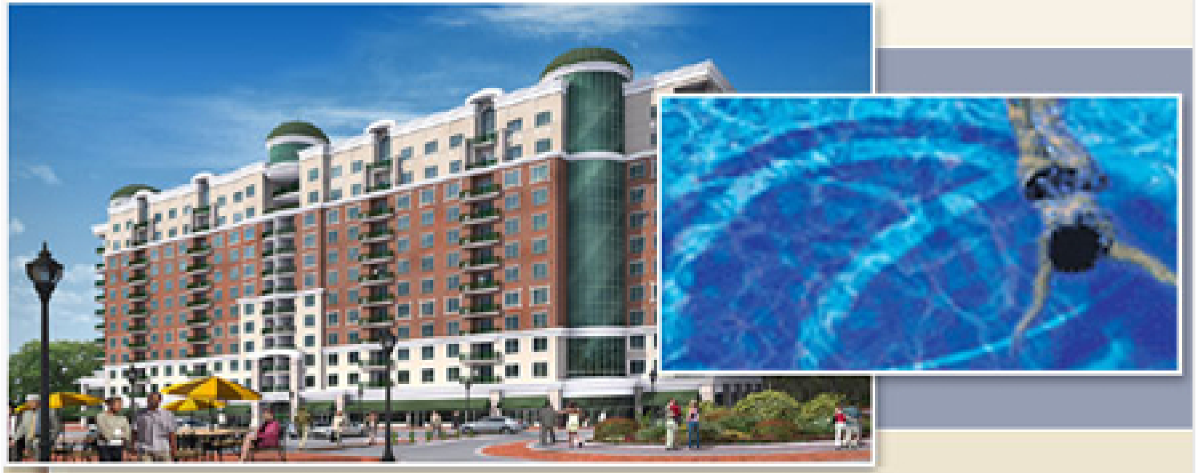
Final Report



GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

ANNAPOLIS, MD

Matthew Karle
Construction Management
Dr. Chimay Anumba
Tuesday, April 7, 2009

GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

1915 Towne Centre Blvd.
Annapolis, MD 21401

BASIC BUILDING STATISTICS

Occupancy Type:	Mixed-Use Luxury Residential
Size:	385,000 SF
Number of Stories:	13 Total
Ground Floor:	Retail
Floors 2-13:	Residential
Construction Dates:	March 2007- March 2009
Overall Project Cost:	$68,500,000
Delivery Method:	CM @ Risk with GMP

DESIGN & CONSTRUCTION TEAM

Master Developer: Greenberg Gibbons Commercial

Owner:	Sturbridge Homes
CM:	*Gilbane ATC, LLC.*
Architect:	The Martin Architectural Group
Stuctural Engineer:	The Harman Group
MEP Engineer:	Gillan & Hartman, Inc.
3rd Party Testing:	ECS Mid-Atlantic, LLC.

ARCHITECTURE

The exterior of the building was designed with elaborate architectural details, showcased by the three unique qualities

-Glass Fiber Reinforced Concrete Cornices
-Curtainwalls
-Cupola dome roofs

-In order to tie the building in with the surrounding architecture, masonry and stucco beige earth colors as well as green domes are used. Large glass curtain walls at two corners compliment its appearance by adding long continuous lines of blue-green glass.

-Glass Fiber Reinforced Concrete (GFRC) decorative elements were pre-cast and hoisted onto metal mounts on the facade. The roof is made of built-up single-ply EPDM.

MECHANICAL SYSTEMS

The HVAC system of the typical residential floors (2-10) consist of packaged self contained Magic-Pak units. These units allow for independent control by the tenants and allow for minimal duct work throughout the building. The penthouse units and common spaces utilize split sytems with gas fired furnaces. The mechanical equipment is located on the mezzanine roof and main roof. A wet-type fire supression system being implemented in the building.

CONSTRUCTION & STRUCTURE

-GrandView consists of a two-way flat slab system with shear resistance elements that include a core elevator shaft and 2 stair towers.

-Favorable soils in the location allowed for shallow foundation work, auger cast piles serve as the primary support system.

-Brick and calcium silicate masonry units comprise the veneer with a unique Henry spray applied air and moisture barrier system.

ELECTRICAL SYSTEM

- 4000 A Main Service Gear (Condos)
- 1000 A Service Gear for Shell
-350 kW Emergency Generator Backup

Matthew Karle
Construction Management
Sponsored By: Gilbane Building Company

http://www.engr.psu.edu/ae/thesis/portfolios/2009/mgk5000/index.html

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Acknowledgements and Credit

Thanks to the Penn State AE Faculty:

Dr. Anumba – CM Consultant and Advisor

Prof. Parffit - CM

Prof. Holland

Dr. Riley – CM Consultant

Professional Thanks To:

STURBRIDGE
HOMES

Gilbane

Tubular Steel, Inc.
Performance you can count on

THG
THE HARMAN GROUP
structural engineers
parking consultants

GREENBERG GIBBONS COMMERCIAL

Special Thanks To:

Tyler Swartzwelder

and the Entire GrandView Gilbane Staff

Every AE Student who put up with me and helped me out with the past 5 years!

Executive Summary

This document includes a comprehensive analysis of current industry issues and construction methods involved with the sustainable and energy efficient design of GrandView at Annapolis Towne Centre at Parole. Three areas of interest are analyzed in addition to the project information and general background. The overlying goal of this document is to research and carry out calculations that deal with sustainable design and constructability, centered on absorbing and reflecting energy from the sun.

The critical industry issue explored deals with the current economic situation with high energy costs and how the construction industry is implementing solar power into infrastructure through constructability. This examination of solar panel constructability and its place in current building design shows that in order to make this renewable energy resource a mainstream competitor to existing energy suppliers, advancement in efficiency and integration into building materials needs to be improved. Ultimately, the overall cost of implementing such a system needs to be reduced either by cheaper panels and quicker installation processes, or by larger government incentives that drastically reduces the payback period of the system.

The first and second analyses both deal with how utilizing and blocking the sun can have great impacts in energy savings of the building. The key issue here is implementing a PV solar array and high thermally rated windows with a low solar gain in such a way as to not have a drastic impact on the construction schedule. The overall construction cost and environmental impact that each system has is also determined. In the first analysis, it is determined that the addition of a 40Kw solar array on the roof of GrandView saves an annual $6,797.10 and reduces greenhouse gas emissions by 39.3 tons all while having little impact on the overall length of the construction schedule.

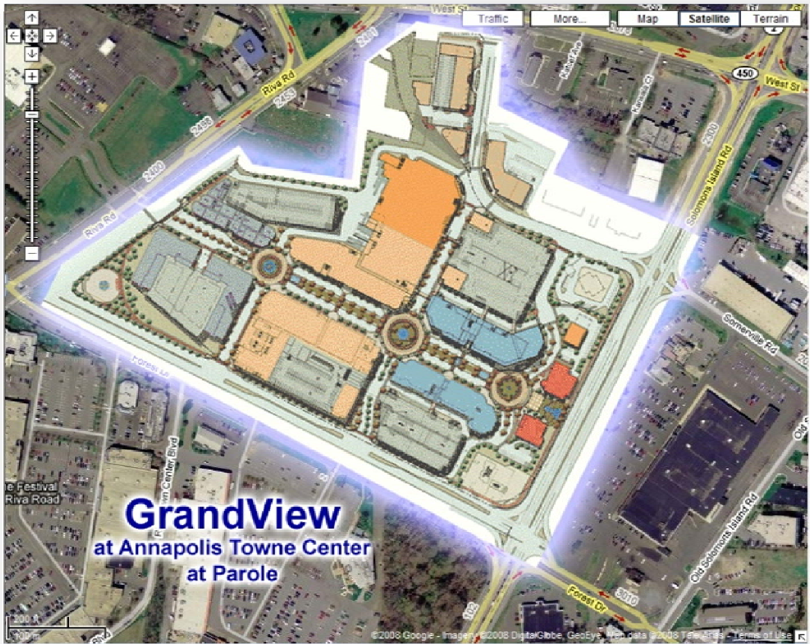
The second analysis maintains current schedule length while implementing a more energy efficient window design. Ultimately, the addition of better glazing reduces solar heat gain and saves $61,783.00 annually on cooling costs and prevents 1197 tons of CO2 from entering the atmosphere. When paired with the efficient Henry air/moisture skin of the envelope along with a Magic-Pak AHU system, moisture is reduced and better scheduling coordination due to less partition and floor penetrations is achieved.

Introduction

GrandView at Annapolis Towne Centre at Parole is a 13 story mixed-use residential and commercial high-rise located in Annapolis, MD. It’s 385,000 square feet will consist of a commercial first floor for tenant fit-out retail spaces, and 12 stories of luxury condominiums. The total project cost is estimated to be $68,500,00 and will provide 125 residential units. Amenities include a rooftop pool and sundeck, fitness center and social club. Situated on 33 acres just outside of Annapolis, the site is considered the second oldest retail venue in the state.

GrandView is only a small portion of the overall massive development that is Annapolis Towne Centre. Greenberg Gibbons serves as the Master Developer and has empowered Sturbridge Homes to act as owner of GrandView. Gilbane ATC, was awarded the contract in October of 2006 as a Design-Bid-Build delivery system with a Guaranteed Maximum Price. The Project broke ground in March of 2007 and is currently on schedule to be completed in June of 2009.

(2.1) Location : Annapolis, MD



Address:

Grandview at Annapolis Towne Centre
1915 Towne Centre Blvd
Annapolis, MD 21401

Project Overview

(3.1) Client Information

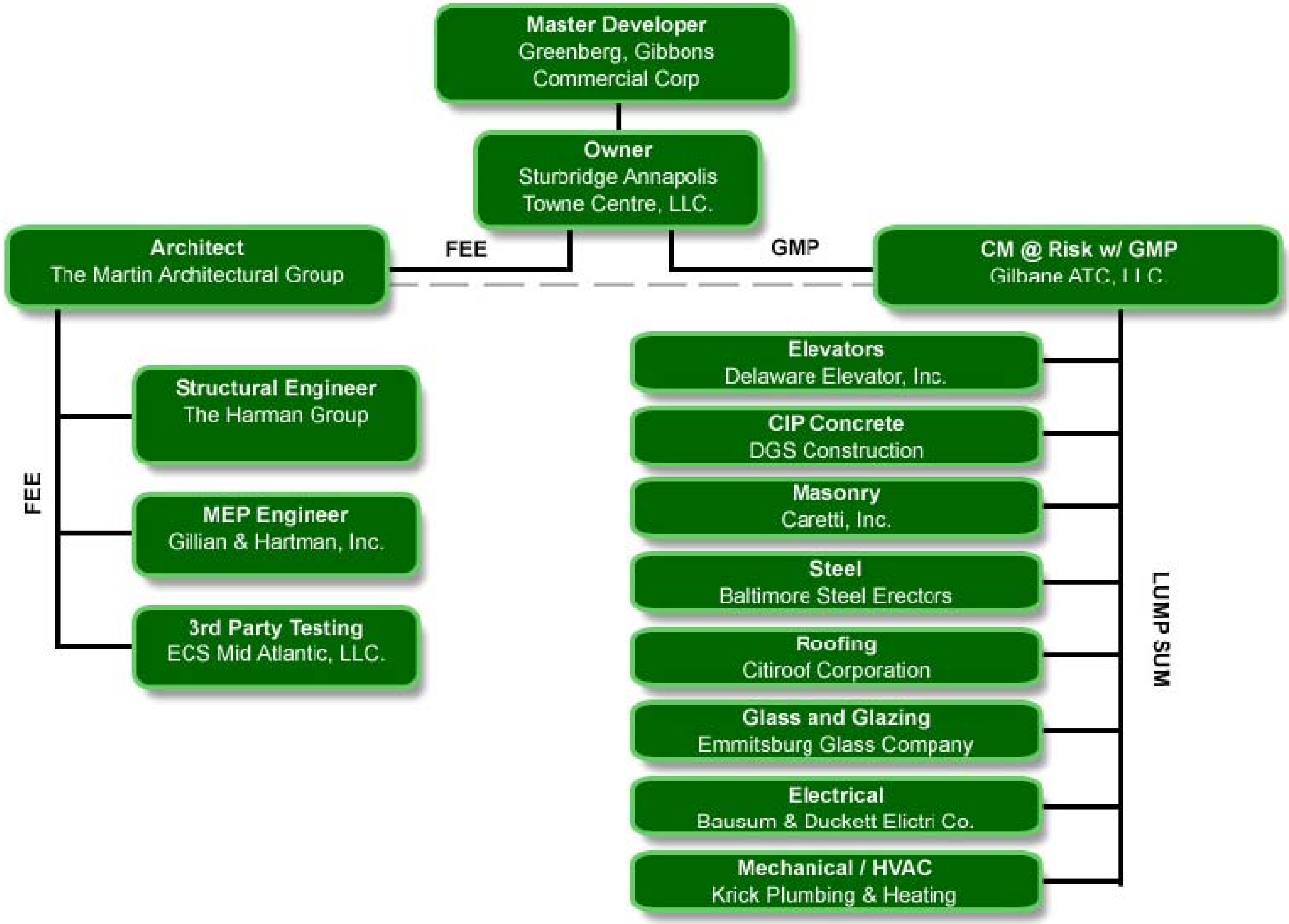
GrandView is only a small part of the large scale development plan that is happening at the Annapolis Towne Centre at Parole. Greenberg Gibbons Commercial Corporation is the Master Developer of the area. Sturbridge Homes is the direct owner of Grandview at ATC and has hired Gilbane ATC to act as the General Contractor.

Annapolis Towne Center is the former site of the Parole Plaza Shopping Center, which was built in the early 1960's, closed in the 1990's, and has remained vacant for a decade. Parole Plaza Shopping Center was the first shopping center developed in the Annapolis area that contained major department stores. This was a defining event in the commercial evolution of the Annapolis area — before the opening of this shopping center, Annapolis residents had to travel to Washington, DC or Baltimore to shop in an upscale department store. The new Towne Centre will create a revitalized living, shopping, entertainment and community center for the city and for Anne Arundel County.

Sturbridge has concentrated mostly on smaller residential villages and complexes This is the first project of this caliber for Sturbridge Homes. The success of this project will no doubt give them the knowledge and respect to obtain similar jobs like this in the future. They proudly earned the Certified Master Builder certification by meeting the highest standards for industry experience, customer satisfaction, financial stability and adherence to accepted building technology standards.

