are damaging the cities’ ecosystem, affecting the heath of the inhabitants and impacting the economy. Although, causes of the heat island seem unavoidable, some basic strategies can be adopted to help cope with these effects. Future construction within the heat island area should be designed in a way to help mitigate the impacts. With a shift in building design strategies, a reduction the heat island can be realized.
CHAPER 2 – BUILDING STRATEGIES TO MITIGATE URBAN HEAT ISLAND EFFECTS

Introduction

Mitigating the effects of the heat island is a complex proposition for the design of new buildings. Not only will these building’s have to deal with the effects created by the present heat island, but the building should also be able to alleviate the future heat island effects as well. Currently, there are many techniques that can be integrated into a building’s design to reduce a building’s core temperature, as well avoid contributing to the current heat island effect. These techniques can be broken into three categories: direct radiant gain, ambient gain and waste heat. Knowing these techniques, and the strategies in implementing them, will help to establish future design systems and construction methods.

Direct Radiant Gain

Direct radiant gain reduction techniques deal with strategies that reduce the absorption of light energy into a building. As previously indicated, a main
contributor to heat island is to large expanses of surfaces with low albedo/reflective materials. Reducing and replacing these materials with more reflective surfaces is an important heat island deterrent. A building with a light covered roof will reflect more light energy than a dark covered roof. According to Berkeley’s Laboratory’s Environmental Energy Technologies Division applying white paint can vastly enhance a surface’s reflectivity. The texture of the exterior materials is also important. A coat of white paint over a smooth surface will reflect light away better than the same paint on a rough surface (see Table 2.1).

<table>
<thead>
<tr>
<th>Material</th>
<th>Reflectivity</th>
<th>Emissivity</th>
<th>Max. Surface Temp. (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White prepainted metal roof</td>
<td>.64</td>
<td>.83</td>
<td>123 - Cool</td>
</tr>
<tr>
<td>Unpainted metal roof</td>
<td>.64</td>
<td>.08</td>
<td>142 - Warm</td>
</tr>
<tr>
<td>Asphalt Shingle</td>
<td>.09</td>
<td>.91</td>
<td>164 - Hot</td>
</tr>
</tbody>
</table>

Table 2.1 reflectivity levels of various surfaces (Drexel)

Reflective exterior materials reduce heat absorption as well. Metal roofs are a primary example. These metal roofs are usually durable and will reduce energy consumption. The consumption of energy is lower due the reduction of cooling needs. In the southeast portion of the United States, cooling accounts for over one tenth of all energy consumed in the average office building (see Figure 2.1). One problem with metal roofs is that while they prevent the conduction of heat into the building, they trap the heat energy inside the building, allowing for ambient gain. This trapping of the heat energy makes these methods less effective than other types of roofing systems. A better metal-based roof is one
that is combined with a polymeric coating, so it becomes even more efficient and realizes greater energy reduction within the building.

![Figure 2.1 Cooling needs in U.S. climate zone five (MLGW)](image)

Other than roofs, sun exposure on the facades also adds to a building's heat gain. One way to reduce direct radiant gain on exterior walls is found in the form of shading techniques. A common rural method is to use trees and shrubs to block out the sun’s energy from hitting the facades of the building (see Figure 2.2). Surfaces under shade are cooler than those under direct sunlight. Unfortunately because of building heights, using tree shade in urban locations is less effective than their rural counterparts.

The reduction of sunlight hitting the façades is perhaps the most crucial component in decreasing heat gain for tall buildings. Tall buildings have a higher percentage of exposed surface area on the facade than on the roof. These buildings are also subject to light energy hitting their exteriors indirectly by the
light energy reflections off of adjacent buildings. Unfortunately, tall buildings struggle to take advantage of trees. This is because most trees will not reach above their fourth story. Therefore, alternative shading techniques must be implored to reduce the heat gain on the buildings.

Attached sun shading devices are one common method to shade tall buildings. Horizontal overhangs and louvers are most effective on southern orientations (see Figure 2.3 and 2.4). The louver also allows for air circulation near the exterior wall. Air circulation further adds to the effectiveness by reducing ambient heat gain. These louvers can be operational or can remain in a fixed position. Vertical louvers are most effective on eastern and western exposures (see Figure 2.5). These louvers may be fixed, operated manually or controlled automatically with photoelectric controls to adapt to the changing sun angle. Eggcrates combine elements from horizontal and vertical louvers (see
Eggcrates, also referred as brise-soleil, are very efficient for hot climates because of their high shading ratio. One disadvantage of attached sun shading techniques is that it will add to the building’s surface area. The extra surface area allows the possibility for more light energy to be absorbed. Then this light energy can then be conducted into the building without proper insulation. Additional concerns for attached sun shading must be addressed to avoid the energy conduction. These concerns include the connections to the building, the types of material used in the construction and the color of these materials.

A building’s orientation and form are other common methods used to minimize its heat gain. First, for orientation, the building should limit the amount of exposed surfaces during peak solar gain periods. Consulting a region’s sun chart can help determine the most effective orientation and sun shading strategies. For example, a building with glass atriums should avoid placement where a sun chart reveals prolonged sun exposure. In building areas where
intense solar gain can’t be avoided, a double skin can be erected to keep much of the radiant energy off the inner wall. Second, a building’s shape can also have an effect on the building’s heat gain. A square form for instance, is not the optimal shape for a sub-tropical climate. The most efficient building shape in such a climate is a form that is elongated along an east-west axis. Buildings elongated at an east-west axis limit sun exposure on the east/west facades. The least efficient form is a building form that is elongated on the north south axis.
Reflective insulation is another way to reduce radiant heat gain. Reflective insulation resists all three types of heat transfer. They are conduction, convection, and most importantly, radiant heat transfer (see Figure 2.8). The insulation incorporates both insulating and reflective materials. When properly installed, reflective insulation will resist convective currents and provides an excellent barrier against air infiltration from the exterior. The insulation also is an excellent vapor retarder. A unique aspect of reflective insulation, unlike types of traditional thermal insulators, is that it does not absorb moisture. In fact, installed in conjunction with thermal insulations, it can help thermal insulation to stay dryer.

Figure 2.8  temperature difference of reflective insulation and thermal insulation (ESP)
Ambient Gain

Reducing ambient heat gain in the urban heat island involves different strategies and techniques. Ambient heat gain is most adverse in urban areas because this where the temperature is most inflated. Ambient temperature is non-directional and cannot be blocked out using sun shading strategies. The main premise in reducing ambient heat gain is preventing or slowing the conduction of heat from the outside to the inside.

One method of reducing ambient heat gain has been around for hundreds of years. Vines on a building can cool the adjacent exterior through evapotranspiration (see Figure 2.9). Vegetative roofs use the same process to cool the building. Trees and other vegetation cool the air is by absorbing water through their roots and evaporating it through leaf pores (see Figure 2.10). This

Figure 2.9 vines on an existing building (flicker.com)
process uses heat from the air to convert water contained in the vegetation into water vapor. Evapotranspiration alone can result in peak summer temperature reductions of 2°F to 9°F. While this process reduces air temperatures, it does add some moisture to the air. The positive cooling effect of vegetation usually outweighs any undesirable gains in humidity and can be minimized by utilizing the wind to ventilate the building.

A double wall system is another way to cool the exterior façade. A double wall system uses two processes to remove the elevated ambient temperatures. First, the outer wall blocks direct light energy from hitting the inside wall surface. Stopping the direct light energy slows the process of heat transmitting through the inner wall. However, light energy will still hit the outer wall surface and will radiate heat off its surface. The radiation of heat from these surfaces will raise
the ambient temperature. Second, is the process of removing the heat energy for the double wall system. By creating a cavity between the two walls in the double wall system, an air movement process will be formed that works similarly to a chimney. In this process, higher air pressure outside the cavity is drawn in. The pressure forces the air within the cavity up and away from the building (see Figure 2.11).

![Figure 2.11 double wall system venting away ambient heat (author diagram)](image)

Thermal insulation is a traditional method that can reduce the ambient gain on a building. Besides providing thermal comfort for the building occupants, thermal insulation reduces unwanted heat loss or gain and can decrease the energy demands of heating and cooling system. Some insulation materials that can slow the transmission of heat include: cellulose, fiberglass, rock wool,
polystyrene, urethane foam and vermiculite (see Figure 2.12).\textsuperscript{8} Other techniques can be implored to further address the modes of heat transfer, conduction, radiation and convection. The effectiveness of insulation is commonly evaluated by its R-value. However, an R-value does not take into account the local environmental factors or the quality of construction for each building. Construction quality issues include deficient vapor barriers, and problems stemming from draft-proofing.

![Figure 2.12  traditional insulation (Hertalan)](image)

A radiant floor system is a unique way to reduce ambient gain. Energy waves from the sun do not heat up the air, rather energy waves contact solid surfaces and then radiate the energy into the air as the surface heats up. A
radiant floor counteracts this process by circulating cold water through to keep the floor surface cool (see Figure 2.13). The water circulation prevents the ambient temperature from rising because all excess heat energy is circulated out. An example of this process is found in the Hearst Tower in New York (see Figure 2.14). The Hearst Tower has a 1.7 million cubic foot atrium. Normally, this atrium would have required massive amounts of energy to cool the space. However, the atrium’s radiant floor system provides a much more efficient way to keep the space cool. In addition to lowering the ambient temperatures, the inclusion of the radiant floor system in Hearst Tower reduces waste heat that would have been generated by alternative systems.

Figure 2.13 radiant floor system verses typical concrete floor (author sketch)
Waste Heat

Reducing waste heat deals with those strategies that limit the use of mechanical systems that generate heat as a byproduct. The simplest ways to reduce waste heat in hot climates are to limit the need for mechanical lighting and cooling. Lighting and cooling represent over fifty percent of the energy demands in a typical office building in the southeastern United States (see Figure 2.15). The integration of daylighting techniques can help reduce this energy demand. One such daylighting technique is using an architectural element know
as a light shelf. A light shelf allows daylight to penetrate deep into a building’s interior. These shelves are usually horizontal elements that overhang an exterior window. They are placed just above eye level and have a highly reflective upper surface. This surface reflects daylight onto an interior ceiling. The light is then diffused off the ceiling and reduces the need for electrical lighting (see Figure 2.16 and 2.17). Light shelves are commonly made of an extruded aluminum or an aluminum composite panel. The extruded surfaces are usually painted or anodized. High-rise office buildings often use light shelves. Typically the light shelves are found on a building’s southern side where the maximum sunlight is found. In addition to providing interior lighting, light shelves also shade the windows below eye level to help reduce glare. As stated, placement of the light shelf is generally on the exterior since that location is more effective than an interior shelve. However, a combination of exterior and interior shelves can work even better in providing daylighting far into the building.
One recent project, The San Francisco Federal Building, takes the reduction of waste heat to a whole new level (see Figure 2.18). The Federal Building was designed to consume less than half the energy of a typical office tower. One way the building has reduced energy consumption is the implementation of natural ventilation. In doing so, the Federal Building became the first building on the west coast to use no air conditioning in over fifty years. In addition, The building further reduces energy consumption by featuring elevators that stop only on every third floor. Building occupants exit elevators
and then either walk up or down one flight of stairs. There is, however, one
elevator which stops on every floor for those unable or unwilling to navigate
stairs. Unfortunately, the Federal Building has been criticized as being
dysfunctional for its employees. According to an employee interviewed by
BeyondChron.com, "Workers seek to relieve the heat by opening windows, which
not only sends papers flying, but, depending on their proximity to the opening,
makes creating a stable temperature for all workers near impossible... some
employees must use umbrellas to keep the sun out of their cubicles."  

![San Francisco Federal Building (San Francisco Chronicle)](image)

Conclusion

There are many design strategies a new building can adopt to reduce its
susceptibility and contribution to the urban heat island. Depending on the
climate, some strategies outlined may be more or less effective. It is important to
identify the unique characteristics of a site to determine what strategies will work
the best. When this is done and is combined with a thorough design process, reduction of the urban heat island may be possible.
CHAPTER 3 – URBAN FORESTS

Introduction

An urban forest is a collection of trees, shrubs and grasses that grow within a city, town or suburb. The urban forest can comprise of just a few trees and other smaller vegetation like that within a roof garden or can be comprised of several square miles like that of Central Park in New York. Regardless of the size, an urban forest plays a key role in the ecology of human habitats. The urban forest filters the air, water and sunlight, and provides relief to the inhabitants during hot or inclement weather. The urban forest moderates local climates by slowing wind and stormwater, and shades buildings, which in turn can provide an energy savings. Such forests are also critical in mitigating the urban heat island effect and can lower the level of unhealthy ozone that plague cities during the summer months. This chapter analyzes the recent study of Tampa’s urban forest and highlights the reasons why such a forest is an important part of the city’s landscape.
Benefits

There are many benefits in having an urban forest. Perhaps the most appealing of these is urban beautification. The presence of trees has been shown to reduce stress and has long been seen to benefit the health of urban dwellers. The shaded areas provided by the urban forest and other green spaces, create places for people to socialize and play. Trees also provide nesting sites and food for birds and other animals. People appreciate watching, feeding, photographing, painting urban trees, and wildlife. Urban trees and wildlife help people maintain their connection with nature.

Another benefit to the urban forest is energy conservation. Trees near a building can provide shade during the day, which in turn reduces energy needs to cool the building during the summer. Depending on the species of tree and the latitude of the location, energy consumption can be raised or lowered during the winter months. In addition to blocking out light energy, a forest canopy can also act as a windbreak. The windbreak can further reduce heat loss during the winter. In the *City of Tampa Urban Ecological Analysis* (CTUEA), an experiment was done to find out the amount of energy conserved by tree shade. The trees in the experiment were twenty feet tall and were less than sixty feet from the observed building\(^{15}\). The CTUEA found that Tampa’s current tree canopy saves nearly 35,000 megawatt hours of electricity per year (see Table 3.1). In monetary terms, the reduction in energy consumption was worth just under four million dollars.
Removal of air pollution is another valuable asset of the urban canopy. Excess air pollutants can create smog and lead to adverse health issues. Some of these pollutants include: carbon monoxide, nitrogen dioxide, ground level ozone, sulfur dioxide and particle matter. Nitrogen dioxide is also a respiratory irritant and can cause a series of health problems. Nitrogen dioxide is an ingredient for the formation of low level ozone as well. As stated in Chapter 1, ozone can cause a variety of health issues as well lead to smog. Trees within a city can cleanse the air of these and other pollutants. A computer model for the CTUEA estimated that Tampa’s tree and shrub population removed 1,360 tons of air pollution in 2007. Further analysis suggests that if artificial ways would have been used to cleanse the same tonnage of pollutants, the cost would have been well over six million dollars (see Table 3.2).

<table>
<thead>
<tr>
<th>Energy Conserved</th>
<th>Heating</th>
<th>Cooling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBtu(^a)</td>
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<td>n/a</td>
<td>2,994</td>
</tr>
<tr>
<td>MWh(^b)</td>
<td>106</td>
<td>34,637</td>
<td>34,743</td>
</tr>
<tr>
<td>Carbon avoided</td>
<td>68</td>
<td>6,117</td>
<td>6,185</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>US Dollars Saved</th>
<th>Heating</th>
<th>Cooling</th>
<th>Total</th>
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<tbody>
<tr>
<td>MBtu</td>
<td>$100,479</td>
<td>n/a</td>
<td>$100,479</td>
</tr>
<tr>
<td>MWh</td>
<td>$12,141</td>
<td>$3,967,322</td>
<td>$3,979,463</td>
</tr>
<tr>
<td>Carbon avoided</td>
<td>$1,389</td>
<td>$124,292</td>
<td>$125,681</td>
</tr>
</tbody>
</table>

\(^{a}\) Million British Thermal Unit  
\(^{b}\) Megawatt-hour

Table 3.1 energy conserved and associated dollar value in 2007 (CTUEA)
Table 3.2 pollutants removed by shrubs and trees (CTUEA)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>English (short) tons</th>
<th>US Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td></td>
<td></td>
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<tr>
<td>CO</td>
<td>66</td>
<td>$57,367</td>
</tr>
<tr>
<td>NO₂</td>
<td>52</td>
<td>$318,661</td>
</tr>
<tr>
<td>O₃</td>
<td>456</td>
<td>$2,796,010</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>209</td>
<td>$855,141</td>
</tr>
<tr>
<td>SO₂</td>
<td>111</td>
<td>$165,773</td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>32</td>
<td>$27,570</td>
</tr>
<tr>
<td>NO₂</td>
<td>27</td>
<td>$167,738</td>
</tr>
<tr>
<td>O₃</td>
<td>236</td>
<td>$1,446,730</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>115</td>
<td>$469,239</td>
</tr>
<tr>
<td>SO₂</td>
<td>56</td>
<td>$84,366</td>
</tr>
<tr>
<td>Total</td>
<td>1360</td>
<td>$6,388,595</td>
</tr>
</tbody>
</table>

Finally, a tree canopy can store and sequester carbon. Carbon dioxide, a greenhouse gas, is used by trees in the process of photosynthesis. As trees grow they incorporate atmospheric carbon into their tissue and store it for life. The removal of carbon from the atmosphere is important because excess carbon dioxide can have a global effect on the earth’s temperature. The CTUEA did a study on the carbon removed from the atmosphere by Tampa’s trees (see Figure 3.1 and 3.2). The study also determined the amount of carbon that Tampa’s urban forest holds, the amount of carbon it sequesters each year, and the monetary value of removing the same amount of carbon using artificial methods (see Table 3.3).
Figure 3.1 Tampa's carbon storage in the tree canopy (CTUEA)

Figure 3.2 Tampa's annual carbon sequestered in the tree canopy (CTUEA)

Table 3.3 Total value of Tampa's urban forest (CTUEA)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Trees</td>
<td>7,817,408</td>
</tr>
<tr>
<td>Tree Cover</td>
<td>28.1%</td>
</tr>
<tr>
<td>Pollution Removal</td>
<td>1,360 tons/year ($6.3 million/year)</td>
</tr>
<tr>
<td>Carbon Storage</td>
<td>511,141 tons ($10,386,389)</td>
</tr>
<tr>
<td>Gross Carbon Sequestration</td>
<td>46,525 tons/year ($945,396/year)</td>
</tr>
<tr>
<td>Compensatory Value</td>
<td>$1,465,600,097</td>
</tr>
<tr>
<td>Value of Energy Conservation</td>
<td>$4,205,623</td>
</tr>
</tbody>
</table>
Distribution

For the urban forest, it is important that the canopy be evenly spread out. An even distribution will lessen the chance stagnant pockets forming. Unfortunately, some locations within cities are lacking in tree and shrub canopy coverage. For instance, the tree coverage in a typical downtown location is lacking because economic factors have forced the roads and buildings closer together. The result is that downtown buildings will occupy a higher percentage of the land over the less dense rural areas. The CTUEA shows that Tampa follows this pattern (see Figure 3.3). The small canopy coverage makes downtown Tampa very susceptible to air pollution generation and stagnation. City wide, Tampa’s canopy coverage is twenty-nine percent. Downtown was found to be at only five percent. Other areas with similarly low canopy coverage were the airports in West Tampa and South Tampa along with various industrial zones. On the other end of the spectrum, areas along the river and bay usually had higher canopy coverage. Although the CTUEA does not indicate an optimal level of canopy coverage, maximization of the tree canopy coverage has quantifiable benefits where as leaving areas barren or underutilized is unsatisfactory.
Figure 3.3 Hillsborough county map of tree canopy coverage (CTUEA)
Roof garden

One important building application of the urban forest is the green roof. A green roof is a building roof that is partially or completely covered by vegetation and soil over a waterproof membrane. In general, green roofs consist of grasses and other small shrubs but may also have trees as. In addition to providing an aesthetic ambiance, green roofs have also been found to dramatically improve a roof's insulation value. As stated in chapter two, an additional important quality of the green roof is the lowering of the ambient temperature through the process of evapotranspiration. A third positive aspect of the green roof is the ability to reduce stormwater run-off. Unfortunately, use of the green roof has found slow adoption within the United States due to added costs of maintenance and structural requirements. However, when planned properly in the design phase, the added costs can often be offset by a building that will have a reduced energy demand.

Conclusion

The value of the urban forest is more than just in beauty, it protects people’s health, conserves energy and saves money. Unfortunately, this protection is limited for the city because of overdevelopment and underutilization. This has caused many city areas to have either low canopy coverage or none at all. It is important that, regardless how developed an area becomes, the location
should always perverse trees and shrubs where possible. In addition, designers and planners should consider the adaptation of green roofs early in the schematic phase as an additional means to attain the benefits of the urban forest.
CHAPTER 4 – ENERGY SAVING SYSTEMS

Introduction

The energy saving systems in a building play an important role in the heat island effect by limiting waste heat production. Waste heat reduction will lower the ambient heat of an area because less heat is generated through artificial means. Energy saving systems can take on many forms. Some are moderately small devices located in a mechanical room, like an air-to-air enthalpy wheel. While others can be a large architectural feature of a building like a double wall system. Regardless of their size and features, energy saving systems will ultimately reduce the energy consumption of a building, thus reducing waste heat.