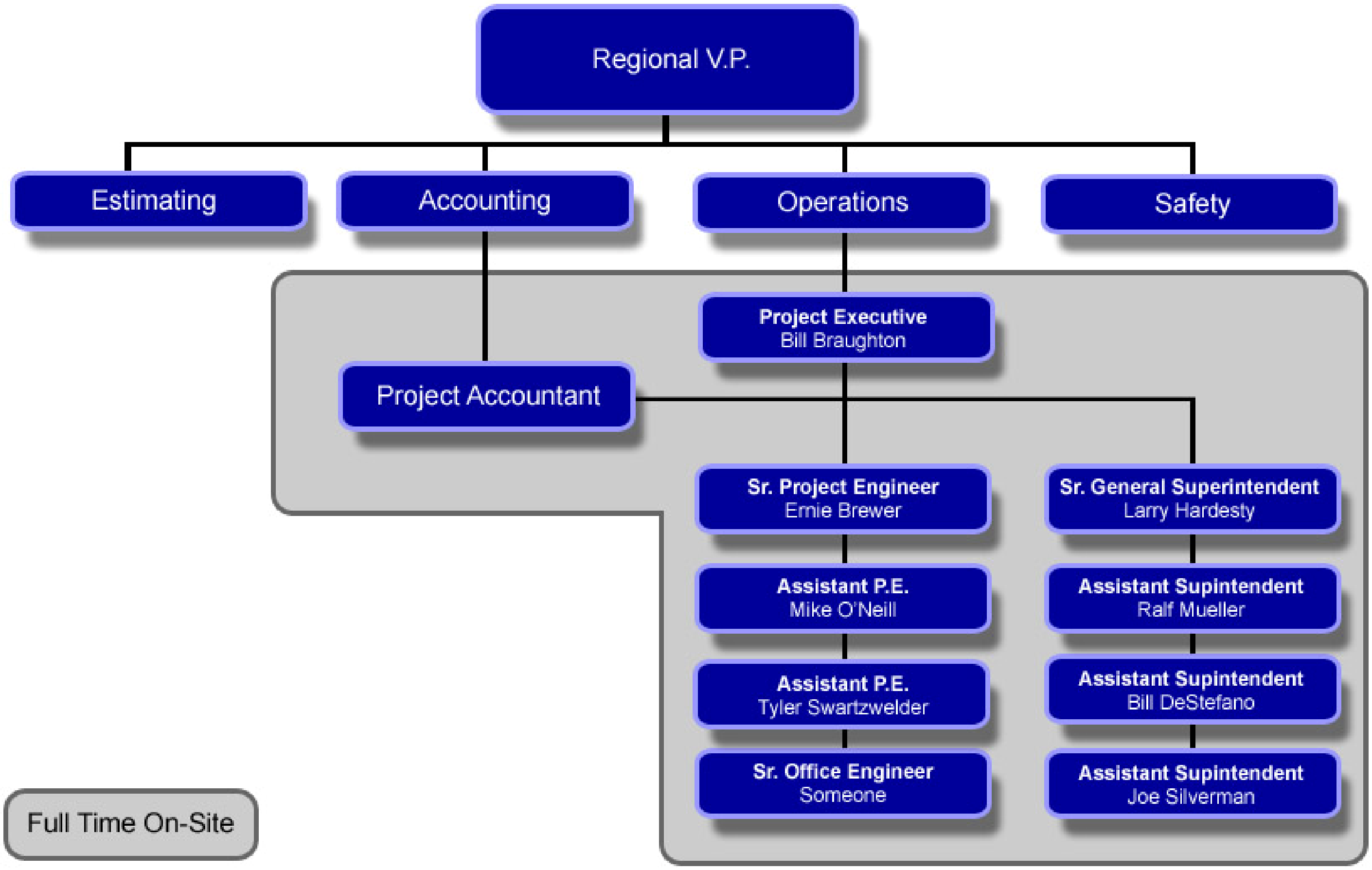
(3.2) Project Delivery System

Gilbane Building Company holds all contracts with the sub-contractors directly as a lump sum bid. Sturbridge hold contracts with the Martin Architectural group as well as the 3rd party testing firms. A close client relationship couple with a great networking team played a large part in the procurement of the project for Gilbane. Because Gilbane was brought on board early in the project, many issues were solved during the GMP negotiations phase. This was beneficial and saved time in early preconstruction.


Master Developer
Greenberg, Gibbons Commercial Corp
Owner
Sturbridge Annapolis Towne Centre, LLC.
FEE
GMP
Architect
The Martin Architectural Group
CM @ Risk w/ GMP
Gilbane ATC, LLC
FEE
Structural Engineer
The Harman Group
MEP Engineer
Gillian & Hartman, Inc.
3rd Party Testing
ECS Mid Atlantic, LLC.
LUMP SUM
Elevators
Delaware Elevator, Inc.
CIP Concrete
DGS Construction
Masonry
Caretti, Inc.
Steel
Baltimore Steel Erectors
Roofing
Citiroof Corporation
Glass and Glazing
Emmitsburg Glass Company
Electrical
Bausum & Duckett Elictri Co.
Mechanical / HVAC
Krick Plumbing & Heating

(3.3) Organizational Chart

On the GrandView project, Gilbane uses a relatively straight-forward and direct staffing plan. The hierarchical configuration allows for fast communication and flow of information and can be seen below.



(4.1) Building Systems Review

Architecture and Layout

Grandview is a 13 story condominium building with the first floor being tenant fit-out retail spaces. The exterior of the building was designed with elaborate architectural details, showcased by the three unique qualities

- Glass Fiber Reinforced Concrete Cornices (GFRC)
- Curtainwalls
- Cupola dome roofs

In order to tie the building in with the surrounding architecture, beige earth colors as well as green domes are used on the façade. Large glass curtain walls at three locations of the building compliment the appearance by adding long continuous lines of blue glass.

The interior of the building has two separate common areas for the condo owners to use collectively. The first being the second floor, containing fitness rooms, bars, social clubs, massage parlor, etc. The other common area is on the rooftop pool deck that includes the swimming pool, social club bar, BBQ Pit, etc. Floors 3-10 are typical with 15 units per floor. While the top two floors, 11 and 12, are penthouse units with 7 units per floor.

Construction

Grandview is just one of a multitude of buildings being constructed in the development at Annapolis Towne Centre. Because of the magnitude of the project multiple owners have hired multiple distinct contractors for each job. Sturbridge Homes, the owner of GrandView, hired Gibane ATC, as the CM @ Risk with a Guaranteed Maximum Price. A typical Design-Bid-Build delivery system was decided upon in which construction space had to be shared with other construction firms on site. Luckily, the site is not in a congested downtown area but in a rather wide open rural space. However, because all the projects are being constructed at once, there was limited space once foundations were established. Therefore, a high level of coordination and cooperation was employed to secure the success of every project.

The twist in the construction will come in a few months when Target, an adjacent store, wants to open to the public. This means that all forms of construction need to be blocked from view of the customers and service roads in which deliveries and equipment are brought in must be closed and re-routed in order to accommodate for customer traffic and parking. This could very well affect scheduling and have some sort of time impact on the project. Time will tell.

Structural System

GrandView is predominately a concrete 2-way flat slab system with shear resistance elements including a central elevator shaft and two stair towers at both the East and West ends of the building. The frame is made up of 16”-24” cast-in-place concrete columns. Favorable soil conditions allow a shallow foundation which consists of a 5” S.O.G with primarily 2’ footings and augured piles. Half of floor two will house more retail and has an 8” 1-way slab. Common residential floors 3-10 and penthouse floors 11-12 all have 8” 2-way slabs. The roof also has an 8” slab with the exception of a 16” slab around the pool area. W12x22 steel columns and miscellaneous structural steel hold up 3 cupola domes that house various mechanical systems on the roof. A typical masonry curtain wall is used for floors 3-10 with a stucco finish primarily at the lower retail portion of the building.

Electrical System

Two different service utilities are incorporated in GrandView in accommodate both the residential and commercial sections of the building. A 120/280V transformer is provided for the residential sections and is fed into a 4000A, 120/208V, 3PH, 4W switchboard. From the switchboard, (2) 2000A bus ducts are fed which help power (8) 1000A meter centers located throughout the levels. From these meter centers, individual distribution panels are fed which power the apartment panel boards.

The commercial section of GrandView is serviced by a 480/277V transformer. Housing equipment, which is used in multi-use areas, is connected by a 1000A 480/277V, 3PH, 4W switchboard. Redundancy is provided by a 350Kw/437.5 kVA 480/277, 3PH, 4W emergency generator.

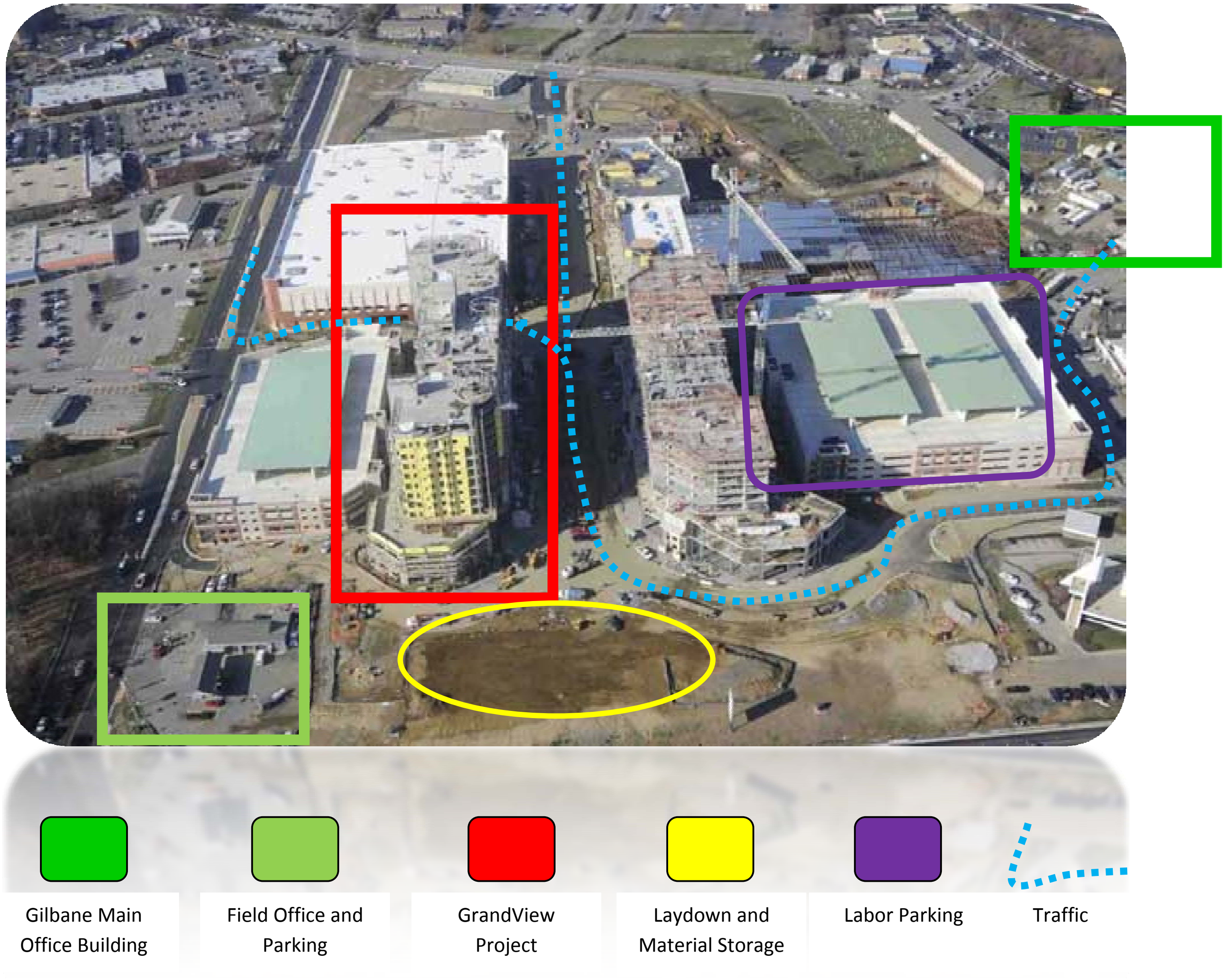
Mechanical System

Typical condo units, floors 2-10, have packaged (Magic-Pak) HVAC systems. These units are housed in vibration isolated closets in one bedroom of each unit. Additional design of an exterior ventilation system (simple copper tubing) was needed in order to ensure an extremely low noise level in each closet. Penthouse units and common spaces utilize split systems with gas fired furnaces.

(4.2) Local Conditions

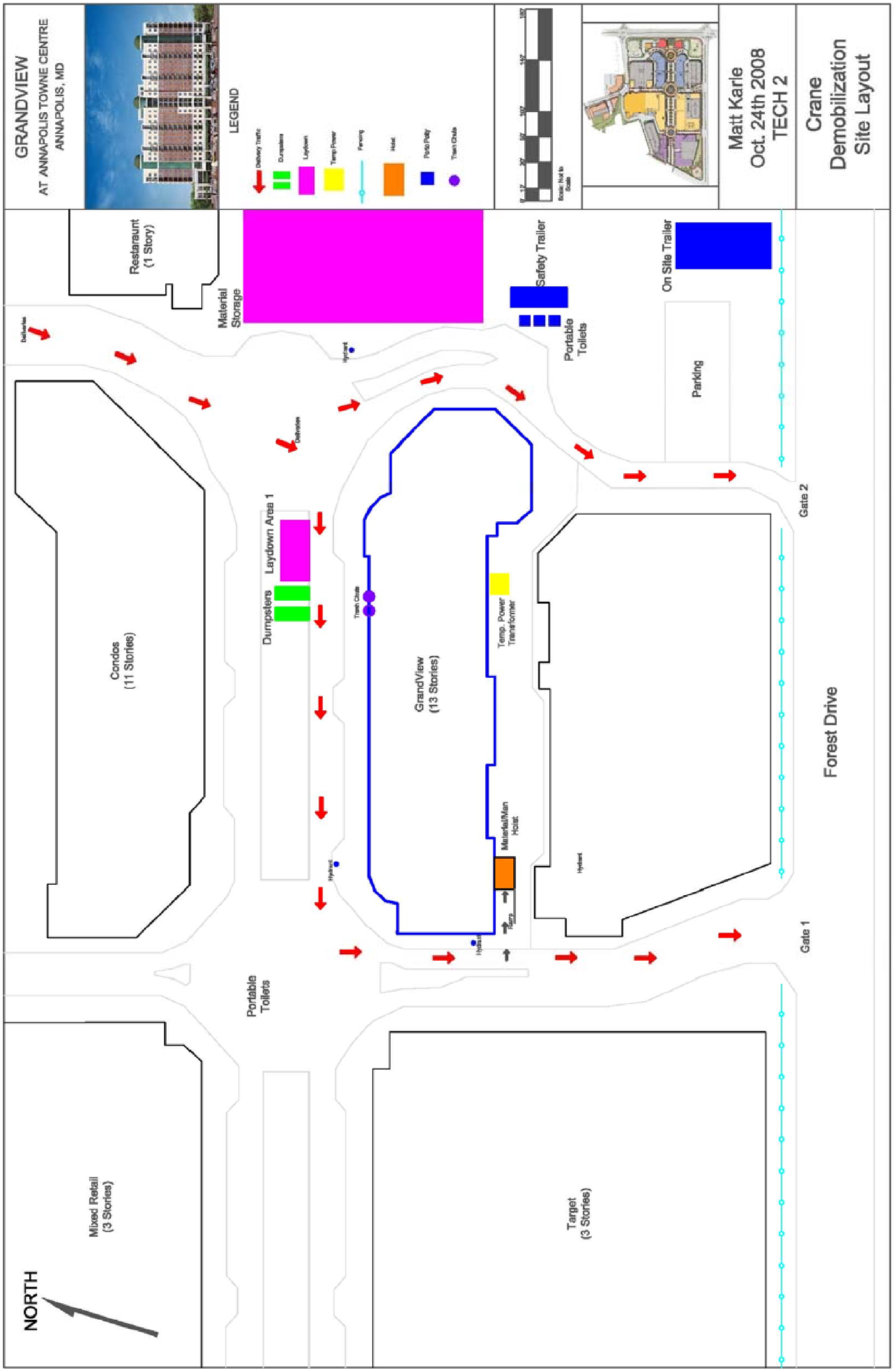
- Regional Soil Types: Clay, Sand, Gravel, Silt
- Preferred Method of Construction: Cast-in-Place Concrete, Masonry, Light Steel
- Available Parking: Existing Parking on outskirts as well as newly built parking garages on the site
- Tipping Fees: The Annapolis area usually imposes a $300-$400 tipping fee. No LEED certification required.

(4.3) Site Layout Overview



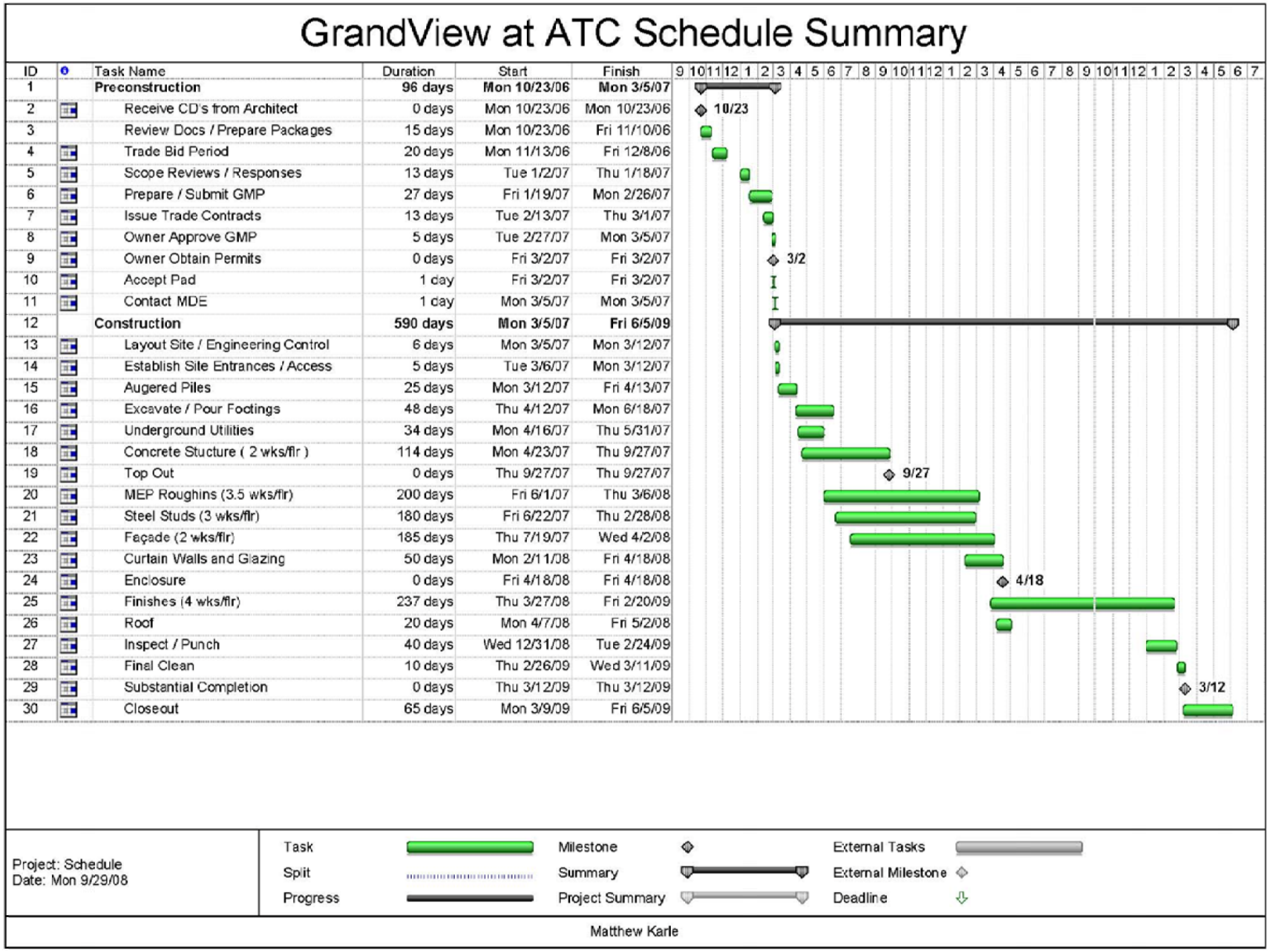
Shown above is the current site layout of GrandView at Annapolis Towne Centre. While it is extremely effective, there are some things that could be improved. The GC office is located relatively far away from the actual construction site as show by the dark green square. By re-locating it to the light green square, a closer proximity to both the site and material storage area would be achieved. Also, deliveries could be received and monitored from the Forest Drive Gate located directly above the proposed site office. A simple one way traffic pattern would provide easy flow of traffic and ease congestion. However, taking general conditions into account, the following site plans during three key phases of construction have held the current office location.

(4.4) Site Layout



Project Logistics

(5.1) Milestone Schedule



GrandView at ATC Schedule Summary

ID	Task Name	Duration	Start	Finish
1	**Preconstruction**	**96 days**	**Mon 10/23/06**	**Mon 3/5/07**
2	Receive CD's from Architect	0 days	Mon 10/23/06	Mon 10/23/06
3	Review Docs / Prepare Packages	15 days	Mon 10/23/06	Fri 11/10/06
4	Trade Bid Period	20 days	Mon 11/13/06	Fri 12/8/06
5	Scope Reviews / Responses	13 days	Tue 1/2/07	Thu 1/18/07
6	Prepare / Submit GMP	27 days	Fri 1/19/07	Mon 2/26/07
7	Issue Trade Contracts	13 days	Tue 2/13/07	Thu 3/1/07
8	Owner Approve GMP	5 days	Tue 2/27/07	Mon 3/5/07
9	Owner Obtain Permits	0 days	Fri 3/2/07	Fri 3/2/07
10	Accept Pad	1 day	Fri 3/2/07	Fri 3/2/07
11	Contact MDE	1 day	Mon 3/5/07	Mon 3/5/07
12	**Construction**	**590 days**	**Mon 3/5/07**	**Fri 6/5/09**
13	Layout Site / Engineering Control	6 days	Mon 3/5/07	Mon 3/12/07
14	Establish Site Entrances / Access	5 days	Tue 3/6/07	Mon 3/12/07
15	Augered Piles	25 days	Mon 3/12/07	Fri 4/13/07
16	Excavate / Pour Footings	48 days	Thu 4/12/07	Mon 6/18/07
17	Underground Utilities	34 days	Mon 4/16/07	Thu 5/31/07
18	Concrete Stucture (2 wks/flr)	114 days	Mon 4/23/07	Thu 9/27/07
19	Top Out	0 days	Thu 9/27/07	Thu 9/27/07
20	MEP Roughins (3.5 wks/flr)	200 days	Fri 6/1/07	Thu 3/6/08
21	Steel Studs (3 wks/flr)	180 days	Fri 6/22/07	Thu 2/28/08
22	Façade (2 wks/flr)	185 days	Thu 7/19/07	Wed 4/2/08
23	Curtain Walls and Glazing	50 days	Mon 2/11/08	Fri 4/18/08
24	Enclosure	0 days	Fri 4/18/08	Fri 4/18/08
25	Finishes (4 wks/flr)	237 days	Thu 3/27/08	Fri 2/20/09
26	Roof	20 days	Mon 4/7/08	Fri 5/2/08
27	Inspect / Punch	40 days	Wed 12/31/08	Tue 2/24/09
28	Final Clean	10 days	Thu 2/26/09	Wed 3/11/09
29	Substantial Completion	0 days	Thu 3/12/09	Thu 3/12/09
30	Closeout	65 days	Mon 3/9/09	Fri 6/5/09

Project: Schedule
Date: Mon 9/29/08

Matthew Karle

(5.2)Detailed Project Schedule

See Appendix A for details

(5.3) Grandview Cost Summary

Division	Division Name	%	Sq. Cost	Projected
0	Bidding Requirements	1.52	$2.67	$1,028,959
1	General Requirements	7.23	$12.74	$4,911,153
2	Site Work	5.13	$9.04	$3,486,503
3	Concrete	7.32	$12.89	$4,970,268
4	Masonry	2.95	$5.20	$2,006,338
5	Metals	1.08	$1.90	$731,112
6	Wood & Plastics	6.4	$11.28	$4,347,291
7	Thermal & Moisture Protection	4.85	$8.54	$3,293,365
8	Doors & Windows	3.21	$5.66	$2,181,016
9	Finishes	10.05	$17.70	$6,824,667
10	Specialties	0.76	$1.33	$514,111
11	Equipment	1.7	$2.99	$1,153,324
12	Furnishings	0.9	$1.59	$613,090
13	Special Construction	0.26	$0.46	$179,227
14	Conveying Systems	1.23	$2.17	$836,355
15	Mechanical	11.57	$20.38	$7,858,061
16	Electrical	7.62	$13.43	$5,175,656
21	Fire Suppression	1.45	$2.56	$985,837
22	Plumbing	4.84	$8.53	$3,288,016
23	HVAC	9.62	$16.94	$6,531,928
26	Electrical	7.83	$13.80	$5,320,263
31	Earthwork	0.93	$1.64	$633,603
32	Exterior Improvements	1.41	$2.49	$958,582
33	Utilities	0.12	$0.22	$83,412
	Total Building Costs	**100**	**$176.16**	**$67,912,135.00**

Research Topic: Energy and the Economy

How demand for energy will affect future Building Systems

(6.1) Problem Statement

The PACE roundtable discussed the importance of energy and what impacts it has on the economy and construction industry. It is well known that the control of natural resources is the most powerful economic position that can be held. Without energy, the United States economy would falter. The continually growing need for energy in the United States is speeding up at a tremendous pace. Efficiency and innovation are the keys to solving the energy crisis that our country is experiencing. One specific way to reduce our consumption is the development of alternate energy sources such as wind and solar technologies. By integrating these types of systems into our infrastructure, energy consumption and carbon emissions can be lowered, which would result in a cleaner and more economically friendly country.

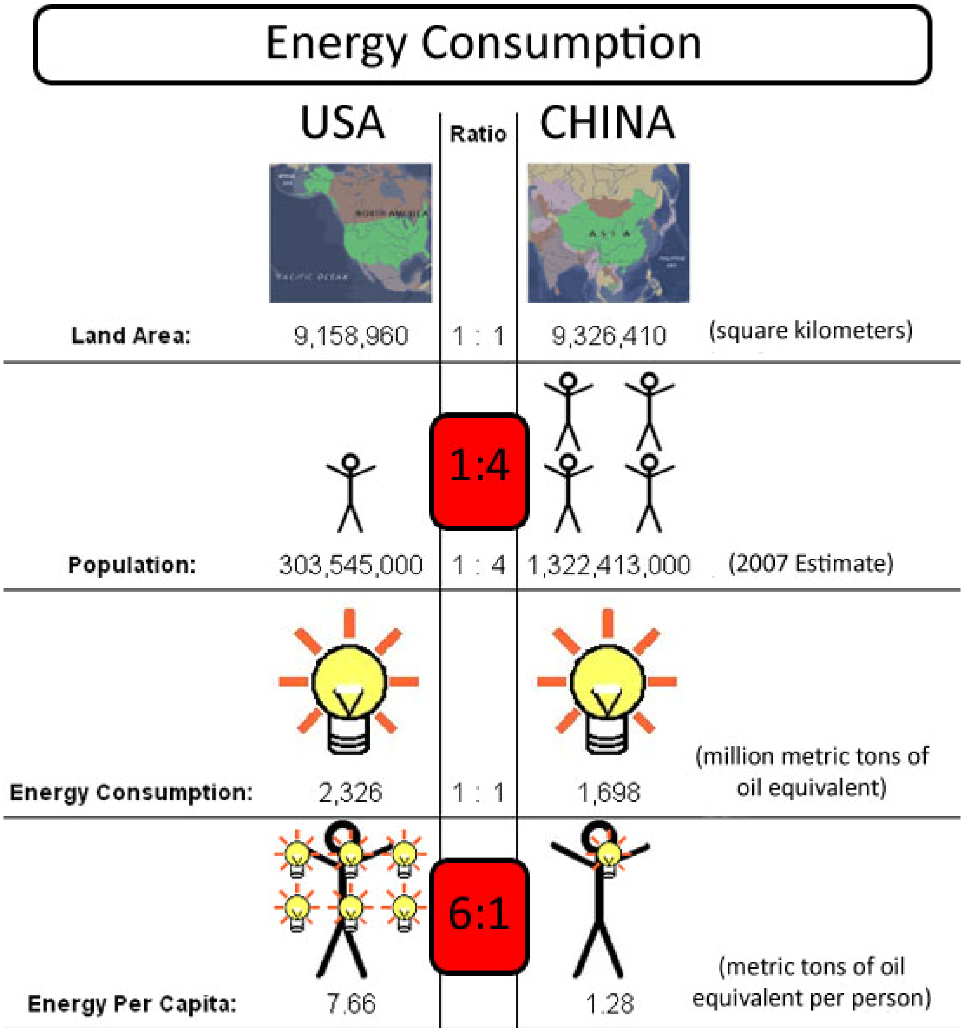
(6.2) Research Goals

The main goal of this analysis is to determine what the construction industry needs to do in order to integrate solar power into the design of a building through constructability aspects. Having the ability to run a building on its own self-generated power would have a great impact on both the economy and environment by reducing the dependency on foreign power sources and proving clean renewable energy that is integrated right into the building itself. The construction industry has taken small steps toward this goal in the last decade and plans to take even greater ones in the future. It is my goal to determine what alternative energy sources will be dominant in the future, and how they will affect the way that we design and integrate them into building systems. A more specific goal will be how they will be integrated into the United States' infrastructure through constructability; specifically focusing on solar power in the Mid-Atlantic region.

(6.3) Background

There is no doubt that as Americans, we are afforded luxuries that the rest of the world does not have access to. Whether it is freedom, schooling, or abundance of resources, it is our duty as human beings to use these luxuries responsibly. It is a known fact that the average American consumes over 25 times more resources than the average person from a developing country. That means that a family in a developing country would have to have 75 children to have the same environmental impact as an American family with three children.

As a quick reference to exactly how much energy the United States uses than the rest of the world. Refer to the diagram on the next page. It compares the United States with China, who some say will overtake the US as the dominate world power in the next few years.



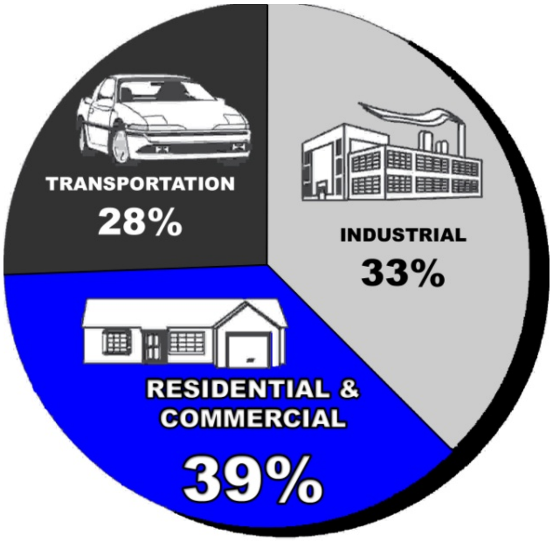
Energy Consumption

	USA	Ratio	CHINA	
Land Area:	9,158,960	1 : 1	9,326,410	(square kilometers)
Population:	303,545,000	1 : 4	1,322,413,000	(2007 Estimate)
Energy Consumption:	2,326	1 : 1	1,698	(million metric tons of oil equivalent)
Energy Per Capita:	7.66	6:1	1.28	(metric tons of oil equivalent per person)

Taking into the account the information provided in the figure above, it can be seen that while the United States and China share an almost equal land area and a relatively close total energy consumption (China still uses 27% less energy) it is striking how much energy the US uses compared to its population. Even though the US has about **one forth** the population of China, the average American uses more than six times the amount of energy than that of an average Chinese citizen. This makes one wonder, why do we need so much energy and what are we using it for?

Still even more staggering is the fact that while the US makes up for approximately 5% of the world population, it uses more than 24% of its resources. Again, the question is posed; why do we need so much and what are we using it for?

(6.4) A Look at Energy Consumption per Sector



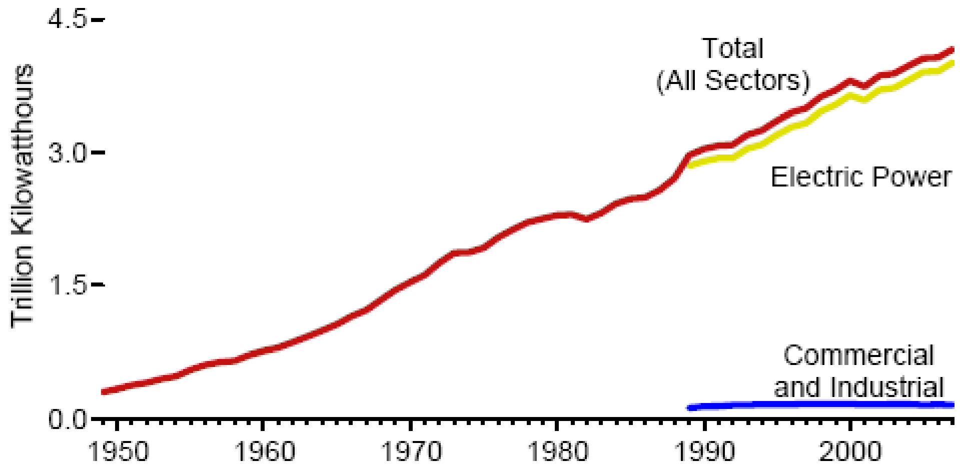
Energy consumption in the United States is broken down into three main sectors:

- Transportation
- Industry
- Residential and Commercial

Among these, residential and commercial account for the highest portion totaling 39%. Residential refers to any place where people live and commercial refers to a place that people work. These are grouped into the same category because the energy consumption is used in basically the same way.