Double Wall Systems

Double walls, or cavity walls, have been created for two main purposes. One is to provide the building natural lighting control with maximum transparency, while the other is to reduce the heating or cooling load by lowering the U-value beyond what a single wall could do alone. In essence, they create
an additional thermal buffer. Depending on the climate, the features and purposes of a double wall systems differ. For instance, in cool and cold climates, the double wall cavity is often not vented and heat is trapped and transmitted to the interior. Conversely, double walls in hot climates will require the air cavity to be vented and the moisture level controlled. The vents in this system are typically located in the spandrel between the floor and ceiling below (see Figure 4.1). The use of a double wall system has long been popular in Europe, but has found limited use within the United States due to less strict efficiency codes

![Diagram of a typical double wall system](image)

Figure 4.1  typical double wall (Katz)

The United States does, however, have a few existing projects utilizing the double wall. One such project is the Seattle Justice Center (SJC). This building has a large section of the west façade using a double skin that is naturally ventilated. The double skin is composed of two separate planes of glass spaced
30 inches apart. This system allows for the penetration of light into the interior space but limits interior heat gain. The reduction of heat gain allows the building to reduce its heating and cooling needs, in turn reducing waste heat. Interior light shelves are used in conjunction with the double wall system in an effort to both reduce the direct heat gain and filter in natural light. In addition, the double wall system at the Seattle Justice Center utilizes automatically controlled louvers at the roof level to release or retain the heat. During the winter months these louvers are closed, and during the summer they are open (see Figure 4.2 - 4.4).
Another project within the United States to use a double wall system is the New York Times Building. The unique feature on the Times façade is the ceramic-rod screen system (see Figure 4.5). The ceramic-rod screen is placed one and a half feet in front of the interior glass curtain wall. These rods block direct radiant gain but also serve as a convex light shelf. Perhaps the most intriguing fact of the rods, is that they are spectrum selective. The rods will only reflect in the cool color spectrum, thus reducing cooling needs even further. Other features of the Times Building include the use of fully glazed low-e glass, mechanical shades controlled by sensors to reduce glare, and more than 18,000 individually-dimmable fluorescent fixtures to supplement natural light. On top of the environmental gains the ceramic-rod screen provides, the screen changes color throughout the day and is dependent on the weather. This offers an appealing aesthetic quality.

Figure 4.5 New York Times Building’s ceramic-rod screen (Science-Beat)
Energy Recovery Systems

An energy recovery system is a mechanical system that exchanges the embodied energy contained within a regular building exhaust with the incoming outdoor air. The main benefit of these systems is the ability of a building to meet construction efficiency standards, improve indoor air quality and reduce the total HVAC capacity. There are two main types of energy recovery systems. First is the Heat Recovery Ventilator (HRV). HRV’s are limited to only transferring sensible heat. Sensible heat is defined as potential energy in the form of thermal energy or heat. Beside just transferring heat to save on energy needs, HRV’s provide fresh air and improve climate control. Common types of HRV’s include heat pipes, rotary heat exchanger and a cross-flow heat exchanger. A unique, but less common example is an earth to air HRV (see Figure 4.6). Earth to air heat exchangers use air cooled underground air rather than regular outside air.

Figure 4.6  earth to air HRV
One advantage of this method is the fact that the air underground remains at a fairly constant temperature.

The second type of energy recovery system is energy recovery ventilators (ERV). ERV’s get their inherent value by being able to transfer both sensible heat and latent heat. The transfer of latent heat entails the ability to transfer energy during a phase transition. For example, the transfer of energy as water transforms from a gas to a liquid. Two types of ERV’s include fixed plates and rotary enthalpy wheels. The rotary enthalpy wheel is a circular heat exchanger which operates on the air-to-air process of heat transfer (see Figure 4.7). It provides an excellent way of recovering energy embodied in conditioned air for hot, humid climates. The process begins with cool and dry exhaust air entering one side of the revolving enthalpy wheel. This chills and dries the wheel’s desiccant coating. The cool and dry part of the wheel then turn into the supply air where it absorbs heat and humidity from the incoming fresh air before

Figure 4.7 rotary enthalpy wheel (Xetex)
the air is mechanically cooled to room temperature. The rotary enthalpy wheel can reduce the air-conditioning load by nearly ninety percent. The lower load capacity will save energy and reduce the size of the required HVAC equipment.

Conclusion

Knowing the types and complexities of varied energy saving systems is crucial for contemporary building design. Significant growth in this field has occurred in the past decade and future breakthroughs are surely on the way. It important to constantly review new techniques and strategies to find out what direction would be most appropriate considering a building's location and climate.
CHAPTER 5 – SITE SELECTON

Introduction

Reducing a building’s heat gain requires a unique set of strategies when addressing the heat island effect in sub-tropical urban areas. Currently, there are many strategies when dealing with the heat island effect. However, there are few examples that apply these current strategies to the urban cores within sub-tropical regions. Many of the traditional strategies that combat the heat island effect do not work well, or at all, in sub-tropical urban cores. A proper site within the sub-tropical urban core must be identified so a strategy may then be developed to best address the heat gain problem.

Reverse Site Analysis

There are many elements involved in choosing a suitable site for this project. The site needs to be in a sub-tropical area and within a dense urban core of a large city. The site’s location should be unable to take advantage of methods used in rural sites and should also have additional adverse conditions that make its location even more gravely affected by the heat island effect.
Selection Criteria

Taking the pervious factors into account, one such site comprising of all of these requirements would be in downtown Tampa. More specifically, a vacant lot on the corner of Franklin Street and Zack Street in the downtown area, which presently is ready to be redeveloped. As stated, the subject of this project deals with the heat island effect in sub-tropical urban areas. The general distinctions of sub-tropical climates entail warm, humid and wet conditions. According to the Koppen Climate Classification, sub-tropical areas in the northern hemisphere lie roughly between latitudes 40° and 25° North and South (see Figure 5.1). The temperature of the climate is between 30°F and 64°F in the winter, and the warmest month is to be above 72°F. For precipitation, the summer months get at least 1.5 inches per month, while the winter months will get approximately one tenth of the precipitation during the wettest months. Major U.S. metropolitan areas like Atlanta, GA; Houston, TX; Charlotte, NC; and Tampa, FL all share these characteristics (see Figure 5.2 and 5.3). The second important
Figure 5.2  Tampa's temperature range (rssWeather.com)

Figure 5.3  Tampa's precipitation range (rssWeather.com)
requirement is a site within of a dense urban core. The city of Tampa meets this requirement. According the U.S. Census Bureau, the Tampa, St. Petersburg and Clearwater metropolitan area ranks as the nineteenth largest metro in the U.S., with 2.7 million people in 2007.\textsuperscript{22} In addition, the city of Tampa has a dense urban core. Tampa’s Central Business District is centered over the intersection of Franklin Street and Kennedy Boulevard.

The corner of Franklin Street and Zack Street for this project also has a many disadvantages over other sites. The site is small and expensive. These characteristics will require any future construction to be high density in nature. In addition, the site is flat and surrounded on all four sides by asphalt paved streets (see Figure 5.4). Finally, because of the tall buildings, this site will suffer from the canyon effect. The canyon effect leads to an increase in temperature due to light energy bouncing off many building facades, allowing the light energy more time to be absorbed by the surrounding environment. The combination of all these factors is why 610 N. Franklin Street is an acceptable selection.

Figure 5.4 downtown Tampa (image modified from Google Earth)
CHAPTER 6 – SITE ANALYSIS

General

As stated, the building site is located in downtown Tampa. The surrounding neighborhoods include the University of Tampa and Hyde Park to the west and southwest. Located to the north is Tampa Heights and to the east is Ybor City. The Channelside District is situated to the southeast and to the south are Davis and Habour Islands (see Figure 6.1). Focusing in towards the site location, the downtown area is broken into many districts. The site is currently located in downtown Tampa’s Franklin Street District (see Figure 6.2). The Franklin Street District includes a major retail corridor and has the highest concentration of office towers in the area. Focusing further, the site is bounded by four streets; Zack Street to the north, Franklin Street to the east, Twiggs Street to the south, and Tampa Street to the west (see Figure 6.3). Both Tampa Street and Zack Street are one-way streets, while Twiggs Street and Franklin Street are two way streets. Similar to other downtown blocks, the dimensions are 210 feet by 210 feet.
Figure 6.1 satellite photo of downtown Tampa and surrounding neighborhoods (Google Earth)

Figure 6.2 district map of downtown Tampa (image modified from Municode)
Figure 6.3  street boundaries and showing in blue the location of 610 N. Franklin Street. (image modified from Google Earth)

Climate

Knowledge of a site’s climate is a critical element to take into account when developing a project. The city of Tampa is no exception and has a variety of important factors to consider. Tampa’s average high temperature ranges from 52°F in January to 90°F in July (see Figure 5.2). Tampa’s precipitation is stable throughout the spring, fall and winter months, averaging from one and half inches to three inches per month (see Figure 5.3). The summer contains by far, the wettest months. Summer rainfall periods are normally short on a day to day basis, but this rainfall is usually intense. Sunshine rates are stable the
throughout year, hovering between seventy five and sixty percent (see Figure 6.4). The solar orientation is another major factor. Tampa is located at approximately 28° north latitude. The low latitude makes Tampa susceptible to near 90° sun angles during the summer months, but yet the sun angle won’t reach 40° during a few days of the winter months (see Figure 6.5). As for prevailing winds, there are a couple of factors at work. First, during the morning, the land heats up quickly. This rise in temperature causes atmospheric pressures to lower, thus allowing the cool ocean air to move inland. This is known as an on-shore breeze. During the night however, the roles are reversed. The ocean will be warmer and will have a resulting off-shore breeze. The second component of the prevailing winds is the a jet stream. During the winter, the jet stream is far enough south to cause most
days to have prevailing winds blowing in from the west to the southwest.

However, the jet stream during the summer moves far to the north, and Tampa will be affected by a tropical flow which runs east to west. The result of the jet stream moving north allows light easterly winds to run west across Florida towards the Gulf Coast and the city of Tampa. Also, an on-shore breeze comes from the west during the day moves east. The collision of these two wind sources causes a convergence where they meet. Rain clouds will then form. This is why it rains nearly every day in Tampa during the summer (see Figure 6.6).
Other concerns include severe weather and tropical cyclones. Florida is the thunderstorm capital of the world.\textsuperscript{23} The "lightning belt" in Florida is an area that extends west from Orlando to Tampa, then south along the west coast to Fort Myers and east to Lake Okeechobee. Thunderstorms are attributed to hot, wet air close to the ground combined with an unstable atmosphere. Often the resulting thunderstorms occur during afternoons, predominantly from June through September. These storms can be as brief as a few minutes or as long as a couple of hours. Lightning is the state's leading cause of weather-related deaths, and Florida has the distinction of having the nation's worst record of deaths by lightning.\textsuperscript{24} Finally, although it has been more than forty years since Tampa has been struck directly by a hurricane, the potential risk for such a storm always exists.
Knowing the climate conditions of a particular site is an important design consideration. Different weather phenomena can cause buildings to be less effective or even fail if the building is built for the wrong set of conditions. Given Tampa’s climate, this project will need to take measure to block direct radiant gain and shed water effectively, among other things.