When breaking down this category even further, we find that heating and cooling loads account for half of the total energy used. This is an important figure when talking about the construction industry because in order to save money, building must be constructed as efficiently as possible.

Advancements in technology have made it easier to save money on electric and gas bills, however, there is still room for improvement.



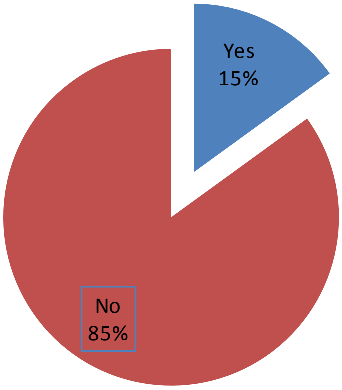
As you can see from the Figure __ above. The total US electricity net generation in all sectors grew from 0.3 trillion kilowatt hours in 1949 to 4.2 trillion kilowatt hours in 2007, failing to increase in only 2 years (1982 and 2001) over the entire span. Most generation was in the electric power sector, but some occurred directly in the commercial and industrial sectors.

(6.5) Solar Photovoltaic Panels and Construction

Solar panels have been around for years. However, our current economic situation coupled with global warming and a fading ozone layer has brought this abundant natural resource we call the sun back into the limelight. Integrating solar panels into buildings has always been a topic of hot discussion for architects, contractors and owners. Architects often found them un-slightly. The design of a solar panel, since just recently, has resorted to a rectangular shape that was dark in color and provided no aesthetic purpose at all. The extremely high initial investment of a solar array is one of the main detracting features that owners are subjected to. Depending on the size and type of system, the payback period could be as large as 60 years. While integrating the solar system into a building has become easier in the past few years through advancements in inverters and the ability to tie-directly into the grid, contractors still face schedule impacts when installing an array.

A survey was sent out to contractors in the Mid- Atlantic region, which asked what the most common constructability concerns of a solar PV system were. 40 results came back, with the majority of them coming from the Greater Washington, DC area. The following section will show relevant results of the survey and attempt to explain the reasons behind the answers.

The first and most basic question that was posed was:

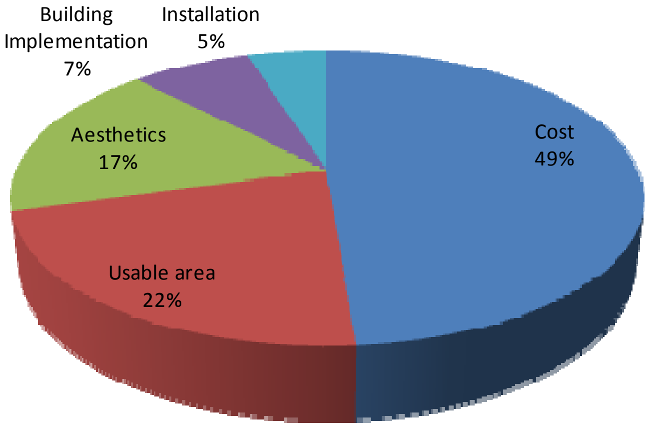


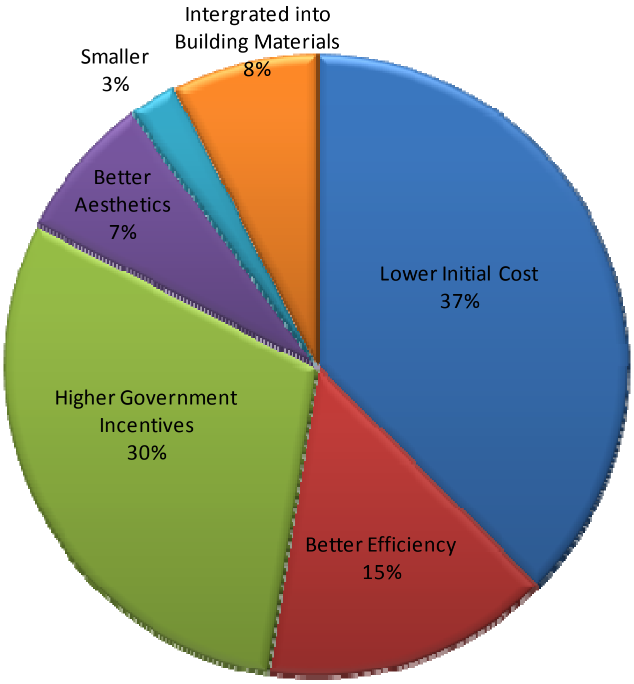
Would you be inclined to install PV panels on the current project you are working on or your home?

A staggering 85% of the 40 respondents polled said that they would not currently install a PV array on their current building or their home. The fact that such a high percentage declined installation alludes to the fact that something is still pushing consumers away from this energy saving technology.

What is the top constructability issue concerning the implementation of a solar array?

Cost was the number one answer that deterred people from installing a system. This is likely due to a low amount of government incentives available as well as the high cost of the panels and installation. Available area and correct orientation is also a major concern. If a building is not oriented South or if it has limited roof area, it makes solar arrays largely unappealing. The bottom three concerns were aesthetics , connecting the system to the building, and overall installation process.

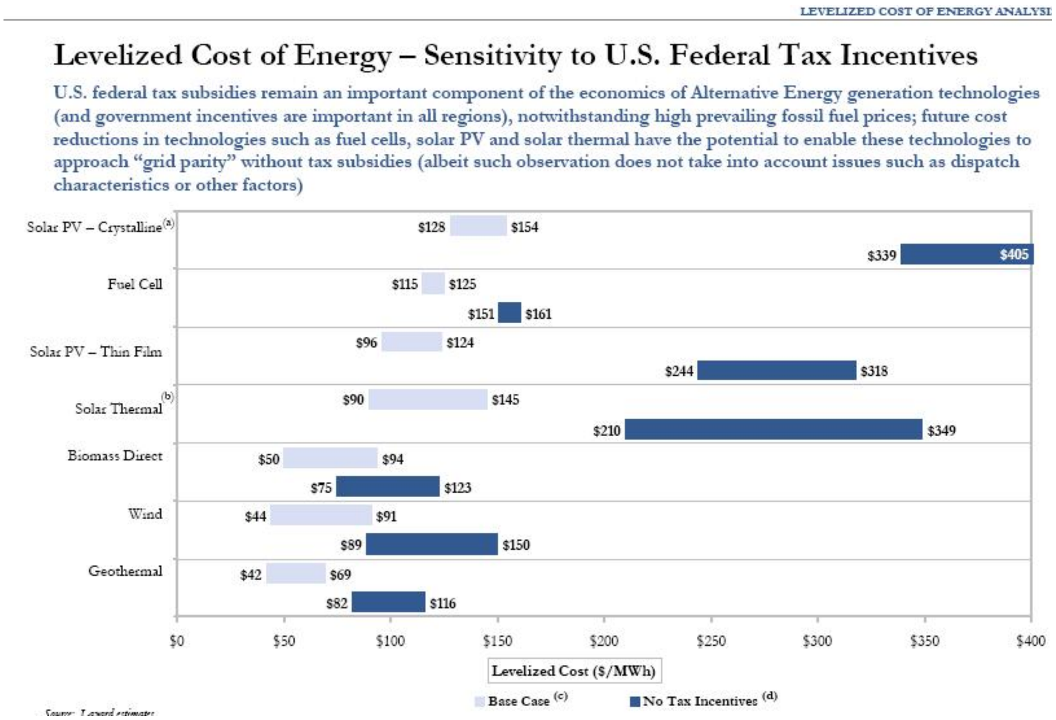




What would make you more willing to install a system?

Initial cost is the main concern in this question. Lowering manufacturing costs would be one way to reduce the initial installation cost of the system. The government has taken small steps in trying to promote the use of clean renewable energy within the country. Providing more incentives seems to be the overall mood of the polled population. A new budget presented by the Obama administration should help future incentives for solar production and installation grow.

Below is a chart of levelized energy cost with tax incentives. It shows costs of PV as they currently stand without any government funding and what amount would need to be given in order for it to compare to other leading renewable sources.



LEVELIZED COST OF ENERGY ANALYSI

Levelized Cost of Energy – Sensitivity to U.S. Federal Tax Incentives

U.S. federal tax subsidies remain an important component of the economics of Alternative Energy generation technologies (and government incentives are important in all regions), notwithstanding high prevailing fossil fuel prices; future cost reductions in technologies such as fuel cells, solar PV and solar thermal have the potential to enable these technologies to approach "grid parity" without tax subsidies (albeit such observation does not take into account issues such as dispatch characteristics or other factors)

Source: Lazard estimates

(6.6) Solar Growth

Decreases in the cost of installation and favorable regulatory environment should protect the continued growth of solar energy production in the US from effects of the economic crisis. It is imperative that the government provide greater incentives to implement such energy technologies so that the US may once again rely on its own self for energy.

Photovoltaic production worldwide has been doubling every two years, increasing by an average of 48% each year since 2002, making it the world's fastest-growing energy technology. 90% of this generating capacity consists of grid-tied electrical systems, in which PV panels generate electricity and interconnect with a utility's power line.

According to a recent report by Global Data, a business information company providing global business information reports and services, the US is the fourth largest solar PV market in the world. The market has grown from 168 megawatts (MW) in 2001 to around 1,111 MW by the end of 2008. Grid-connected solar PV grew to 61% of all solar PV installations, accounting for 677 MW in 2008.

The solar industry is poised for a rapid decline in costs that will make it a mainstream power option in the next few years, according to a new assessment by the World Watch Institute in Washington, D.C., and the Prometheus Institute in Cambridge, Massachusetts. Global production of PV cells, has risen six fold since 2000 and grew 41 percent in 2006 alone. While this growth is significant, it is still restrained by a shortage of manufacturing capacity for purified polysilicon, the main component is solar cells.

There is great news for future production with the advancements in thin-cell technology and more efficient production of polysilicon. The current situation will be reversed in the next two years as more than a dozen companies in Europe, China, Japan, and the United States bring on unprecedented levels of production capacity. Combined with technological advances, the increase in polysilicon supply will bring costs down rapidly. According to Prometheus estimates, the price is expected to decrease 40% in the next three years. By roughly 2010, electrical utilities will be looking to manage the competitive threat posed to their markets by distributed solar generation.

Results and Recommendations

The Maryland Energy Administration has proposed New Energy Incentives in order to promote building implementation in homes and businesses in Maryland, this would directly apply to GrandView if a solar PV array was installed in the future.

For homeowners:

- Increases a 10 percent tax credit for energy efficiency improvements to a 30 percent tax credit
- Eliminates caps for specific improvements (such as windows and furnaces), and instead establishes an aggregate cap of $1,500 for all improvements placed in service in 2009 and 2010 (except biomass systems, which must be placed in service after the act is enacted).
- Tightens the energy efficiency requirements to meet current standards. For residential renewable energy systems, the act removes all caps on the tax credits, which equal 30 percent of the cost of qualified solar energy systems, geothermal heat pumps, small wind turbines and fuel cell systems.
- Eliminates a reduction in credits for installations with subsidized financing

For businesses:

- A new 30 percent investment tax credit is available for projects that establish, re-equip, or expand manufacturing facilities for fuel cells, microturbines, renewable fuel refineries and blending facilities, energy saving technologies, smart grid technologies, and solar, wind and geothermal technologies. The credit also applies to the manufacture of plug-in electric vehicles and their electric components, such as battery packs, electric motors, generators and power control units. The credit may also be expanded in the future to include other energy technologies that reduce greenhouse gas emissions.

It is my recommendation that the US government provide higher tax incentives and grants for solar installation. Energy research funding should be focused on the development of higher efficiency solar panels and their overall manufacturing process. Savings can be passed on to the consumer by reducing the cost to manufacture such panels.

As far as the constructability of an array is concerned, advancements of cell mounting and delivery should enable manufactures the ability to incorporate PV's into building materials that would both save time when installing and provide more aesthetically pleasing features that are less noticeable.

Analysis 1: Photovoltaic Panel Implementation and Life Cycle

(7.1) Problem Statement:

Everywhere we turn in today's economy it seems that energy is driving all that we do. Between gas prices and electric bills, the cost of energy consumption is overwhelming. There are many technologies out there waiting to be tapped into such as the harnessing of the sun's power. Advancements in technology such as NanoSolar's super thin PV panels are giving the industry cheaper and more efficient options. Their manufacturing process allows PV panels to actually be printed out on a roll that is a fraction of the thickness of conventional panels and much cheaper.

The use of photovoltaic panels is not new to the industry. If PV panels were implemented into the roof system of GrandView, tenant's bills would be reduced and therefore money would be saved. Although PV panels are more expensive in the initial investment, I believe that the owners/tenants would benefit in the long run.

The roof of GrandView is for the most part, unused. There is a small portion in the center of the deck that is used for the social club and pool area. The rest is blocked from view. Would the area of the roof provide enough available space to install a PV system that would have a great enough impact as to reduce monthly electric bills?

* GrandView is connected to a large parking garage that has perfect southern exposure. The deck has a covered roof that is solely there to provide protection to the vehicles underneath.

(7.3) Research Goals:

It is my intention to determine the feasibility, advantages and disadvantages of implementing photovoltaic panels onto the roof of GrandView. A quantification of the amount of energy that a standard PV panel will be obtained and then translated into power generation that the building could provide as a whole. The analysis will cover the initial costs of installation as well as the energy savings and utility costs that would be accrued over a longer period of time. A separate CO2 quantification will be carried out to determine how much CO2 per year the implementation of a PV array will prevent from entering the atmosphere.

It is my hope that the implementation of PV panels in GrandView Apartment Complex will reduce the energy consumption by the tenants in the long term operation of the building. It is understood that there will be a greater upfront cost of the addition of the panels. However, through analysis, I hope to find that the long term benefits will outweigh the short-term investment and ultimately save the tenants and owner money.

Note: "CO2" stands for CO2-equivalents (which means other greenhouse gases are included).

(7.4) Tools:

a. PV Watts Calculator
b. National Renewable Energy Laboratory
d. Google SketchUp
f. Gilbane Building Company
g. Calls to solar panel companies

(7.5) Background

Solar power harnesses the sun’s energy to make clean electricity. Its value to the consumer depends on factors such as geography and local policies, including the terms for selling surplus power to the public grid. PV power is growing at a rate of about 48% per year and presents an economical and intelligent way to cut energy costs, reduce exposure to rising utility prices and help safeguard the environment.

There are predominately two types of photovoltaic technologies being implemented today; thick crystalline and thin film cells. The first and most predominately used is thick crystalline cells. While more efficient than their paper thin cousin, these cells weigh far more and use more material. Because of their size, they cost more and are more difficult to install. Efficiency rangers are between 11% and 14%. The total energy produced by a 223 W panel is about 12 Watts per square foot.

Figure 7.1: Thick Crystalline Solar Array

The most eco-friendly and quickest emerging type is known as ‘*thin film*’. These modules are made with less than 1% of the silicon used crystalline lines and are manufactured using automated equipment in fewer steps. This means a step-function change in cost per watt and a lower effective cost per kilowatt hours for large-scale applications. As far as efficiency goes, Sharp’s thin film modules convert nearly 9% of the sun's total energy into electricity and have almost reached the 10% mark. For every kW of rated power, thin film delivers more kilowatt hours-up to 10%-than its crystalline silicon cousin, due to substantially greater resistance to losses caused by typical mid-day operating temperature.

Figure 7.2: Thin Film Solar Array

When dealing with power storage and distribution of a solar array, two types of approaches can be taken. The array can either be a stand-alone or grid-tied system. Stand-alone systems are typically used in smaller applications where access to power lines is difficult. Benefits to a grid-tied system are as follows:

- Excess electricity produced by the PV array can be fed back into the grid and stored
- The array acts up as a support system during the peak hours of operation which lowers the power consumption from the grid
- There is a 100% efficiency rating

(7.6) Sun Path and Shadow Analysis

Because of protrusions on the roof, it was hard to determine where to place the solar arrays as to avoid any shadows. A study done by National Semiconductor claims that even if 8-16% of the array is covered during the day, it results in an average power loss of 35%-40%. Therefore, it is imperative that the arrays be placed in the area that receives full sunlight during the peak hours of the day.

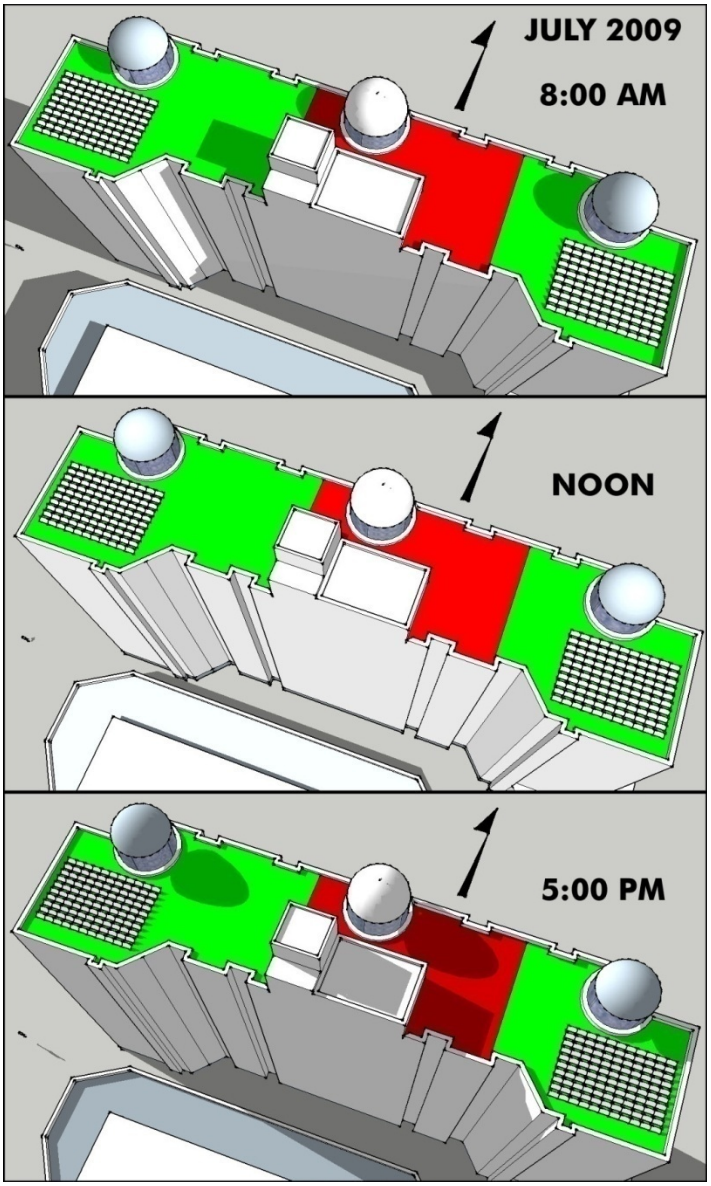


Figure 7.3: July Shadows

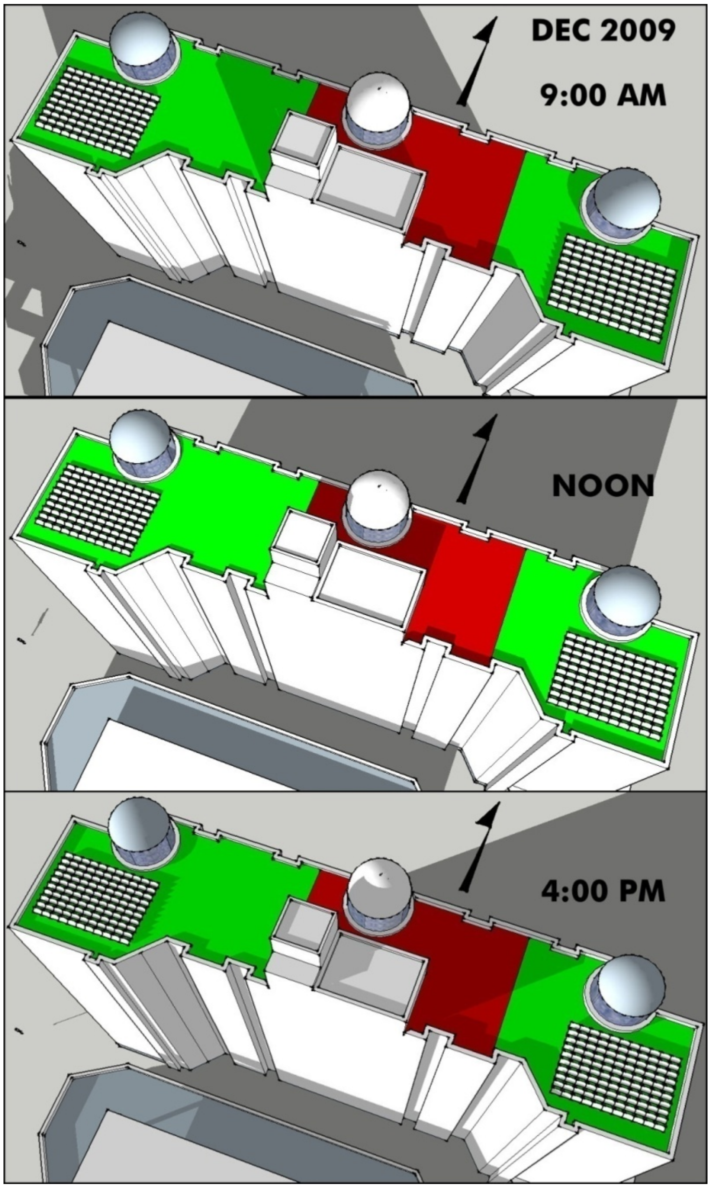


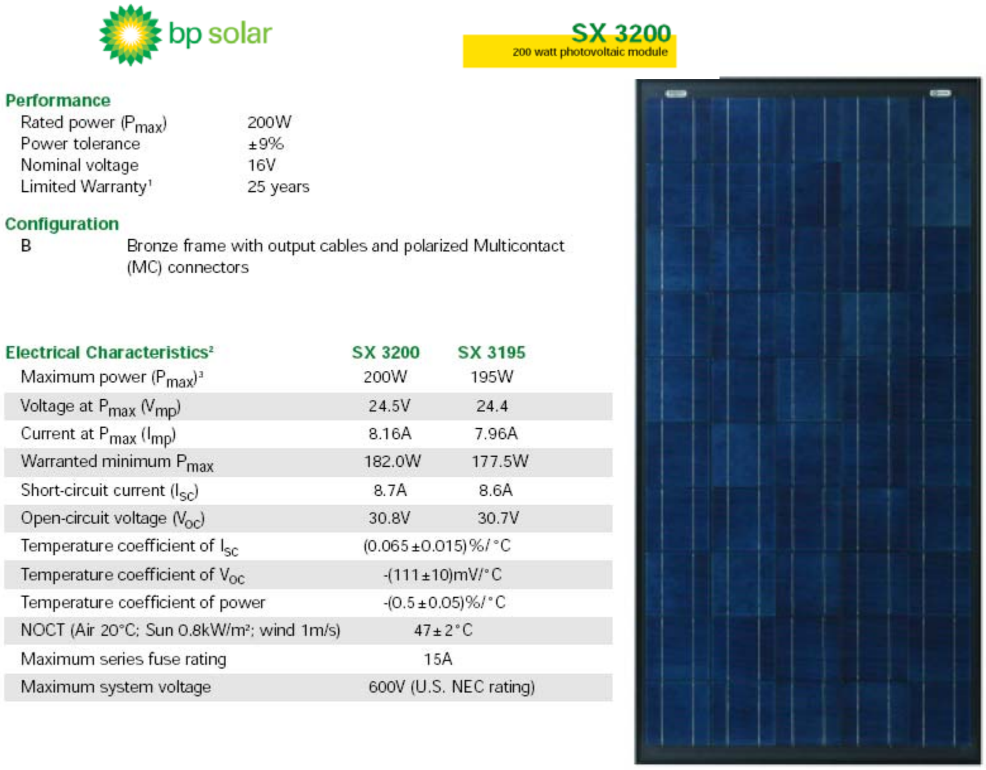
Figure 7.4: December Shadows

According to a shadow analysis of the building rooftop during each time of the day, the array was determined to be best suited in two separate areas on the East and West ends of the building.

(7.7) Product Information

In order to reduce utility costs of GrandView, several different solar ideas were presented. The first of which was integrating the panels into the glass foot windows in the south side of the building. This was quickly determined to be too small of an area and relatively ugly when talking about the aesthetic features of the building. Placement on the roof proved to be the best location for the solar arrays. In order ease calculations, a standard 200 W conventional multicrystalline silicon PV module was chosen.

Photovoltaic Panel Type: BP Solar sx3200 200 Watt PV Module



bp solar

SX 3200
200 watt photovoltaic module

Performance

Rated power (P_{max})	200W
Power tolerance	±9%
Nominal voltage	16V
Limited Warranty[1]	25 years

Configuration

B	Bronze frame with output cables and polarized Multicontact (MC) connectors

Electrical Characteristics[2]	SX 3200	SX 3195
Maximum power (P_{max})[3]	200W	195W
Voltage at P_{max} (V_{mp})	24.5V	24.4
Current at P_{max} (I_{mp})	8.16A	7.96A
Warranted minimum P_{max}	182.0W	177.5W
Short-circuit current (I_{sc})	8.7A	8.6A
Open-circuit voltage (V_{oc})	30.8V	30.7V
Temperature coefficient of I_{sc}	(0.065±0.015)%/°C	
Temperature coefficient of V_{oc}	-(111±10)mV/°C	
Temperature coefficient of power	-(0.5±0.05)%/°C	
NOCT (Air 20°C; Sun 0.8kW/m²; wind 1m/s)	47±2°C	
Maximum series fuse rating	15A	
Maximum system voltage	600V (U.S. NEC rating)	

Inverter Type: Xantrex GT 5.0 Series Grid Tie Solar Inverter

INVERTER SPECIFICATIONS: GT5.0	
Power Data	
Max AC Power Output	5000 W : 4500 W
AC OUTPUT (nominal)	240 V : 208 V
AC FREQUENCY (nominal)	60 Hz
Max Continuous Output Current	21-22 A
Max Output over Current Protection	30
Max Utility Backfeed Current	12:00 AM
Power Factor	>0.99
Output Characteristics	Current Source
Size	
Weight	58 lbs.
Dimensions	29" x 16 " x 6"

ELECTRICAL BREADTH

(7.8) Design Methodology

The following section will provide a detailed look into the design of the PV system and its eventual integration into the building through a step by step process.

GIVEN **Basic Array Design and Layout**

- Two (2) Separate Array locations at opposite ends of the roof
- Each Array consists of 100 panels arranged in rows of 10 (200 total panels)
- Panels are rated at 200W and measure 66" x 33" for a total area of 15.13 ft^2
- The Array is fixed facing directly south with the optimal 39.2 degree tilt for its location
- Xantrex GT5.0 Inverters have been chosen to convert to AC power

STEP 1 **Determining the Number of Panels in a Series**

Using the open circuit voltage of 30.8V per panel and the U.S. NEC Rating of 600V, it is determined that 19.5 panels are allowable per series which converts to a round number of 20 panels per series.

Number of Panels in Series = (600V)/(30.8V/Panel) = 19.48 = 20 Panels

STEP 2 **Sizing the Inverters**

In order to size the inverters, the number of panels in a series is multiplied by the max power of each panel.

Size of Inverter = (20 Panels)(200 W/Panel) = 4000 W = 4 kW

Based on this data the Xantrex GT 5.0 was chosen which is rated at 5000 W and has a 208 V AC output. The full specs for the GT 5.0 Inverter can be found in Appendix C

STEP 3 **Determining the Number of Inverters Required**

Calculating the number of inverters required is as simple as dividing the total number of panels in the array by the number of panels in a series. The result yields a total of 10 inverters.

Number of Inverters = (200 Panels)(20 Panels/Series) = 10 Inverters

KNOWN — Electrical Impact and System Integration

- Integrate into powering the rooftop and all of the corridor lighting loads
- Electrical Rooms on the Roof and 12th floors have room to house the inverters
- Rooms are close to inverters and array system which requires minimal wiring
- Inverters are considered single phase loads and require 2 “spare locations” for the 2 phase wires
- Each of the two separate 20 Kw array systems will be fed into two separate panel boards

STEP 1 — Confirm Panel Boards have Sufficient Load Capacity

Using the open circuit voltage of 30.8V per panel and the U.S. NEC Rating of 600V, it is determined that 19.5 panels are allowable per series which converts to a round number of 20 panels per series.

Max Panel Loading = (175 A)(208V)$(3)^{1/2}$ = 63046.6 W = 63 kW

STEP 2 — Checking to Confirm the Total Inverter Load on the Panel Board

Since 10 Inverters will be placed on this panel board, it is necessary to determine whether or not the total load of the inverters is less than the panel board load capacity. In order to determine the number of inverters was multiplied by the load that each supplies.

Total Inverter Load = (10 Inverters)(4.0 kW) = 40 kW

From the above calculations it is determined that 40 kW < 49.8 kW therefore the Panel Board can support the load supplied by the inverters.

The 49.8 kW comes from the total capacity minus the existing load (63 kW – 13.2 kW)

STEP 3 — Determining Load Each Inverter has on the Panel Board

For a single phase, it is determined that the load of each inverter needs to be divided by 2 in order to get the loading of each on the panel board.

Load Per Inverter on P.B. = (4.0 Kw)/(2) = 2.0 kW

STEP 4 Sizing the Circuit Breakers

To size the circuit breakers, divide the watts of the inverter by 208V. this will yield amperes.

Circuit Breakers Size = (5000 W)/(208 V) = 24.04 = 25A Circuit Breaker

However, each inverter is only receiving 4000 W therefore, as 20A Circuit breaker should suffice. It can always be switch out for a higher capacity if the array is added to in the future

STEP 5 Wire Sizes

Based off the circuit breaker size and considering the inverter comes with a ___ knockout for the wires, it is determined that 2 - #12 AWG and 1 #12 AWG wire sizes should be used. This conforms to THHN/THWN AT 600V.