Surrounding Influences

The most prevalent surrounding influences deal with the adjacent zoning and building uses (see Figure 6.7). The site is surrounded almost entirely by developed property. Perhaps the most thorough development is along Franklin Street. Franklin Street has numerous small retail shops and small restaurants. One specific location along Franklin, the intersection with Zack Street, has two plazas carving out the northwest and southeast corners. This creates a very pleasurable experience for those relaxing outside (see Figure 6.8 and 6.9). Along Twiggs Street, as with Franklin Street, many small cafes and shops dominate the street frontage (see Figure 6.10). Perhaps the most intimate location along the Twiggs block is the Franklin and Twiggs intersection. On the south side of this intersection, the street is closed to vehicular traffic. This allows the two cafes on this intersection to engage the street (see Figure 6.11) In addition to the cafes, this intersection also has a historic building on northeast side, called The Franklin Exchange (see Figure 6.12). On north side of the site, Zack Street represents a developing block. Future growth should be expected as
vacant retail under a new tower completed in 2007, called SkyPoint, has yet to be occupied (see Figure 6.13). In addition, a parking lot is for sale along Zack Street and the property is zoned for retail at the ground level. Besides the future development, two banks are located along Zack Street in the adjacent blocks. Usage along Tampa Street is the least developed. This may be due to the fact that the street is one way and that vehicles speed down this street (see Figure 6.14 and 6.15). Although not adjacent this site, further south along Tampa Street, more shops and cafes can be found.

Figure 6.7 ground level usage (image modified from Google Earth)
Figure 6.8 plaza on corner of Franklin Street and Zack Street (author photo)

Figure 6.9 Franklin Exchange Plaza (author photo)
Figure 6.10  Twiggs Street shops and cafes (author photo)

Figure 6.11  Franklin-Twiggs intersection looking south (author photo)
Figure 6.12  Franklin Exchange (author photo)

Figure 6.13  vacant retail under Skypoint at Zack Street and Tampa Street intersection (author photo)
Figure 6.14  lack of development on Tampa Street (author photo)

Figure 6.15  lack of development on Tampa Street (author photo)
Access

Surrounded by streets and public sidewalks on all four boundaries the building will be able to be accessed from any side. The most common way people will arrive to this location, will be by car. Noting that both Zack Street and Tampa Street have one-way vehicular traffic, and that Franklin Street prohibits vehicles south of Twiggs Street, only a few appropriate locations exist for the parking ramp into the project (see Figure (6.3)). This parking ramp will have to accommodate both the entering and exiting of vehicles without causing traffic congestion on the streets.

Mass transit access to the project site is fairly limited. The Purple Line does have a trolley stop on the west side of the site, but those using buses will have to walk a couple of blocks to get to the project (see Figure 6.16).
Bike lanes and pedestrian right-of-ways are the remaining ways to access the site. A bike route runs along Tampa Street and public sidewalks surround the site. As stated, Franklin Street south of Twiggs is closed to vehicles. Although hindering vehicular movement, this closure results in a strengthened connection of the pedestrian right-of-way along Franklin Street.

Zoning Regulations

Tampa’s city codes are the most extensive and complex in its central business district. Below is a listing of some of the most impactful codes that will be of great concern for this project.25

1. This district will contain compact, mixed-use development.

2. Structures shall be compatible with any significant natural, historic or architectural resources in proximity to the project site. Examples of ways to achieve compatibility include design features such as height-to-setback ratios or stepped or graduated building faces.

3. All buildings with a height in excess of one hundred (100) feet shall be equipped with a fire control system approved by the city fire department.

4. Developments in the Central Business District (CDB) that propose a redevelopment of an entire city block (excluding waterfront developments) under one (1) unified plan shall provide a minimum five-foot average building setback on all sides. The purpose of the
averaged setback is to accommodate widened, pedestrian-oriented sidewalks and more functional open public space. The area created by the required building setback may be counted towards the open public space requirement as required and defined by this article.

5. The design of the parking structure and/or the design of the facades of parking structures which are incorporated in the building footprint, or which extend from the principal building component, shall be architecturally integrated.

6. The design of the parking structure must conceal vehicles from grade-level views.

7. The design of the parking structure must utilize landscaping elements or other design features to soften the appearance of the exterior facade.

8. All service and loading areas shall be effectively screened from pedestrian view.

9. The on-site parking requirement is one car per one thousand square feet of office space.

10. A major entry must be located along all retail that boarders the Franklin Street edge.

11. All uses along the Franklin Street frontage shall contribute to the active pedestrian character of the corridor and shall include retail, personal services, and public facilities.
12. A minimum depth of twenty (20) feet, as measured from the building line along the entire Franklin Street frontage, shall be provided for these uses.

13. All spaces fronting on Franklin Street shall locate a major entrance onto Franklin Street.

14. All spaces fronting on Franklin Street (and where feasible in major renovations) shall be visible from Franklin Street by devoting not less than fifty (50) percent of the ground level facade plane to transparent material.

15. The design of all new structures shall maintain at least eighty (80) percent of the building line at the property line along Franklin Street.

16. Ground floor parking which fronts on Franklin Street in parking garages is prohibited along Franklin Street.
CHAPTER 7 – OFFICE BUILDINGS WITH SELF CONTAINED PARKING

Introduction

One of the key aspects of this project is choosing a site with no special advantages concerning the urban heat island. For that reason a small site in middle of a downtown Tampa has been chosen. In addition, with consideration of economic factors, the project will need to be high density in nature and have self-contained parking within the building. Proper attention must be paid on how a building with these components functions. This chapter will examine these types of buildings and it hopefully will show how design strategies for the heat island can be incorporated into this typical office building. The analysis conducted, focuses on three buildings in downtown Tampa. These buildings are: 501 Kennedy Boulevard, The Franklin Exchange and Park Tower

Parking

One of the biggest issues with downtown office building, especially in Tampa, is parking. Parking can determine whether a project succeeds or fails. Currently Tampa’s downtown minimum parking spaces per office square footage
is one space per thousand square feet. However, the minimum amount is far below what tenants expect if they are to lease downtown office space. Of the buildings analyzed, the parking spaces per office square foot was close to the minimum. Park Tower has just over one per thousand square feet. 501 Kennedy has 1.3 parking spaces per thousand square feet. Finally, the Franklin Exchange has roughly 1.5 spaces per thousand square feet. The building managers, Michelle Cummings of 501 Kennedy and Mary Ayo of Park Tower, both expressed problems in securing tenants due to limited parking. They lose many tenants to Tampa's Westshore District because that landlords in that district can offer all the parking the tenants need. Both Cummings and Ayo feel that any new building in downtown Tampa should at least try and achieve a 1.5 parking spaces per thousand square feet of office space. Anything less might be an unsuccessful venture.

Another issue with parking downtown is where to locate parking within the program of the building. All three buildings analyzed had parking begin on either the second or third floor and was stacked together above that. In some instances, the parking levels were also partially sectioned off to provide room for mechanical space. For example, Park Tower’s fifth and sixth parking floors where partially occupied by the HVAC equipment. In general, a parking level comprising an entire downtown Tampa block can achieve around 100-130 parking spaces. This is the case for both 501 Kennedy and Park Tower. The Franklin Exchange however, achieves around seventy spaces per floor with
parking level taking up nearly half the block. Refer to figures 7.1-7.3 for the parking layouts of each of these towers.

Figure 7.1 501 Kennedy Boulevard. parking is shown in grey, office space in red, retail in orange and mechanical in light blue. (author diagram)

Figure 7.2 The Franklin Exchange. parking is shown in grey, office space in red, retail in orange and mechanical in light blue. (author diagram)
Figure 7.3 Park Tower. parking is shown in grey, office space in red, retail in orange, mechanical in light blue, restrooms in blue and elevator lobbies in dark grey. (author diagram)

The parking entry is another concern. Since parking is located above the ground floor, the building must provide a ramp to take vehicles up as soon as possible. Doing so will prevent wasting valuable ground floor space. This is the case for all three of the analyzed buildings. However, there are slight differences. The Franklin Exchange for instance, is the only building of the three
that has a separate entry and exit for its parking garage. The 501 Kennedy building has a ramp that runs through the center of the building all the way to the third level. And, Park Tower’s entry condition is unique because it is very unpronounced from its location on Tampa Street (see Figure 7.4).

Finally, is the issue concerning the parking’s architectural integration into the building as a whole. All buildings along the Franklin Street must adhere to the Tampa Central Business District Urban Design Guidelines. These guidelines state that the exterior façade of parking levels along Franklin Street must be architecturally integrated. The code also requires landscaping features or other design elements to soften the appearance. One example of this is at Tampa’s new condominium SkyPoint (see Figure 7.5).

Figure 7.4 parking entry and exit to Park Tower (author photo)
Figure 7.5  design elements on SkyPoint’s parking garage (author photo)

Building Core and Leasable Office Space

Another important issue concerning this type of office building is the building core. It is important that the building core be situated in a way that allows for maximum flexibility for the office floors. A speculative office building needs to maximize leasable office space while minimizing its core functions. There should also be few interior obstructions. Both the 501 Kennedy and Park Tower have bay sizes around thirty feet by thirty feet. The main goal, however, is to was the maximization its office space square feet ratio to core square feet. A high office space to core ratio can be achieved if the vertical circulation and
mechanical system can be centrally located. Grouping these functions centrally in a core is common for tall buildings. Not only will the core serve as the building’s vertical circulation and mechanical spaces, the building core can also act as a resistance to wind and other structural loads. Park Tower houses both of its elevator banks, two stairwells, restrooms and the mechanical rooms in this core (see Figure 7.6). As Park Tower continues up, one bank of elevators discontinues on the twenty-fifth floor (see Figure 7.3). At this level, Park Tower’s floor plan changes. The restrooms and mechanical room have are relocated over the elevator shafts and elevator bay below. The room adjustment opens up additional office space for the tower’s upper floors. All together, Park Tower’s twenty-eight floors of office space average over 14,000 square feet per floor for a

Figure 7.6  Park Tower’s fourteenth floor. cyan is office space, red is elevators, blue is restrooms, grey is stairs, magenta is non office corridors, white is service (provided by Mary Ayo)
total 500,000 square feet of leasable office space. Each office level of the tower has roughly eighty-two percent of the square footage dedicated to the office space.

The building core functions and layout for 501 Kennedy is slightly different. Perhaps the biggest difference that affects the core is in the design and location of the mechanical space at the top floor. 501 Kennedy, unlike Park Tower has its air handler on this floor. This location allows each floor to be less consumed by air handler rooms. 501 Kennedy has a 5 foot chase for all of the mechanical piping (see Figure 7.7). Another slight difference is the way 501 Kennedy leases office space. The shared hallways in Park Tower are considered leasable, whereas in 501 Kennedy they are not. The shared hallway square footage in the Colonial is divided among the tenants that share that particular floor.