- **(2) #12 AWG (THHN) +(1) #12 AWG (THWN)**

Load Description	Wire and Conduit	Kw Load			CB/Phase	Circuit No.	Φ
		A	B	C			
INVERTER 1	(2) #12 AWG	2.0			25/2	13	A
	(1) #12 WAG G		2.0			15	B
INVERTER 2	(2) #12 AWG			2.0	25/2	17	C
	(1) #12 WAG G	2.0				19	A
INVERTER 3	(2) #12 AWG		2.0		25/2	21	B
	(1) #12 WAG G			2.0		23	C
INVERTER 4	(2) #12 AWG	2.0			25/2	25	A
	(1) #12 WAG G		2.0			27	B
INVERTER 5	(2) #12 AWG			2.0	25/2	29	C
	(1) #12 WAG G	2.0				31	A

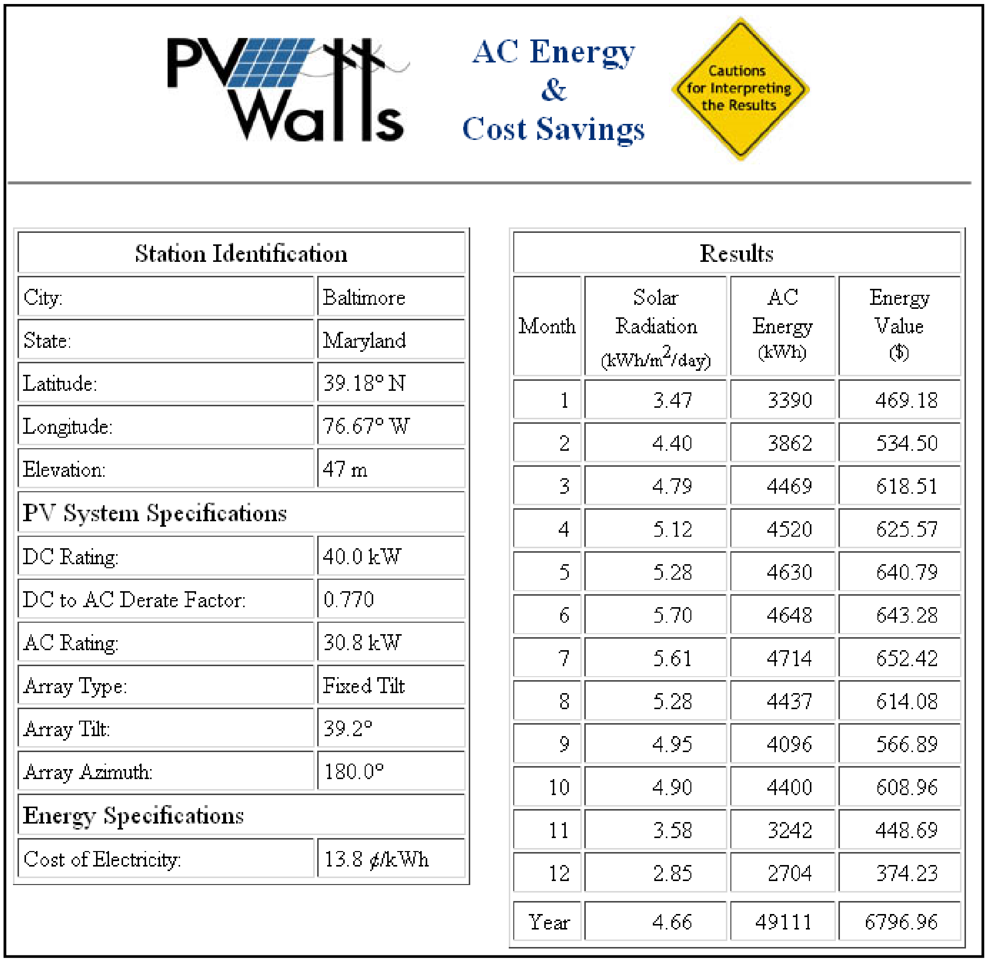
Table 7.1: Inverter 1-5 Panel Layout

Φ	Circuit No.	CB/Phase	Kw Load			Wire and Conduit	Load Description
			A	B	C		
A	14	25/2	2.0			(2) #12 AWG	INVERTER 1
B	16			2.0		(1) #12 WAG G	
C	18	25/2			2.0	(2) #12 AWG	INVERTER 2
A	20		2.0			(1) #12 WAG G	
B	22	25/2		2.0		(2) #12 AWG	INVERTER 3
C	24				2.0	(1) #12 WAG G	
A	26	25/2	2.0			(2) #12 AWG	INVERTER 4
B	28			2.0		(1) #12 WAG G	
C	30	25/2			2.0	(2) #12 AWG	INVERTER 5
A	32		2.0			(1) #12 WAG G	

Table 7.2: Inverter 5-10 Panel Layout

(7.9) Array Analysis using PV Watts Energy Calculator

The size of a photovoltaic (PV) system is its nameplate DC power rating. This is determined by adding the PV module power listed on the nameplates of the PV modules in watts and then dividing the sum by 1,000 to convert it to kilowatts (kW). PV module power ratings are for standard test conditions (STC) of 1,000 W/m^2 solar irradiance and 25°C PV module temperature. The default PV system size is **40 kW**. This corresponds to a PV array area of approximately **3025 ft^2** (280 m^2).



Station Identification	
City:	Baltimore
State:	Maryland
Latitude:	39.18° N
Longitude:	76.67° W
Elevation:	47 m
PV System Specifications	
DC Rating:	40.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	30.8 kW
Array Type:	Fixed Tilt
Array Tilt:	39.2°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	13.8 ¢/kWh

Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	3.47	3390	469.18
2	4.40	3862	534.50
3	4.79	4469	618.51
4	5.12	4520	625.57
5	5.28	4630	640.79
6	5.70	4648	643.28
7	5.61	4714	652.42
8	5.28	4437	614.08
9	4.95	4096	566.89
10	4.90	4400	608.96
11	3.58	3242	448.69
12	2.85	2704	374.23
Year	4.66	49111	6796.96

Figure 7.5: PV WATTS Calculation Results for 40 kW array

To calculate the energy production of a solar array in the Maryland region, a program developed by the National Renewable Energy Laboratory was used. The PV Watts Calculator determines the cost of electricity a solar array produces given the location of the array and the tilt. For this analysis, two different tilt angles are shown. This is partly due to the construction costs of tilting the array. For all intensive purposes, the maximum solar gain with the tilt of 39.2 degrees will be used in the calculations.

As for C02 emissions otherwise known as greenhouse gases (GHG) , the EPA reports that each kilowatt-hour of electricity produced from coal creates 2.3 lbs. of carbon dioxide.

(7.10) Constructability of Support System

It is important to note that the array on the roof will be a fixed tilt array set at 39.2 degrees in order to maximize energy absorption. This also allows the array to partially shade the section of the roof that it is on while letting air pass underneath.

In this case a lightweight structural aluminum frame for each row will be constructed prior to mounting. The array could in fact be placed flush with the roof at a 0 degree tilt. When this scenario was run in the PV WATTS calculator it was determined that the overall (AC) output of the system would be approximately, 42,009 kWh per year. This is 7,102 kWh or 14% less than if it were mounted on tilted support structure.

Constructability issues of flush mounted system:

- Reduced initial investment in structural support system and installation
- A greater area available for PV array because the panels would not need spacing between them
- Lighter load on the roof itself because no structural support necessary
- Maintenance becomes an issue when trying to access panels in the center of the array
- Higher heat gain conducted through the roof due to lack of air circulation under the panels

Constructability issues of structural tilt mounted system:

- Higher initial investment due to support material and labor costs
- Slightly higher load on roof due to support system
- Shading effect comes into play which reduces solar gain on the roof

Structural Materials and Cost of Installation

A quote from Tubular Steel Inc was maintained outlining the design and labor cost of a structural support system needed to house the proposed 39.2 degree fixed tilt array. It was determined that a $4700 total implementation price would be incurred. This resulted in an additional **$1.50** per square foot be added to the base amount of **$6.50** for flush mounted system, making the total panel and installation cost of a tilted array system **$8.00** per square foot. The initial investment of

Post-Report-Completion Analysis (Angels and Spacing)

Due to a realization at the end of the report, I decided to add this section just to clear up my thinking process and mistake. It was determined after a quick geometry calculation and sun angle calculation that the spacing required between rows of panels would need to be 50" as to not cast shadows on the panels behind them during the winter months. Due to the relatively low energy loss compared to a flush mount system and the fact that 1.5 more panels could be placed in the same area with a flush mounted system, it is only logical that a flush mounted system be used. However, this stage of enlightenment was realized after the completion of the report, and therefore should be noted, but the final results will be given with the tilted fixed support system.

(7.11) PV Impact on Building Cost and Environment

After considering the shadow analysis of GrandView's rooftop and the incentive to keep the solar array hidden from pedestrian and adjacent views for aesthetic purposes, the following cost and power analysis provides initial cost estimates and environmental impacts.

It is assumed the area provided on the roof will not take GrandView off the grid. That is, it cannot provide enough power to all the residencies by itself. Therefore, it is proposed that the solar array system be specifically tailored to power the rooftop amenities such as the lounge, area pool area, club and interior corridor lighting. A solar energy system is ideal for this type of situation because the peak energy production occurs during the summer when this area is used the most. During the winter, solar energy production decreases with the use of the area.

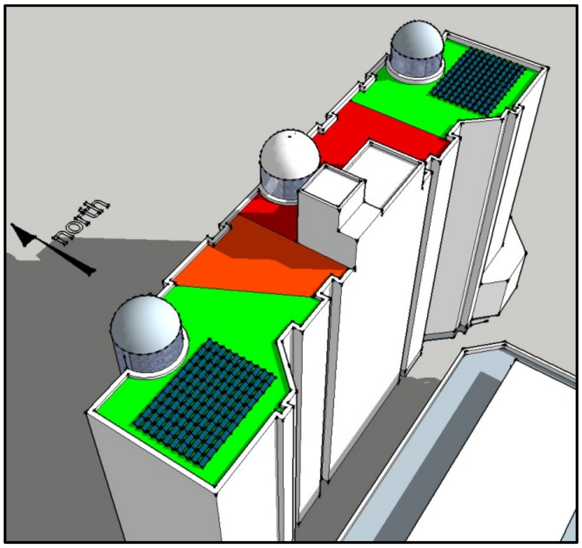
The first thing that needs to be analyzed is the potential solar radiation gain that an array system of this size and location can produce. Using the PV Watts software seen on the previous page the following results were obtained.

Power Data (kWh/m2day) Angled Array- Annapolis, MD												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Power	3.49	4.41	4.79	5.11	5.26	5.67	5.59	5.27	4.95	4.91	3.59	2.86

Table 7.3: Generated Power Data per Month

For Annapolis, MD a 40 kW array system can produce a total of 49,111 kWh per year (AC), with the maximum gain occurring in June and the minimum occurring in December.

The initial investment of a system is often one of the main detracting points when thinking about installation. It is important to remember that while the initial investment may be significant, the overall life-cycle cost and environmental impact should also be considered and weighed greatly. This is due to the fact that over time, if properly maintained and utilized, the system should pay for itself. After that point it is considered savings.



Cost Offset: When analyzing the amount of power generated by the solar array, the following figures where used in accordance with the Power Data shown in ***Table 7.3*** above:

- Panel Power: 200W (Max Power)
- Panel Voltage: 30.8V (Open Circuit Voltage)
- Maryland Energy Price: $0.138/kWh
- Coal CO2 equivalent of 1.6 lbs./kWh
- Panel and Installation: $8.00 / watt

Initial Investment

While researching the cost of photovoltaic system and installation, it was determined that the overall cost of would amount to about $8.00 per watt including the installation and support structure for the incline of 39.2 degrees needed for maximum solar gain. This is relatively low due to some other figures that were found. It was assumed that the lowest cost found would be used due to rapid technological advances in solar technology including thin film. The following is the initial investment cost of the system:

INITIAL INVESTMENT			
Item	Quantity	Cost / Unit	Total Cost
PV Panels	40000 W	$8.0/W	$320,000.00
Inverters	10	$3,060	$30,600.00
Savings	Federal: $10,000		-$10,000.00
	State: $3,000		-$3,000.00
Total Cost			**$337,600.00**

Table 7.4: Initial Investment

Assumptions on incentives were made on the fact that the Maryland Energy Administration is considering revising its clean energy grant programs for fiscal year 2010 (which starts July 1, 2009.) This enables residents to claim 30 percent of the total installed cost of solar PV, solar hot water, and geothermal heat pump systems against their federal income tax.

For photovoltaic property the maximum incentive was taken totaling $10,000 because the size of the system exceeds per watt incentive calculations.

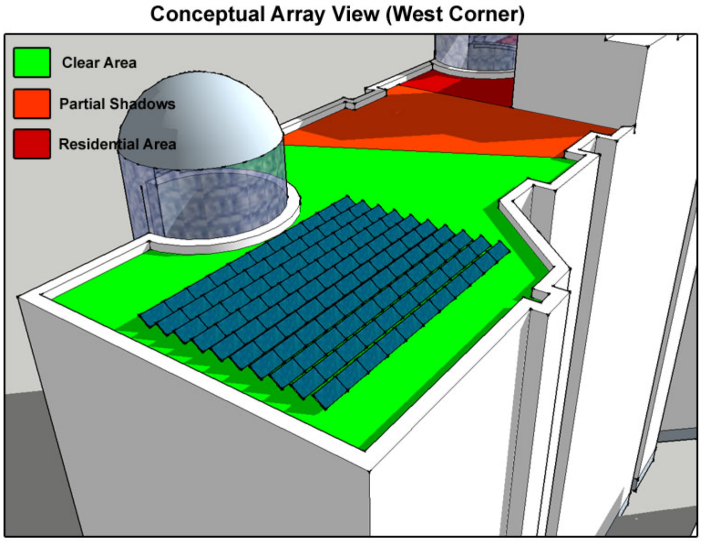


Figure 7.6: Conceptual West Array

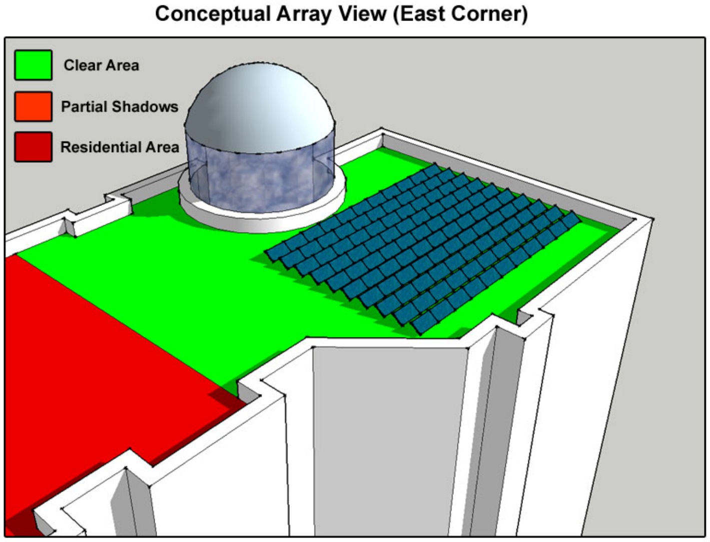


Figure 7.7: Conceptual East Array

(7.12) Savings and Life-Cycle

Using the data provided by the PV Watt Calculator and environmental factors, the following power and CO2 savings was calculated:

SAVINGS PER YEAR			
Month	(AC) kWh/month	Savings($)	Savings(lbs of CO_2)
JAN	3390.00	$469.18	5424
FEB	3862.00	$534.50	6179
MAR	4469.00	$618.51	7150
APR	4520.00	$625.57	7232
MAY	4630.00	$640.79	7408
JUN	4648.00	$643.28	7437
JUL	4714.00	$652.42	7542
AUG	4437.00	$614.08	7099
SEP	4096.00	$566.89	6554
OCT	4400.00	$608.96	7040
NOV	3242.00	$448.69	5187
DEC	2704.00	$374.23	4326
TOTAL SAVINGS		**$6,797.10**	**78,579**

Table 7.5: Electrical Cost Savings and CO2 Savings

The addition of the 40 kW solar array would essentially save **$6,800.00 on electricity** cost and keep **39.3 tons of CO2** from entering the atmosphere annually. This equates to a total of $136,000 of energy produced (assuming the cost of energy stays the same) and 786 tons of CO2 saved over the span of 20 years.

This would reduce its total carbon footprint due to electricity consumption by **%13.**

Considering the Initial Investment of $337,600 and the fact that the array provides $6,800.00 per year in savings, the total payback period for the system would be approximately **49 years**. However, this did not take into account the inflation of energy price over time. Therefore, the payback period would most likely be less the 49 years. Assuming that the life cycle of the building is 50 years, the initial investment would in the end pay off. However, newer and more efficient technologies are likely to emerge that surpass the existing solar technologies.

Knowing that only a small amount of energy can be produced due to the limited roof area and cast shadows, I wondered if it would be possible to provide GrandView with enough solar power that it did not need to tap into the grid for energy. GrandView provides parking in the adjacent 4 story parking garaged that is connected to the lobby by a bridge. Most of the upper lever is open except for a small 'shade' roof centered in the middle. The question posed was would I be able to erect a solar array that would provide both shade for the cars beneath it as well as enough energy to power GrandView's electrical load.

(7.13) Quick Analysis: Feasibility of Utilizing Adjacent Parking Structure

An adjacent parking garage that provides 4 levels of parking for the tenants of GrandView provides a perfect area to install a large additional array. The 4th floor of the structure is open air space; therefore, a shading structure could be erected for the cars parked on the roof that incorporates solar panels. An array of this size using 200 watt PV panels would result in **43,900 ft2** which is equivalent to the area of a football field not including the end zones. Obviously, there is not nearly this much available space on the roof of GrandView so taking the residencies off the grid using solar power in this case is highly unlikely. Therefore, the goal of PV panel implementation would be to reduce the monthly energy consumption costs and provide clean renewable energy.

> ***Theory**: In theory, if an efficient layout was used on the roof of GrandView for a solar array, and the following was neglected; rooftop views, aesthetics, structural loads, and cost, a potential 4000 ft2 solar array collected could be constructed. In addition to the roof area, the attached parking garage could be utilized. Adding a solar array to the roof of the garage would not only give an additional 43,900 ft2 of collective surface, but would also provide protection to the parked cars which currently are only protected by a small shading roof that already exists. The total collective area provided by both the roof and garage would be 46,900 ft2, which would provide 10 times the amount of energy as just a roof array system alone as well as shade for parked vehicles.*

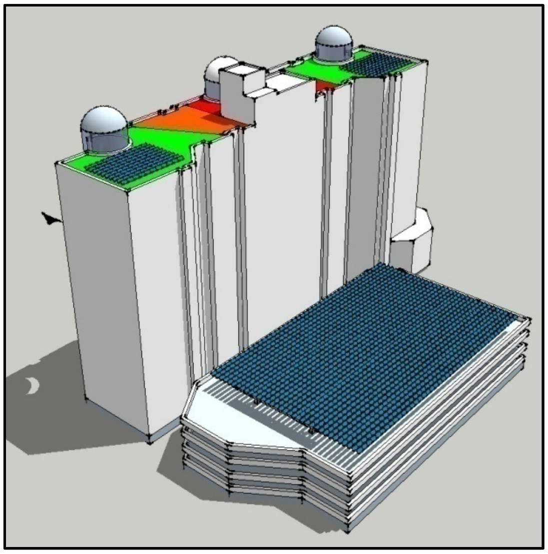


Figure 7.8: Solar Array above Parking Deck

INITIAL INVESTMENT			
Item	Quantity	Cost / Unit	Total Cost
PV Panels	630000 W	$7/W	$4,410,000.00
Inverters	3	$100,000	$300,000.00
Structure	Support		$180,000.00
Total Cost			**$4,890,000.00**

Table 7.6: Initial Investment

Total Area:	46,900 ft2
Number of Panels	3116
Power Provided	630 kWh
Total System Cost	$ 4.9 million
Payback Period	46 years
Amount of CO2 saved	618 tons/year

Assumptions:

- Best Case Scenario With incentives and Tax Credit in Maryland
- Assume 13.8 cents per kWh does not inflate over time
- Payback Period accounts for $107,000 energy savings per year
- CO2 savings is equal to 1.6 lbs of coal burned per kWh
- CO2 savings accounts for 774,000 kWh of AC produced per year

(7.14) Constructability Review

In order to determine the feasibility of construction and the impact the installation of the panels would have on the design of the building, some key areas of constructability were looked at.

Panel Weight
In order to ease the concern of whether or not solar panel addition would require a structural re-design, BP solar panels are extremely lightweight (34 lbs). as to not exceed load limitations.

Mounting
A fixed mounting system at a 39.2 degree tilt is the optimal design. Each row would need its own support system which would consist of simple steel tubing or wood.

Inverters
Since the inverters tie directly into the panels, there are no batteries to deal with which alleviates added construction and maintenance time as well as cost

Wiring
The system is set up so each panel is pre-wired. All that needs to be done once they are in place is a quick connection.

Maintenance
Solar PV systems are considered highly durable and require a minimal amount of maintenance. Since, the panels are at roof level and have gaps between each row, if a panel does malfunction, it can be accessed extremely easily.

Utility and Inspector Requirements
A local inspector would need to be contacted in order to evaluate the system and determine if it meets the area requirements. The utility company would need to be notified prior to connection into the grid.

Transport
Due to the lightweight nature of the panels, the elevators can be used to transport them to the roof. At 34 lbs, a roofer should have no trouble carrying and placing each panel by themselves. A system of this size could easily be installed in a day.

Schedule Impact

The impact that this type of system would have on the schedule is minimal. It can be installed at any point after the completion and water tight test of the roof. It is not considered to be on the critical path and therefore trades can work on the installation virtually unimpeded.

Results and Recommendations

Through the analysis the following results overall results were determined:

- A 40kWh solar array would occupy ft^2 of roof space and provide **49,111 kWh** annually
- An array system of this is would require a **$337,600.00** initial investment
- Through a savings and life cycle cost analysis, it was determined that **$6,797.00** worth of electricity would be produced annually. This equates to an approximate annual savings of $49.00 per apartment unit.
- The environmental impact of this system prevents **39.3 tons of CO2** from entering the atmosphere annually and reduces its total carbon footprint due to electricity consumption by **%13**
- The payback period of a 40 kWh array system would be **49 years**.
- If the adjacent parking garage was utilized a **630 kW** solar array system could be erected that would generate power for GrandView as well as provided shade and protection for the cars.

These results have led me to recommend that the array system not be installed *at this time*. From an owners view, the benefits do not outweigh the initial investment and environmental impact.

However, solar technology has been advancing exponentially in the last few years with thin film technology and more efficient designs. New government incentives and energy acts bring down initial investments costs in the near future. Based on these facts, it is my recommendation that an eventually solar array be installed in 5 years after new low cost panels are introduced into the market and government incentives allow for a greater reduction in initial investments.

Since the roof will remain unused in the areas specified in the analysis, quick installation would be possible and there would be minimal disturbance to the tenants.

The Alternative Thermal Window Design in the following analysis also got me thinking of a way to create a larger surface area for the solar array on the roof while simultaneously providing a shade curtain for the south facing wall during the summer months to cut down on solar heat gain through the fenestrations. If I had another chance to do a solar analysis redesign, I would definitely look into this option. Please see Figure 7.9 for a rough idea of how the cantilevered shading system would work.

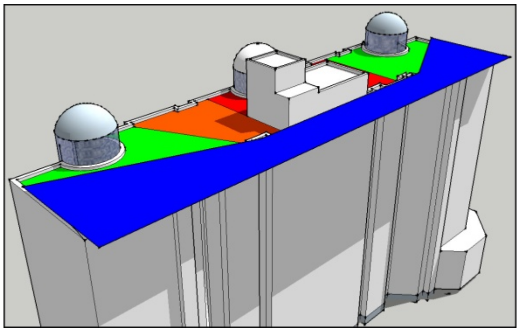


Figure 7.9: Proposed Solar Curtain

The blue area indicates a cantilevered glass curtain design that has solar cells implemented in it with spacing to allow light through. This would both collect and shade the southern façade of the building letting some light through in hopes of reducing the cooling cost incurred from solar heat gain.

Of course this would have a great structure impact and would require a whole new breadth in this area.

Analysis 2: Alternative Thermal Window Design

(8.1) Problem Statement:
In the first analysis, the cost and environmental impacts of the addition of solar PV panels to the roof of GrandView was determined. Keeping with the theme of solar energy and minimizing schedule impact and the fact that the building employed an advanced Henry air/moisture skin, it was determined that the windows installed in the residential units were not meeting the overall envelope purpose of saving energy. What would happen if alternative thermal window designs were substituted, and what affect would this have on conductive and solar heat gain relating to the cooling system?

(8.2) Research Goals:

The goal of this analysis is to compare the energy savings and environmental impact the substitution of more energy efficient windows has on the building. Three aspects of the windows will be analyzed and then combined to produce the final results. First, a low E glazing will be added to prevent solar heat gain through the windows as well as help with moisture control. Second, a more advanced double pane and triple pane system will be substituted to help lower the overall U-Value of the unit. Finally, the current aluminum frame will be replaced with a fiberglass insulated frame. It is my hope that the life cycle costs of the energy saved by this substitution will offset the initial investment.

(8.3) Background

Pairing energy efficient windows with an efficient building skin maximizes energy savings. The current skin of GrandView consists of a Henry Air and Moisture Barrier system, which was used to enhance the air leakage and insulation properties of the system.

Controlling moisture is critical to maintaining the durability of a building as well as the health of its occupants. When moisture condenses it can damage finish materials, reduce the R-value of insulation, and lead to decay. High moisture levels are necessary for the growth of molds and dust mites which can endanger human health.

The current windows account for 36% of the building’s overall façade area. Low-E glass improves the energy efficiency of windows and can improve interior comfort and reduce the occurrence of condensation on windows. This glass allows high levels of natural light to enter the home, reducing the need for supplementary artificial lighting during the daytime. Solar control glass also reduces interior surface reflectivity which can prevent occupants from seeing outside at night. In some cases, using solar control glass can reduce cooling loads so greatly that cooling system capacity can be reduced or that glass area can be added without increasing cooling loads. It offers the greatest energy savings in areas where cooling costs are higher than heating costs.

The current window package for the residential portion of the building amounts to $1,875,430.00.

(8.4) Design Methodology

There are three fundamental elements of window design that affect the thermal performance:

- Glass – Affects the thermal loss out of the building and the solar gain into the building.
- Glazing – Affects the solar heat gain through the glass
- Frame - Affects the thermal loss out of the building through conduction and air loss.

The current window system that makes up the residential portion of the building consists of simple thermally broken frames and double pane glass, high solar gain glazing.

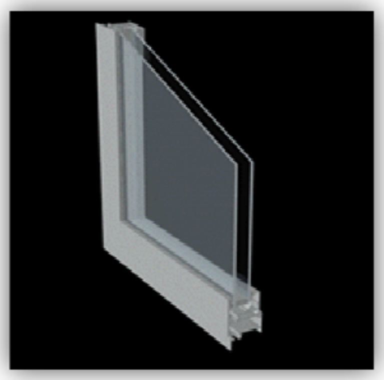
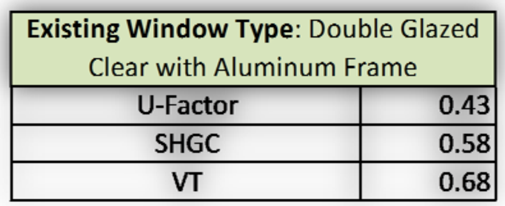


Figure 8.1: Double Glazed Aluminum Window



Existing Window Type: Double Glazed Clear with Aluminum Frame	
U-Factor	0.43
SHGC	0.58
VT	0.68

Table 8.1: Existing Window Type

In order to achieve better energy efficiency through solar and convective gain, the following two window types are going to be analyzed. The addition of a Low-E, low solar gain glazing will be applied to both a double and triple pane window system with a fiberglass frame. Fiberglass frames have a far better U-factor than aluminum frames when it comes to convective and solar heat transfer. The Low-E glazing will help lower the solar heat transfer as well as maximize light transmittance.

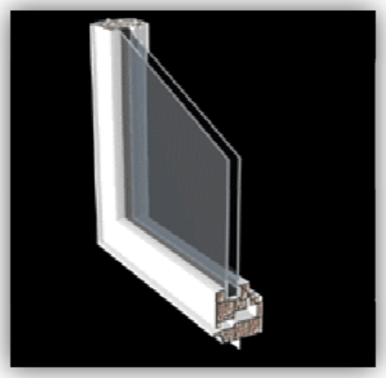
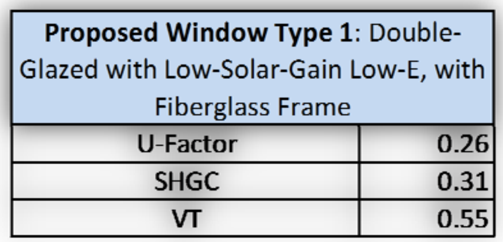
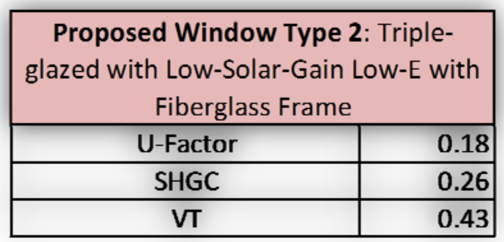


Figure 8.2: Double Glazed Fiberglass Window



Proposed Window Type 1: Double-Glazed with Low-Solar-Gain Low-E, with Fiberglass Frame	
U-Factor	0.26
SHGC	0.31
VT	0.55

Table 8.2: Design 1



Proposed Window Type 2: Triple-glazed with Low-Solar-Gain Low-E with Fiberglass Frame	
U-Factor	0.18
SHGC	0.26
VT	0.43

Table 8.3: Design 2

Definitions

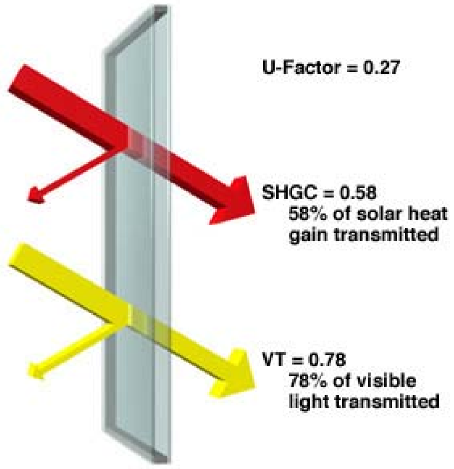


Figure 8.3: Solar Heat Gain Values

U-factor (U-value). A measure of the rate of non-solar heat loss or gain through a material or assembly. It is expressed in units of Btu/hr-sq ft-°F (W/sq m-°C). Values are normally given for NFRC/ASHRAE winter conditions of 0° F (18° C) outdoor temperature, 70° F (21° C) indoor temperature, 15 mph wind, and no solar load. The U-factor may be expressed for the glass alone or the entire window, which includes the effect of the frame and the spacer materials. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value.

Solar heat gain coefficient (SHGC). The fraction of solar radiation admitted through a window or skylight, both directly transmitted, and absorbed and subsequently released inward. The solar heat gain coefficient has replaced the shading coefficient as the standard indicator of a window's shading ability. It is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits, and the greater it's shading ability. SHGC can be expressed in terms of the glass alone or can refer to the entire window assembly.

Visible transmittance (VT). The percentage or fraction of the visible spectrum (380 to 720 nanometers) weighted by the sensitivity of the eye, that is transmitted through the glazing.

High-performance windows not only provide reduced annual heating and cooling bills; they reduce the peak heating and cooling loads as well. This has benefits for the homeowner, in that the size of the heating or cooling system may be reduced, and it also benefits the electrical utilities, in that load factors are reduced during the peak times in summer.

SOLAR AND MECHANICAL BREADTH

(8.5) Fenestration Heat Gain Analysis

In order to determine the heat gain through solar rays, building orientation, surface area of the windows, surface irradiance bust be determined. Utilizing previous calculations done by Todd Povell, the solar irradiance of each side of the building was determined. It is important to note that in order to create an accurate heat fenestration excel sheet, building orientation needed to be adjusted. In Grandview's case, the following changes needed to be made to the fenestration data provided.

North irradiance becomes GrandView's **East**
South irradiance becomes GrandView's **West**
East Irradiance becomes GrandView's **North**
West irradiance becomes GrandView's **South**

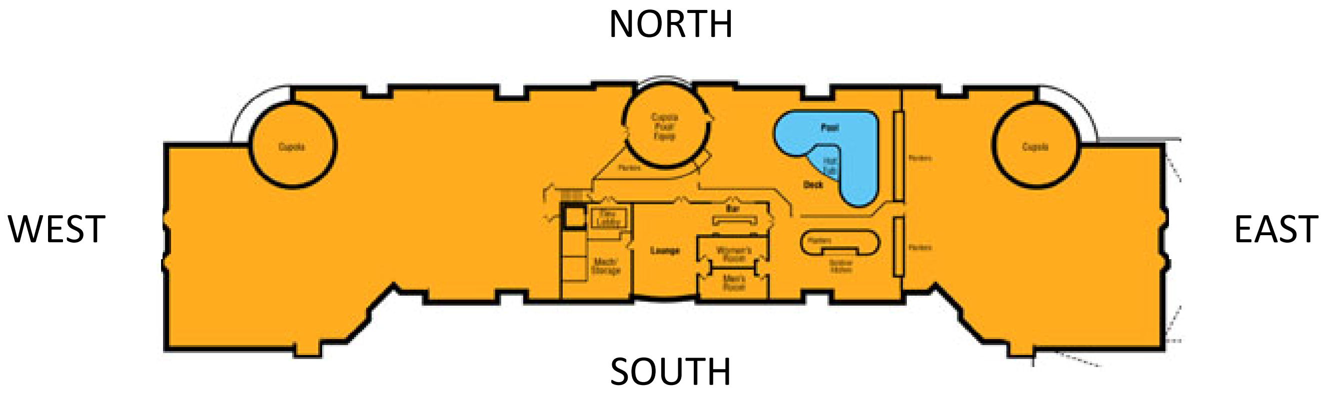


Figure 8.3:

STEP 1 **Determining Total Fenestration Area**

In order to determine the area of fenestration, a simple hand take-off was calculated from the drawings. This area consists of all the windows and glass facades that are present in floors 2-12. The first floor is retail and has not been included in this analysis due to different window type and energy consumption requirements.