![Diagram of 501 Kennedy office floors](image)

**Figure 7.7 501 Kennedy various office floors (author diagram)**
Ground Level Program

The final key component of these office buildings was the program at the ground level. First, 501 Kennedy has a small “back of house” consisting of a security room, trash room, mail room, and fire control room. Two stairwells from the core make their way out to the street via fire-rated corridors. The program also includes a lobby with an adjacent elevator bay and information deck. A unique vehicular path runs thru the building, and also functions as a porte cochere (see Figure 7.8). Adjacent to the vehicular passage is the parking entry and the ramp. This ramp continues all the way up to the third floor. The rest of the program is then dedicated to retail space.

Figure 7.8  porte cochere at 501 Kennedy Boulevard (author photo)
Second, Park Tower’s is similar in its first floor program. Retail makes up the largest component of first floor. A lobby and large interior hallway slices thru the center of the building. The core consists of mechanical space, two elevator shaftways and two stairwells. Adjacent to the core is the information desk, which overlooks both elevator lobbies. A loading dock is located on the first floor within the building and has adjacent maintenance rooms and a security room.

Third, The Franklin Exchange is quite a bit different from these two. Only a small portion of its first floor is taken up by retail space (see Figure 7.9). Only the southeast corner is usable for retail or office space. The rest of the first floor is taken up by the typical stairs, lobby and elevator shafts. The main culprit in the loss of retail space is the mechanical room being located on the ground level.

Figure 7.9  The Franklin Exchange ground level (author diagram)
Designing a building that succeeds in combating the urban heat island but fails in providing a functional program is a failed building. Current buildings in downtown Tampa show, the basic steps in achieving a functional program. The buildings detailed were in many cases using similar strategies when formulating the vertical and office program. Using the ideas garnered here, it will help to anchor basic design concepts and layouts for a new building.
CHAPTER 8 - PROGRAM

Introduction

A project within Tampa’s urban core presents a unique programming challenge. Buildings located in the downtown area should seamlessly blend a variety of functions within a constrained area. In addition, many local codes restrict the functions at the ground or street level. By these codes, the ground level perimeters should be pedestrian friendly and have easy access for all building users. Likewise, service functions should also be easily accessed by utility personnel. Parking restrictions also affect programming decisions. Buildings in the downtown cores require nearby or onsite parking in order for the buildings to be successful. Buildings in the urban core are among the most challenging buildings to program due to the afore mentioned factors.

Goal and Objectives

The prime program goal for this project is to house and integrate the unique characteristics of three different building use types, while minimizing the heat gain on the building’s exterior and roof. The three primary usage types are
office, retail and a parking structure. In accordance with other buildings in downtown Tampa, the best way to layout these unique functions is to place retail at the base, parking above the retail levels and office space in a tower (see Figure 7.1 - 7.3 and 8.1). Secondary program goals include a vibrant pedestrian street level environment and a rooftop terrace with an adjoining restaurant. These goals meet the city’s vision of downtown Tampa. To accomplish this, the building must contain several features. Due to being adjacent to the pedestrian mall along Franklin Street, retail will play an important role on the east side of the building. Franklin Street is an important retail artery in the downtown area and enjoys a unique blend of retail shops and restaurants, both south and north of the project site. Although parking along Franklin Street is limited for the retail, the street has become a very pedestrian friendly corridor as the speed limit is reduced and traffic is prohibited in some locations just south of the site.

Figure 8.1  vertical program layout of a typical downtown office building (author diagram)
Cultural Issues

A special issue regarding the project is the adjacent location of the city's Cultural Arts District. The Cultural Arts District encompasses the main Tampa Public Library and the Tampa Bay Performing Arts Center. In addition, the Tampa Art Museum and Children’s Museum are currently under construction (see Figure 8.2). These nearby features should give the project a unique identity and cultural significance. In addition to the cultural buildings, the downtown area also places an emphasis on Franklin Street as a cultural corridor. As stated, Franklin Street is a very pedestrian friendly. The street has unique signage, places to sit, landscaping features and special lighting. However, these features remain underdeveloped at the project site and represent a void in Franklin Street’s overall makeup. Zack Street, which is the northern boundary of the site, has a growing cultural importance. Zack Street connects the Tampa Theater to the two museums under construction and to the waterfront as well. Zack Street runs east west and intersects Franklin Street. The cultural importance of Zack Street has been steadily growing and the street will become ever important once the Children’s Museum and Tampa Art Museum are completed.
Figure 8.2  cultural features (image edited from Municode)
Public Transportation

Currently only one public transportation line has adjacent access to the project site. The In-Town Trolley’s Purple Line has a stop on Tampa Street (see Figure 8.3). The Purple Line’s main source of pedestrian usage comes from Harbour Island to the south. Those living at Habour Island and using the Purple Line would exit the trolley onto Florida Avenue in the morning and enter back on the trolley from Tampa Street in the evening. An additional source of public transportation may originate from the Marion Transit Center located just north of the downtown area. Those using this center can then either take the Purple Line or the Marion Street Transit Parkway. The building program’s exterior accessibility should reflect these public transportation methods.

Parking

Parking for the 610 Franklin Street Building is another major issue. As with other office buildings in the downtown area, parking must be located near the site or on the site. For this project, parking will need to be located on-site for this location as no adjacent public parking lots currently exist (see Figure 8.3). For this reason, attention should be placed on developing a well integrated parking garage within the building.
Vehicular Functions

In addition to the program location of the parking, other vehicular issues will need to be addressed. Perhaps most crucial is the amount of parking needed. Currently the code requires there to be one parking spot per one thousand square feet of net office space. These spots are then generally given to the leasee based on the total of square footage leased. Visitor parking, as with most downtown buildings, should be located on the streets and in public parking garages within the downtown area. Since no nearby public garages
exist, the project may need to include additional on-site parking for the retail establishments to be successful. In addition, if a rooftop restaurant is located within the project, it will also require additional parking. As for service vehicles, a single loading bay may be appropriate. Both Park Tower and 501 Kennedy have a loading bay at the grade level. Both of these loading bays were separated from the private parking ramp entrance.

Time Use (Daily, Weekly and Annual Cycles)

The 610 Franklin Street Building should have full access to the building lobby during the normal business day. Employees, customers and deliveries will be very frequent throughout the day. In particular, the morning rush, noontime and evening rush will experience increased traffic flow. Areas where pedestrian traffic intersects, design considering will need to be taken so that proper egress and life safety requirements have been accounted for. Areas where pedestrians can linger should be provided with seating and focal points where people can easily gather. The retail space along the street will experience its most pedestrian traffic during the noontime rush. Since the daytime heating is most prevalent during this time, the retail area should be provided with adequate shading to allow for optimal outdoor comfort. During the weekends, when less pedestrian traffic is expected, the environment should be conducive to draw people to the retail area along the Franklin Street corridor. As for annual cycles, the summer months will be of the greatest concern. The temperature in Tampa
during the summer months average between 85 and 90 degrees. Providing shading during these months may not be enough to provide an appealing atmosphere. Tampa City Center, located a few blocks south out the site, combines structural shading, tree shading and water features to lessen the ambient temperature (see Figure 8.4). The Tampa City Center model is one desirable way to combat Tampa’s adverse summer conditions.

Figure 8.4  Tampa City Center (author photo)

Exterior spaces

As stated in chapter 5, the summer months in Tampa are hot and humid. For this reason, exterior patios and terraces should be covered in the downtown area. These outdoor patios and terraces should be well shaded, whether by vegetation on construction elements. Since most of the activity outside will be
from retail patrons, a protected and comfortable atmosphere should provide a more pleasurable shopping and leisurely environment. In addition, Tampa’s summer months will often experience brief periods of intense downpours in the evening. Any successful evening outdoor use will have to take this into account.

Landscaping requirements

Vegetation on the site should be used at grade level, building terraces and perhaps on the facades as well. Trees located above the grade level must have adequate support and spacing to allow for natural growth. They also must be easily accessed by maintenance staff as they will need to watered and pruned on a regular basis. The species of vegetation chosen should relate to vegetation surrounding the 610 site and should be native to the Tampa area to minimize irrigation needs. Some attention should be taken to use building water runoff to fill the watering needs of this vegetation. For the facades, if vines are chosen, care and choice of material must be considered. The facades must be able support and facilitate the growth of these vegetation types.

Circulation Issues

Circulation issues should be a focus on Franklin Street. There should be adequate entry locations for businesses along this street as well as a well coordinated way to get to the retail patrons on the second level. This will allow
for additional retail on Franklin Street. Circulation should be open to the public in most cases, while having limited access to the “back of house” spaces reserved for security, utility and maintenance personnel. The outdoor areas should be protected from the weather in areas where pedestrian traffic is most pronounced. As a whole, the circulation should be easily navigated as not to create a labyrinth of corridors or alleyways.

Separate Access Requirements

Other than the main lobby access, there will need to be additional access points around the building. Secondary access to the lobby will almost certainly be necessary if the building has a central core. The code restricts dead end corridors to 20 feet, so if there is a central elevator bay, two means of exit must be provided. For delivery and utility entry, direct access can be located along the street or it can be accessed through a loading bay. For a loading bay, it could be either connected directly to the street or could be accessed through the parking garage. There will also have to be street access to all ground level retail shops. If retail is to be located on the second floor as well, either elevators, stairs or even escalators may be necessary to provide the essential accessibility requirements.
Sustainability Issues and Requirements

Project sustainability issues will be a priority concern for this project. The program must be able to compliment the issues of limiting heat gain. Vegetative facades and roofs is one program factor that will play an important role in the layout and interrelationships of the interior spaces. The building skin, in those areas that are not vegetated, will need to be designed in such a way to either vent or cool the air space directly adjacent to the building’s envelope. Any program relationship that contributes to heat gain or adds to the generation of unnecessary waste heat is not desirable.

Security Issues and Requirements

Security issues that may affect the site’s program will involve the location of the security office. The nearby Tampa building, Park Tower, has a security office at the ground level. The room is located in the “back of house” area but has several connections to the interior lobby and adjacent corridors. In addition, the security staff at Park Tower also runs the information desk flanking the elevator bays. The location allows security staff to observe all incoming and outgoing pedestrian movement at the ground level. The 610 Franklin Street Building should follow these basic guidelines when addressing security’s program location.
Solid Waste Collection

Waste collection should not block circulation. The waste should be collected on the ground level in a closed access room. The room should have adjacent access to the loading dock. The loading dock should then have access to the street, preferably a street that has less emphasis on the pedestrian environment. Waste collection within the office tower will be done floor by floor. A janitorial room on each floor will be require for this type of waste removal. As with Park Tower and the 501 Kennedy Building, this waste will be collected during the afterhours to avoid congestion with the building employees.

Adaptability and Flexibility Issues

610 Franklin Street should have a flexible office space arrangement. Park Tower’s building manager, Mary Ayo, expressed that “having office space surrounding the elevator core is easier to lease out. This type of floor layout allows lesasers more ability to expand on a floor and even add floors.” Ms. Ayo also expressed that bay sizes were important as well. She stated “The larger the bay size, the more flexibility a new client has in designing their office layout.” For the reasons Ms. Ayo expressed, 610 Franklin Street Building should have a comparable bay size and a central core.
Day lighting Requirements for Occupied Spaces

All the office floors at 610 Franklin Street should have exterior windows. On the south sides of the building, where light is ample throughout the day, strategies should be explored in order to reduce glare. At the same time, it will also be beneficial to bounce light far back into the occupied space. For example, a well placed light shelf could reduce the overall lighting needs of a space, thus reducing the generation of waste heat for the building.(see Figure 2.16 and 2.17) The east and west exposures of the building, although affected by sunlight for shorter periods of time, will be affected with the worst glare. This is due to the fact that the sun’s ray will strike the building more on a horizontal angle. Mechanized vertical louvers may be most effective in controlling this type of natural light condition. In addition mechanical louvers can be opened to allow ambient light to enter when the sunlight no longer strikes its surface.

HVAC systems

Due to size of the project, large considerations and allocations of space must be given to the HVAC system. From research obtained on nearby buildings, a cooling tower, chiller and air handlers will be needed. Air handlers should be located on each floor, at a central location, to reduce the need for large vertical ducts moving through the building. Then, either a dropped ceiling or an access floor system can provide all the air movement needs for each office level.
Chilled water should be pumped to each floor thru a vertical shaft. The cooling tower, which removes heat from the chilled water system, will need to have adequate ventilation and should be located away from the outdoor restaurant and other areas used by building patrons and employees.

Other Mechanical Systems

Electrical, plumbing, communications, and fire protection systems will all need to be run vertically thru the building. Although the space needed will be much less than the HVAC system, some space will need to be allocated on each floor. The review of other downtown office buildings in Tampa shows that the best place for these systems is to locate them at the building core. Mechanical systems located at the building core prevent the removal of valuable outer office space. In addition to these vertical spaces, distribution rooms for each system will need to be located within the building. Nearby Park Tower places each of these systems in a corner of the parking garage. 501 Kennedy locates these distribution systems on the first floor. Yet, the Franklin Exchange locates a majority of them in the basement. Regardless of where the location will be, the noise level for some of these systems must be taken into account and access for maintenance crews must be considered.
<table>
<thead>
<tr>
<th>TYPICAL OFFICE FLOOR</th>
<th>ROOM PROGRAM LIST</th>
<th>QUANTITY</th>
<th># OF OCCUPANTS</th>
<th>SQUARE FOOTAGE NEEDED</th>
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<td></td>
<td>300 ea</td>
</tr>
<tr>
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<td>2</td>
<td>10</td>
<td></td>
<td>150 ea</td>
</tr>
<tr>
<td>Men's Room</td>
<td>1 to 2</td>
<td>4</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Women's Room</td>
<td>1 to 2</td>
<td>4</td>
<td></td>
<td>200</td>
</tr>
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<td></td>
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<td></td>
<td>50</td>
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<tr>
<td>Mechanical Room</td>
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<td></td>
<td>200</td>
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<tr>
<td>Plumbing Room</td>
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<td>0</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Communication Room</td>
<td>1</td>
<td>0</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Hallway/Circulation</td>
<td>1</td>
<td>10</td>
<td></td>
<td>2000</td>
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</table>

Notes:
The circulation on each floor is variable. The total should not exceed more than 10% of the total floor. Access will need to be made to every room from the circulation area.

Table 8.1 typical office floor program (author table)

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<tr>
<th>GROUND FLOOR LAYOUT</th>
<th>ROOM PROGRAM LIST</th>
<th>QUANTITY</th>
<th># OF OCCUPANTS</th>
<th>SQUARE FOOTAGE NEEDED</th>
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<td>20</td>
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<td>2000 - 8000 ea</td>
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<td>Stairwells</td>
<td>2</td>
<td>10</td>
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<td>150 ea</td>
</tr>
<tr>
<td>Men's Room</td>
<td>1</td>
<td>8</td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>Women's Room</td>
<td>1</td>
<td>8</td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>Lobby</td>
<td>1</td>
<td>0</td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Parking Ramp</td>
<td>1</td>
<td>0</td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Loading Dock</td>
<td>1</td>
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<tr>
<td>Security Room</td>
<td>1</td>
<td>0</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Kiosk</td>
<td>1</td>
<td>0</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Child Care Center</td>
<td>1</td>
<td>10</td>
<td></td>
<td>1000</td>
</tr>
</tbody>
</table>

Notes:
The total ground floor area for the site is approximately 40000 square feet. Assuming that the building footprint takes up most of this space, retail take up the remainder of square footage not taken the rest of the ground floor program.

The retail stores should be located on Franklin Street.

Table 8.2 ground floor program (author table)
Figure 8.5  typical floor layout (author diagram)

Figure 8.6  vertical adjacency diagram (author diagram)
CHAPTER 9 – GOALS AND OBJECTIVES

This thesis project deals with architectural strategies in reducing heat gain in the sub-tropical urban heat island. The goal and objectives of this project must compliment the problems identified. The following is a series of key design considerations and suggestions that should be resolved to provide a successful solution to this problem.

First, this project will need to provide a developed exterior envelope that reduces the heat gain on building. The envelope should not only limit direct heat gain onto the building but should also use materials and strategies to reflect away heat gain and prevent the heat from conducting into the building. Whatever the method, the envelope should be economically feasible.

Second, this project should include a developed green roof system. Although tall buildings will have a majority of its surface area located on the elevations, roofs will still be a substantial components of the building's exterior envelope. In addition, the green roof system should have complete or partial access to the public as these green spaces can add to the human health qualities in the urban center.
Third, the project should provide an environment at the street level that can add to the ambience to the downtown area. The street level should provide relief from oppressive and inclement year round. The street level should also incorporate the city’s intentions and vision for Franklin Street.

Fourth, the project should provide a high usable office space to building space ratio, plentiful parking, and additional amenities into the program. The project must be plausible in layout and in price so that it could theoretically compete for the city’s best tenants in leasing out its office space. The project may still be among the highest for comparable cost within the city, but its amenities must justify this considerable cost inflation.
Figure 10.1  office tower proposal (author model)
Introduction

The design of this project takes into account the strategies and techniques determined to be most appropriate to reduce or lesson the impact of the heat island effect and to lesson or eliminate its own contribution to the heat island already present. Some of the strategies this project entails are: the use of green roofs, the orientation of the building, the development of façade specializing and individualizing, the use of light shelves and vertical sun-shades, the implementation of a double wall façade and the use of reflective light colored surfaces.

Orientation and Site Layout

One of the key problems with the site location, is that the site is square and located among many other skyscrapers (see Figure 10.2 -10.4). As stated in chapter two, a building in a hot climate should limit its east and west exposure. For this reason the building tower above the parking garage has been orientated to have four office bays facing south and north, and three office bays facing east and west (see Figure 10.5). In addition, the north façade has two additional half office bays pulled from the building. See Figures 10.6-10.12 for all plan types.
Figure 10.3 and 10.4 site model (author)
Figure 10.5 tower orientation (author)
Figure 10.6 first floor plan (author)
Figure 10.8  third floor plan (author)
Figure 10.9 fifth floor plan (author)
Figure 10.10 ninth floor plan (author)
Figure 10.11 twelfth and twenty second floor plan (author)
Figure 10.12 twenty fifth and twenty ninth floor plan (author)
Façade specialization and optimization

Perhaps the key component of this project is the use of three different façade types for the office tower. The office tower component of this project runs from ninth floor to the thirty-sixth floor. This expanse makes the office tower portion of the project the largest percentage of building surface area. Through the research, it was found that the quality and type of light energy hitting the building vastly differed. The north façade, for instance, had little to no direct light. The west and east facades suffered from low altitude light and had a variable azimuth. Yet the south had light originating from a high altitude and a constant azimuth. A light study was conducted at various times to see what techniques should be implemented (see Figures 10.13-10.18). The key differences of the facades include: types and sizes of louvers and light shelves used, introduction of a double wall system, thickness of the wall, and added ventilation shafts within the double wall to carry away ambient heat. Figures 10.19 – 10.26 show additional details of this system.
(left) Figure 10.19 south elevation (right) Figure 10.20 west elevation (author)
Figure 10.21  south façade tower section (author)
Figure 10.22  north façade tower section (author)
Figure 10.23 double wall system, west and south façade. west façade with vertical louvers (author)
Figure 10.24 double wall system vent stack (author)
Figure 10.25  north-south building section showing overall shading (author)
Figure 10.26 retail level section model (author)
Green Roofs

As detailed in chapter 3, the urban forest contributes to the reduction of the heat island through reducing direct radiant gain and the transfer of energy through evapotranspiration. This design proposal incorporates four roof gardens and carves out a courtyard at the grade level for additional tree canopy coverage. Although the amount of tree canopy coverage is much less than in rural areas, the incorporation of roof gardens where allowable is a necessary component in the reduction of the heat island. Through the design process it was a standard notion that any terminating volume of the tower would feature a roof terrace or garden at the top (see Figures 10.6, 10.9, 10.10, 10.12 and 10.27-10.28)

Figure 10.27 entry plaza (author)
Figure 10.28  model showing roof-top garden locations (author)
Additional Graphics of Design Proposal

Figure 10.29  site rendering (author)

Figure 10.30  tower perspective (author)
Figure 10.31  model showing east façade (author)
Figure 10.32  model showing south façade (author)
Figure 10.33 model showing west façade (author)
Figure 10.34  model showing north façade (author)
CHAPTER 11 – SUMMARY

Introduction

The intent of this project is to show that the implementation of strategies and design features in a building can reduce the heat island effect, even the most challenging area. The area and building type selected for this project had no inherent advantages over any other typical site or building typology. In addition, it was important for this project to show that the design implementations were effective and inexpensive. This final chapter will look into cost analysis data, energy analysis data and give suggestions on what should be done for future projects within a downtown setting.

Cost Analysis

Any new office buildings within the Central Business District in Tampa must have competitive rental rates against other similar office space in the area. If this is not done the project will either fail or never be built. Additionally it is necessary to provide certain amenities to meet certain office classifications. Some of the data needed to conclude if this project is viable are: the average
rental rates of a downtown Tampa building, the rentable space within this project, the operational expenses to service a building, the cost to build a similar building and a cost projection for this project.

First, this project encompasses roughly 413,000 square feet of office space and 40,000 square feet of retail space. The cost to construct this proposal came out to $77,000,000 (see Appendix A). The cost analysis was derived from a program called DProfile developed by Beck Technologies. Using the same program, it was predicted that the energy needs of the building would be $9.95 per square foot over a fifteen year period. Based on these numbers, the rental rate before the inclusion of a profit margin and personnel costs, came out to $21.95 per square foot.

Second, according to the online publication Collier Arnold the average class A rental space in downtown Tampa was $23.45 a square foot in September 2008. Based on these numbers it is plausible to assume that this project proposal is viable considering construction feasibility.

Energy Analysis

A second important component of this project is to show that the proposed project will have a reduced impact on the heat island effect. Unfortunately, two components of the heat island effect, direct heat gain and ambient heat are difficult to model using computer software. However, programs like DProfile from Beck Technologies can show the reduction of waste heat by modeling a
building’s energy consumption. As described in chapter two of this document, the reduction of waste heat has a direct relation with both the reduction of ambient heat and direct heat gain. So if a building can reduce its own total energy consumption, it will likely limit its own direct heat gain and will reduce the locations ambient heat.

To show the buildings energy consumption was lowered due to design strategies, a cost comparison analysis was done. The cost comparison analysis comprises of three studies (see Appendices A-C for complete analysis). The first is a study of the proposed project as is. The second is the same project but substitutes the building skin of a double wall system for a full glass curtain wall. The third is the same as the first study but with the project rotated ninety degrees clockwise.

Careful analysis between study one and two shows that’s a building that takes into consideration the effects of direct heat gain, costs considerably less and uses less energy (see Figure 11.1-11.3). The inherent advantage of a double wall is reduction of direct heat gain on the building. The reduction of direct heat gain allows a building to reduce its air handling needs. On the reverse end of the spectrum, a glass curtain wall building does not address direct heat gain at all. This is why the data shows that the air handling needs between the two skin types is five hundred tons for the same building, a cooling load reduction of twenty-five percent. Because of the reduced air handling needs, electrical use in the building drops over ten percent. During a fifteen year life span of the mechanical systems from initial purchase and year to year
operational costs, a savings of 1.6 million dollars can be expected based on the projections.

A similar comparison can be drawn up on a buildings orientation. As stated in chapter two, a buildings form and orientation can help lower heat gain. A building in a hot humid climate typically should be orientated to limit sun exposure on the east and west. Study one, the project proposal, has the tower orientated with four bays facing south and three bays facing east/west. Study three is the opposite. By analyzing the data from these two studies, this simple move proved to be cost effective for the proposed project (see Figure 11.1-11.3). Study one lowered the air handling needs by fifty-eight tons over the less optimal study three. The result is an energy and monetary savings as well.

![Figure 11.1  electrical use (graph using data from DProfile)](image)
Figure 11.2  peak building load (graph using data from DProfile)

Figure 11.3  life-cycle costs (graph using data from DProfile)
Energy Recovery Analysis

One additional development deals with the energy that can be recovered from the HVAC systems. Although not architectural in nature, energy recovery systems can play a significant role in the reduction of waste heat. As covered in chapter four of this document, one type of energy recovery system is a rotary enthalpy wheel. These wheels transfer energy stored in building exhaust to the fresh incoming air. These systems can be quite large and should be appropriated for early in the design process. A computer model was run to see if such a system would be effective for this project (see Appendix D for complete results). The results data concluded that using an enthalpy wheel would reduce the total cooling load by twenty-five tons. Although this is only a reduction of two percent of the total load capacity, the reduction will save on energy year to year and total initial mechanical cost would be reduced as well.

Conclusion

The urban heat island contributes too many negative effects on its inhabitants and to the environment. Many cities are in dire need to change its urban make-up to lesson these negative effects. Unfortunately, construction companies have been slow to come to terms and have avoided various methods detailed in this document for fear of increased costs. Through the process of this thesis, it is clear that much can be done to reduce the effects of the heat island in
the urban setting while still reducing costs. Things as simple as positioning the
building along the correct axis have a significant impact on mechanical and
lighting needs. Construction of a double wall, like that of the New York Times
tower can have higher up-front costs but will reduce life-cycle costs through lower
energy needs. Even just the dedication of fifty additional square feet for an
energy recovery system can recoup its own cost within a year or two through
energy savings. Regardless of the methods used, there is still much that can be
done to create an impact on the urban heat island effect.
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28 Michelle Cummings, personal interview, 10 June 2008.


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Hertalan. 6 June 2008 <http://www.hertalan.co.uk/index.html>.


APPENDICES
# Appendix A: Energy Analysis One

**Figure A.1** project proposal cost analysis (DProfile)

**Location:**

33602

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<th>Building Summary Information</th>
<th>Cladding Summary Information</th>
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</tr>
<tr>
<td><strong>Subtotal Direct Cost</strong></td>
<td><strong>$68,366,285.62</strong></td>
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<table>
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<th>General Conditions and Fees</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>General Conditions</td>
<td>3,418,314.28</td>
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<tr>
<td>Design Allowance</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Inflation Allowance</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>General Liability</td>
<td>35,892.30</td>
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<tr>
<td>Excess Liability</td>
<td>35,892.30</td>
<td>0.04</td>
</tr>
<tr>
<td>Builder's Risk</td>
<td>64,606.14</td>
<td>0.07</td>
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<tr>
<td>Contingency</td>
<td>2,153,538.00</td>
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<tr>
<td>Fee</td>
<td>2,512,461.00</td>
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<td>Indemnification</td>
<td>717,846.00</td>
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<td><strong>Subtotal Fees</strong></td>
<td><strong>$8,936,550.02</strong></td>
<td><strong>$9.58</strong></td>
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</table>

**Total Cost**

$77,304,835.64  $82.87
Figure A.3 project proposal energy analysis (DProfile)
Figure A.4  project proposal energy analysis (DProfile)
Figure A.5 project proposal energy analysis (DProfile)
Appendix B: Energy Analysis Two

Location:

33002

<table>
<thead>
<tr>
<th>Building Summary Information</th>
<th>Cladding Summary Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Building Area: 932,793.80 sf</td>
<td>Solid Cladding Area: 65,583.89 sf</td>
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<tr>
<td>(includes garage)</td>
<td>Glazing Cladding Area: 300,136.17 sf</td>
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<tr>
<td>Rentable Building Area: 450,000 sf</td>
<td>Other Cladding Area: 0.00 sf</td>
</tr>
<tr>
<td>Building Footprint Area: 43,286.00 sf</td>
<td>Glazing Percentage: 82.07 %</td>
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Figure B.1 alternate 1 project proposal cost analysis (DProfile)
<table>
<thead>
<tr>
<th>Uniformat Code</th>
<th>Cost</th>
<th>Cost / SF</th>
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<tbody>
<tr>
<td>--- UNKOWN CATEGORY</td>
<td>9,922,068.44</td>
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<tr>
<td>A SUBSTRUCTURE</td>
<td>559,860.48</td>
<td>0.60</td>
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<tr>
<td>B SHELL</td>
<td>36,922,377.73</td>
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<tr>
<td>C INTERIORS</td>
<td>1,672,973.45</td>
<td>1.79</td>
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<td>D SERVICES</td>
<td>27,702,413.61</td>
<td>29.70</td>
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<tr>
<td>E EQUIPMENT &amp; FURNISHINGS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F SPECIAL CONSTRUCTION</td>
<td>-</td>
<td>-</td>
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<tr>
<td>G BUILDING SITEWORK</td>
<td>-</td>
<td>-</td>
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<td><strong>Subtotal Direct Cost</strong></td>
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<td><strong>$82.31</strong></td>
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<td><strong>General Conditions and Fees</strong></td>
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<td></td>
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<td>4.12</td>
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<td>Design Allowance</td>
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<td>Inflation Allowance</td>
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<td>0.00</td>
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<tr>
<td>General Liability</td>
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<td>Builder's Risk</td>
<td>72,558.81</td>
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<td>Contingency</td>
<td>2,418,560.35</td>
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<tr>
<td>Fee</td>
<td>2,821,653.74</td>
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<td>Indemnification</td>
<td>806,186.76</td>
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<td><strong>Subtotal Fees</strong></td>
<td><strong>$10,038,561.05</strong></td>
<td><strong>$10.76</strong></td>
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<tr>
<td><strong>Total Cost</strong></td>
<td><strong>$86,818,254.76</strong></td>
<td><strong>$93.07</strong></td>
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</table>
Figure B.3  alternate 1 project proposal energy analysis (DProfile)
Figure B.4 alternate 1 project proposal energy analysis (DProfile)
### Figure B.5  alternate 1 project proposal energy analysis (DProfile)

#### Annual Electric Consumption

- Area Lighting: 40.00%
- Task Lighting: 0.00%
- Misc. Equipment: 0.00%
- Space Heating: 51.00%
- Space Cooling: 51.00%
- Heat Radiation: 0.00%
- Pumps & Acc.: 0.00%
- Ventilation Fans: 0.00%
- Refrigeration: 0.00%
- Heat Pump Supp.: 0.00%
- Water Heats: 0.00%
- Exterior Usage: 0.00%

#### Annual Natural Gas Consumption

- Water Heating: 95.00%
- Space Heating: 20.00%
Appendix C: Energy Analysis Three

Location:

33602

<table>
<thead>
<tr>
<th>Building Summary Information</th>
<th>Cladding Summary Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Building Area: 932,793.80 sf (includes garage)</td>
<td>Solid Cladding Area: 259,784.80 sf</td>
</tr>
<tr>
<td>Rentable Building Area: 450,000 sf</td>
<td>Glazing Cladding Area: 109,526.12 sf</td>
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<tr>
<td>Building Footprint Area: 43,286.00 sf</td>
<td>Other Cladding Area: 0.00 sf</td>
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<td></td>
<td>Glazing Percentage: 29.58 %</td>
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Figure C.1 alternate 2 project proposal cost analysis (DProfile)
<table>
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<th>Uniformat Code</th>
<th>Cost</th>
<th>Cost / SF</th>
</tr>
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<td>--- UNKNOWN CATEGORY</td>
<td>9,313,066.58</td>
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<td>A SUBSTRUCTURE</td>
<td>559,860.48</td>
<td>0.60</td>
</tr>
<tr>
<td>B SHELL</td>
<td>23,463,664.57</td>
<td>25.15</td>
</tr>
<tr>
<td>C INTERIORS</td>
<td>2,420,647.30</td>
<td>2.60</td>
</tr>
<tr>
<td>D SERVICES</td>
<td>27,702,413.61</td>
<td>29.70</td>
</tr>
<tr>
<td>E EQUIPMENT &amp; FURNISHINGS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F SPECIAL CONSTRUCTION</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>G BUILDING SITWORK</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>

Subtotal Direct Cost  
$63,459,652.53  $68.03

**General Conditions and Fees**

<p>| | | |</p>
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<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>General Conditions</td>
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<td>3.40</td>
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<tr>
<td>Design Allowance</td>
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<td>Excess Liability</td>
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<td>Builder’s Risk</td>
<td>56,969.37</td>
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<td>Contingency</td>
<td>1,998,979.05</td>
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<td>Fee</td>
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<tr>
<td>Indemnification</td>
<td>666,326.35</td>
<td>0.71</td>
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</table>

Subtotal Fees  
$8,297,032.27  $8.89

Total Cost  
$71,756,684.80  $76.93
Figure C.3 alternate 2 project proposal energy analysis (DProfile)
Figure C.4  alternate 2 project proposal energy analysis (DProfile)
Figure C.5  alternate 2 project proposal energy analysis (DProfile)
Appendix D: Energy Recovery Ventilator Data

ERV
Energy Recovery Ventilator
Belt Drive
Arrangement H

STANDARD CONSTRUCTION FEATURES:
Energy recovery wheel constructed of fluted synthetic media containing water selective molecular sieve desiccant - Cassette assembly slides out for easy access and consists of energy recovery wheel, drive motor, and drive components - Removable access doors provide access to all internal components - Ventilator cabinet consisting of a minimum 18 gauge galvanized steel housing mounted to a minimum 16 gauge galvanized steel base - Cabinet internally lined with 1" thick, 3 lb. density, FSK insulation - Two DWDI forward curved steel blowers mounted on vibration isolators - Blower wheel bearings rated at 200,000 hours average life - Blower wheels are factory adjusted to specified RPM - Standard size 2" thick, 30% efficient pleated filters in supply and exhaust air streams - All electrical components pre-wired for single point power connection - Interlock disconnect on hinged control panel door.

Performance

<table>
<thead>
<tr>
<th>Qty</th>
<th>Catalog Number</th>
<th>Airstream</th>
<th>Flow (CFM)</th>
<th>SP (inw.c)</th>
<th>Fan RPM</th>
<th>Bhp (HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ERV-7000</td>
<td>Supply</td>
<td>7000</td>
<td>.500</td>
<td>693</td>
<td>3.01</td>
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<tr>
<td></td>
<td></td>
<td>Exhaust</td>
<td>6800</td>
<td>.500</td>
<td>739</td>
<td>3.39</td>
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</table>

Altitude (ft): 10

Motor Information

<table>
<thead>
<tr>
<th>Airstream</th>
<th>HP</th>
<th>RPM</th>
<th>Volts/Ph/Hz</th>
<th>Enclosure</th>
<th>Mounted</th>
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</thead>
<tbody>
<tr>
<td>Supply</td>
<td>5</td>
<td>1725</td>
<td>200/3/60</td>
<td>ODP</td>
<td>YES</td>
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<tr>
<td>Exhaust</td>
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<td></td>
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</table>

Electrical

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<tr>
<th>ERV Full Load Amps</th>
<th>Minimum Circuit Amps</th>
<th>MOCP*</th>
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<tr>
<td>35.6</td>
<td>44.5</td>
<td>50</td>
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</tbody>
</table>

* Maximum Overload Circuit Protection

Design Conditions

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<th>Outdoor</th>
<th>Indoor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry Bulb (°F)</td>
<td>Wet Bulb (°F)</td>
</tr>
<tr>
<td>Summer</td>
<td>94.0</td>
<td>80.0</td>
</tr>
<tr>
<td>Winter</td>
<td>36.0</td>
<td>33.6</td>
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</tbody>
</table>

Supply Conditions

<table>
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<tr>
<th></th>
<th>Flow (CFM)</th>
<th>Dry Bulb (°F)</th>
<th>Wet Bulb (°F)</th>
<th>Relative Humidity</th>
<th>Humidity Ratio (Gr/Lb)</th>
<th>Humidity Ratio (lb/lb)</th>
<th>Dew Point (°F)</th>
<th>Enthalpy (BTU/Lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>7000</td>
<td>81.3</td>
<td>60.7</td>
<td>56.6%</td>
<td>90.6</td>
<td>0.01294</td>
<td>64.4</td>
<td>33.72</td>
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<tr>
<td>Winter</td>
<td>60.1</td>
<td>49.2</td>
<td>44.9%</td>
<td>34.5</td>
<td>0.00493</td>
<td>38.7</td>
<td>19.80</td>
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Figure D.1  energy recovery wheel data (Cook)
Figure D.2 energy recovery wheel data (Cook)
Figure D.3  energy recovery wheel data (Cook)
**ERV**

**First Cost / Payback Analysis**

<table>
<thead>
<tr>
<th>Performance</th>
<th>Design Conditions</th>
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<tbody>
<tr>
<td><strong>Catalog Number</strong></td>
<td><strong>Flow (CFM)</strong></td>
</tr>
<tr>
<td>ERV-7000</td>
<td>Supply</td>
</tr>
<tr>
<td></td>
<td>7000</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**A/C Equipment Savings**

| w/o Energy Recovery | 40.23 | 0.00 | 40.23 | 50.00 | $1,500 | $75,000 |
| w/Energy Recovery | 14.67 | 0.00 | 14.67 | 15.00 | $1,500 | $22,500 |
| Savings | 25.56 | 0.00 | 25.56 | 35.00 | $1,500 | $52,500 |

**Net First Cost**

| ERV Unit Cost* | $21,100 |
| A/C Equipment Savings | $52,500 |
| Net ERV Cost | -$31,400 |

* Estimated installed cost including accessories.

**Payback**

| Net ERV Cost | -$31,400 |
| Annual Energy Savings* | $3,917 |
| Payback Period | Instant |

* Includes ERV operating costs ($2.23/hr) associated with wheel pressure drop.

**Operating Assumptions**

| Location | TAMPA, FL |
| Altitude (ft) | 10 |
| Operating Time | 6 am - 10 pm, 5 Days/Week |

**Energy Criteria**

| Source | Cost | Efficiency |
| Cooling System | Electric | .09 $ / kw/h | EER = 10 |
| Heating System | Gas | 1.30 $ / therm | Effic = 70% |

Figure D.4  energy recovery wheel data (Cook)
### Energy Savings Analysis

#### Performance

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Flow (CFM)</th>
<th>Wheel Effectiveness</th>
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<td></td>
<td>Supply</td>
<td>Exhaust</td>
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<tr>
<td></td>
<td>Sensible</td>
<td>Latent</td>
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<tr>
<td>ERV-7000</td>
<td>7000</td>
<td>6800</td>
</tr>
<tr>
<td></td>
<td>68.9%</td>
<td>63.7%</td>
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</tbody>
</table>

#### Design Conditions

<table>
<thead>
<tr>
<th></th>
<th>Outdoor</th>
<th>Indoor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry Bulb</td>
<td>Wet Bulb</td>
</tr>
<tr>
<td></td>
<td>(°F)</td>
<td>(°F)</td>
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<tr>
<td>Summer</td>
<td>94.0</td>
<td>80.0</td>
</tr>
<tr>
<td>Winter</td>
<td>36.0</td>
<td>33.6</td>
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#### Cooling Savings

<table>
<thead>
<tr>
<th>Temperature Bin (°F)</th>
<th>Total Hours</th>
<th>Enthalpy (BTU/Lb)</th>
<th>Cooling Load w/o ERV (BTU)</th>
<th>Cooling Load w/ERV (BTU)</th>
<th>Energy Saved (BTU)</th>
<th>Dollars Saved*</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.5</td>
<td>2</td>
<td>41.26</td>
<td>206,832</td>
<td>296,709</td>
<td>530,224</td>
<td>$4,124</td>
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<tr>
<td>92.5</td>
<td>103</td>
<td>39.76</td>
<td>37,708,940</td>
<td>13,872,000</td>
<td>24,126,900</td>
<td>$194,544</td>
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<td>87.5</td>
<td>508</td>
<td>38.10</td>
<td>175,497,100</td>
<td>94,320,400</td>
<td>111,176,700</td>
<td>$842,699</td>
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<tr>
<td>82.5</td>
<td>953</td>
<td>36.52</td>
<td>251,708,100</td>
<td>93,143,430</td>
<td>158,564,700</td>
<td>$1,150,14</td>
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<td>77.5</td>
<td>661</td>
<td>34.69</td>
<td>136,624,200</td>
<td>91,432,310</td>
<td>45,191,900</td>
<td>$363,36</td>
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</table>

Cooling Totals: 602,555,300BTU = 222,864,600BTU + 379,690,700BTU = $2,764,85

#### Heating Savings

<table>
<thead>
<tr>
<th>Temperature Bin (°F)</th>
<th>Total Hours</th>
<th>Heating Load w/o ERV (BTU)</th>
<th>Heating Load w/ERV (BTU)</th>
<th>Energy Saved (BTU)</th>
<th>Dollars Saved*</th>
</tr>
</thead>
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<tr>
<td>69.5</td>
<td>416</td>
<td>7,862,400</td>
<td>2,446,123</td>
<td>5,417,277</td>
<td>$4,99</td>
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<td>64.5</td>
<td>399</td>
<td>22,623,300</td>
<td>7,035,630</td>
<td>2,587,670</td>
<td>$197,77</td>
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<td>59.5</td>
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<td>18,049,500</td>
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<td>12,436,280</td>
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<td>54.5</td>
<td>171</td>
<td>22,623,300</td>
<td>7,035,636</td>
<td>15,587,660</td>
<td>$250,16</td>
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<td>49.5</td>
<td>125</td>
<td>21,263,500</td>
<td>6,812,433</td>
<td>14,450,070</td>
<td>$243,34</td>
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<td>44.5</td>
<td>70</td>
<td>14,553,000</td>
<td>4,525,845</td>
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<td>$170,13</td>
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<tr>
<td>39.5</td>
<td>21</td>
<td>5,159,700</td>
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<td>3,555,082</td>
<td>$6,120</td>
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<td>34.5</td>
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<td>881,658</td>
<td>1,953,342</td>
<td>$33,98</td>
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<td>29.5</td>
<td>1</td>
<td>212,300</td>
<td>99,921</td>
<td>123,379</td>
<td>$3,97</td>
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</table>

Heating Totals: 115,290,090BTU = 35,854,980BTU + 79,435,980BTU = $1,152,53

Annual Totals: 717,845,300BTU = 258,718,708BTU + 459,126,600BTU = $3,917,38

* Includes ERV operating costs ($0.23/kwh) associated with wheel pressure drop.

#### Operating Assumptions

- Location: TAMPA, FL
- Altitude (ft): 10
- Operating Time: 6 am - 10 pm, 5 Days/Week

#### Energy Criteria

- **Source**: Electric
  - Cost: $0.09 / kWh
  - Efficiency: EER = 10
- **Source**: Gas
  - Cost: $1.30 / therm
  - Efficiency: Efficiency = 70%

---

Figure D.5 energy recovery wheel data (Cook)
### Weather Bin Details

<table>
<thead>
<tr>
<th>Temperature Range (°F)</th>
<th>Total Hours</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>107.5 &gt;105.0 to 110.0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>102.5 &gt;100.0 to 105.0</td>
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<td>0</td>
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**Cooling Mode**

**Heating Mode**

**Total** | 4176 | 368 | 320 | 352 | 336 | 368 | 336 | 352 | 352 | 368 | 336 | 336

Hourly weather data is based on Typical Meteorological Year (TMY2) data obtained from the National Renewable Energy Laboratory.