Window Area by Façade Face: **North** = 16380 ft^2 **South**= 14976 ft^2
East = 3159 ft^2 **West** = 3861 ft^2

STEP 2 **Estimating Exterior Temperature**

With this type of analysis, the exterior temperature is needed to determine whether heat will be transferred into or out of the building. Data for the DC area was found with the help of the National Oceanic and Atmospheric Administration (NOAA) and the United States Naval Observatory (USNO). Together they provided minimum, maximum and mean temps for the area along with sunrise and sunset times. Through these sets of data, a temperature gradient was determined for one day of each month (21st). The data can be found in Appendix E.

STEP 3 **Calculating Total Surface Irradiance**

Now that the area of fenestration for each face of the building is known, surface irradiance for each face needs to be calculated. Fortunately, these calculations have been provided. It is important to note that a re-orientation of the irradiance was done in order to apply them to GrandView. The basic footprint is almost identical in orientation to the provided data. See the previous page for a detailed explanation.

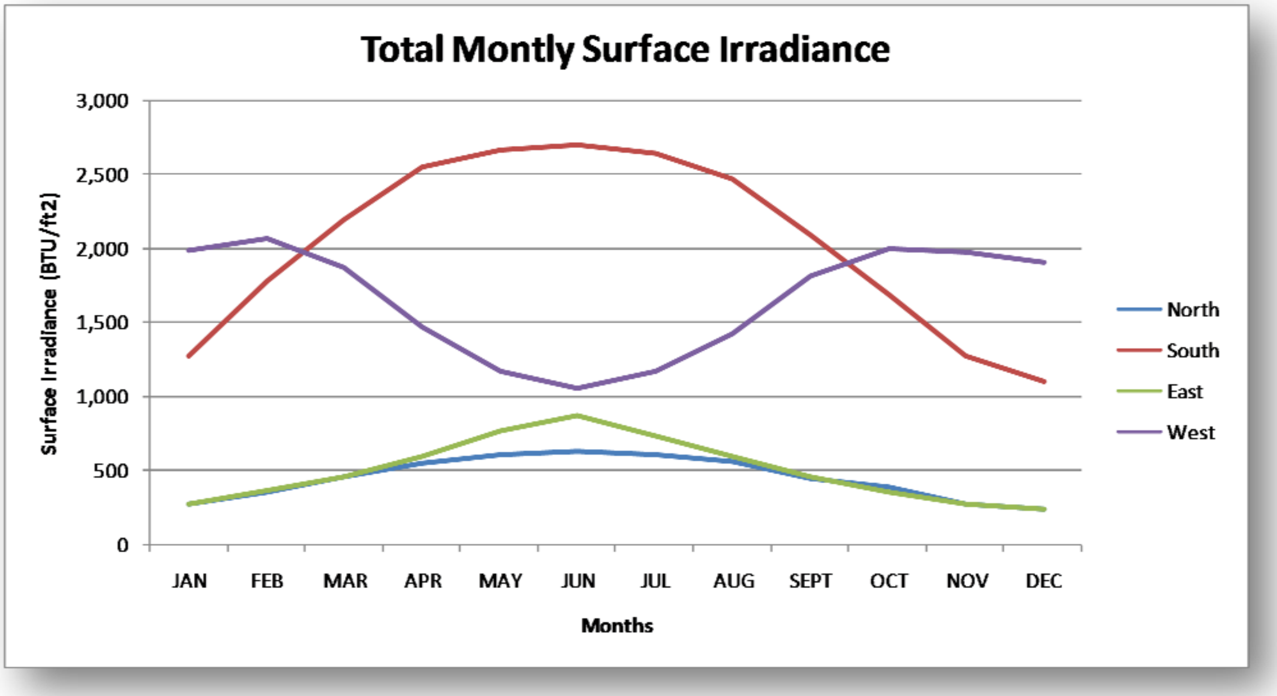


Figure 8.4: the southern facing façade gains the most solar energy while the north and east gains the least

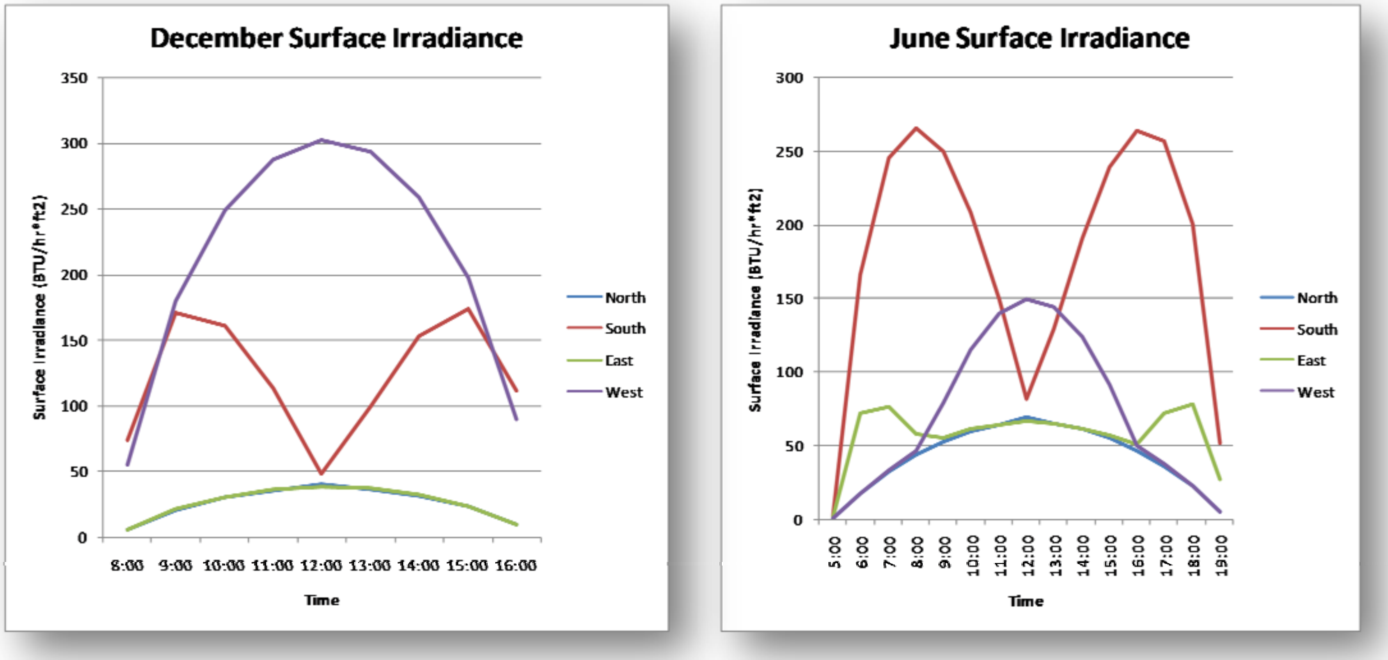


Figure 8.5:

Figure 8.6:

STEP 4

Calculating Fenestration Heat Gain

A fenestration is defined as the openings in a building's envelope including windows, doors, and skylights. The following analysis will only deal with windows.

In order to determine the instantaneous heat transfer through the window system, the following equation was utilized from the 2005 ASHRAE Handbook of Fundamentals (page 31.3, equation 1)

Equations

$$Q = Q_{cond} + Q_{sol}$$

$$Q = AU(T_{OUT} - T_{IN}) + SHGC(A)(E_T)$$

Definition of Terms

Q	Instantaneous Energy Transfer	BTU/hr
U	Overall Coefficient of Heat Transfer	$BTU/(hr*ft^2*F)$
A	Area of Fenestration	ft^2
t_{out}, t_{in}	Exterior and Interior Temperatures	F
SHGC	Solar Heat Gain Factor	-
E_t	Incident Total Irradiance	$BTU / (hr*ft^2)$

GIVEN

Assumptions made for Cooling Load Analysis

- The indoor air temperature was set at a comfortable 72 degrees F for the whole year. The scope of this breadth focuses specifically on the energy transfer through the windows, a constant temp. removes variables such as tenant's specific requirements. Because GrandView is a luxury apartment complex, it is assumed that cooling and heat loads would be constant.
- While the heating load was calculated in Appendix E, it was omitted for the sake of cooling load calculations. Only net heat gains through the windows were accounted for because variables such as computers, lights, humans, and mechanical equipment are essentially all part of the heating load.
- Both residential common windows and the large curved glass facades were taken into account. However, since the glass facades all face north, there is no significant solar heat gained through them as compared to southern facing windows.
- The two design types, double pane with Low-E glazing, and triple pane with Low-E Glazing were compared to the current window type. Cumulative Cooling Savings are based off of this comparison.
- It was also assumed that the windows were unobstructed, that is, no curtains or drapes were over them as to detract from solar gain. Also, in order to calculate the maximum energy possible. It is assumed that there is no cloud cover during the day. In reality, it is more than likely that a certain percentage of the calculated solar gain would be obtained.

The following page contains a condensed table of the Monthly Cooling Loads as found in Appendix E as well as a graphical representation of the Monthly Cooling Loads of Design 1 and 2 compared to the current window system shown in Figure 8.7. The Cumulative Monthly Energy savings of Design 1 and 2 can be found in Figure 8.8.

END BREADTH

(8.6) Cooling Load Cost and Life Cycle Analysis

Monthly Cooling Load Values

		Total Daily (Million Btu's)			Total Monthy (Million Btu's)			Total Savings (Million Btu's)	
Time	**Days**	**Current**	**Design 1**	**Design 2**	**Current**	**Design 1**	**Design 2**	**Design 1**	**Design 2**
JAN	31	14.6	6.0	4.1	454.1	185.0	128.1	269.1	326.1
FEB	29	19.3	7.9	5.5	560.9	230.0	159.3	330.9	401.7
MAR	31	24.2	10.2	7.1	748.8	316.3	219.0	432.5	529.8
APR	30	29.4	12.8	8.9	882.6	385.2	266.7	497.4	616.0
MAY	31	31.8	14.1	9.8	987.0	437.3	302.8	549.7	684.3
JUN	30	34.7	15.8	10.9	1040.3	472.8	327.4	567.5	713.0
JUL	31	36.1	16.7	11.6	1119.1	518.2	358.8	600.9	760.3
AUG	31	30.4	13.6	9.4	943.8	420.8	291.3	522.9	652.4
SEPT	30	26.8	12.0	8.3	805.1	359.1	248.6	446.0	556.5
OCT	31	21.1	9.1	6.3	654.4	282.3	195.4	372.0	458.9
NOV	30	15.9	6.7	4.7	477.4	201.7	139.7	275.6	337.7
DEC	31	13.0	5.3	3.7	402.7	163.5	113.2	239.2	289.5
			Yearly Totals		**9076.2**	**3972.4**	**2750.1**	**5103.8**	**6326.1**
				Percent Savings		**Percent Savings**		**56%**	**70%**

Table 8.4: Monthly Cooling Loads

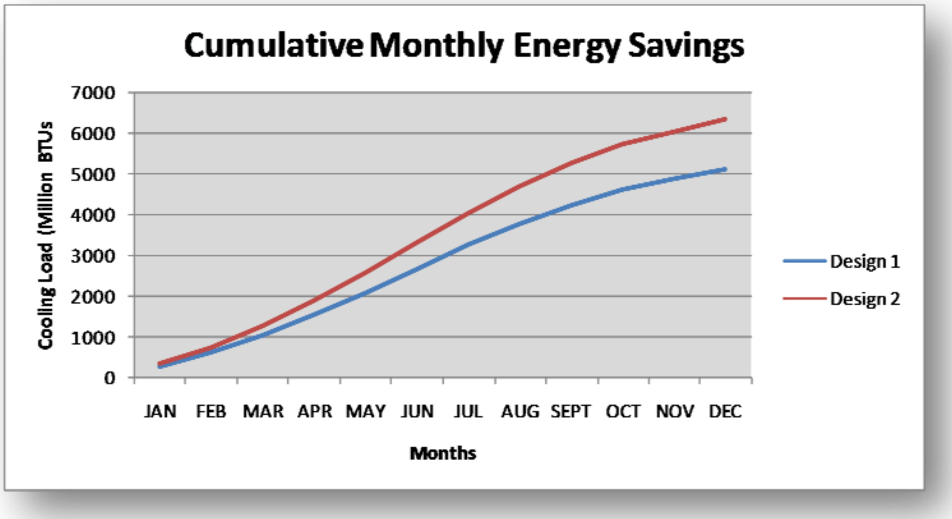


Figure 8.7: Cumulative Monthly Savings

Monthly Cooling Savings

Cumulative Savings (Million BTU's)

Design 1	Design 2
269	326
600	728
1033	1258
1530	1873
2080	2558
2647	3271
3248	4031
3771	4683
4217	5240
4589	5699
4865	6037
5104	6326

Table 8.5: Cumulative Cooling

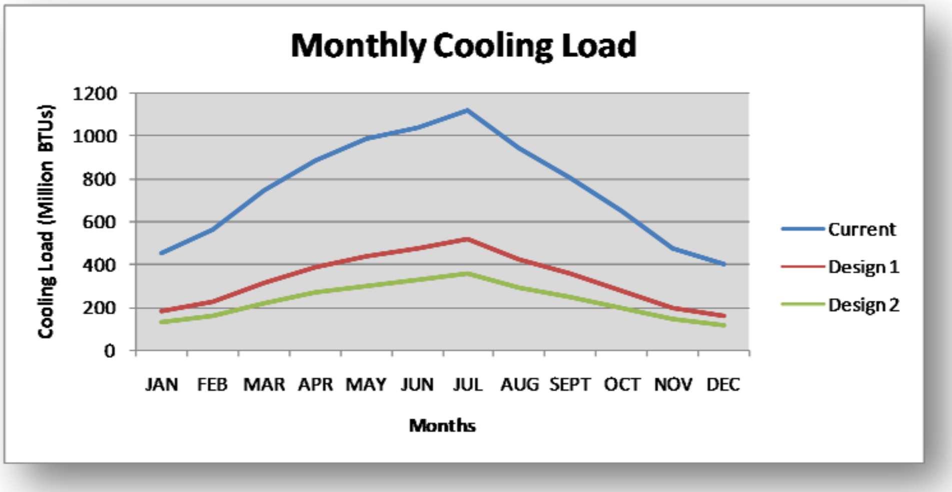


Figure 8.8: Monthly Cooling Load

Magic-Pak AHU Implementation

In order to reduce wall and floor penetrations, it is proposed that GrandView employ the use of individual Air Handling Units in each apartment. The MAGIC-PAK MCB model is design so it can have direct access to the outside though a penetration in the façade. Reducing the floor and wall penetrations needed for duct work would reduce the need for coordination between trades and save on material costs of duct work due to a smaller size.

Typically, these units are placed on a vibration reducing pad in a closet. The SEER Rating for this particular AHU is 11.4.

Advantages of a MAGIC-PAK System:

- Unobtrusive design – small footprint and
- wall-opening requirement
- Low operating sound levels
- Standard and high-efficiency cooling models
- Fully insulated cabinet
- Low installed, maintenance and life-cycle costs
- Individual Tenant Control

In order to determine the Cooling Load a SEER Rating of 11.4 is used to determine the efficiency of the cooling unit.

In *Table 8.4* the annual savings of both the single and double pane windows were established. These values can be applied to the following financial savings equation:

$/year = [(BTU/year)($/kWh)] / [(SEER)(1000w/kW)]

The higher the SEER rating, the lower the cooling cost.

Cost Comparison							
Design	Difference in Cost per SF	Area (SF)	Initial Cost Difference	Magic-Pak SEER	Annual Cooling Cost	Annual Cooling Savings	Percent Savings
Current	$ -	38,376	$ -	11.4	$ 109,870	**$ -**	0%
Design 1	$ 2.41	38,376	$ 92,486.16	11.4	$ 48,087	**$ 61,783**	56%
Design 2	$ 5.22	38,376	$ 200,322.72	11.4	$ 33,291	**$ 76,579**	70%

Table 8.6: Cost Comparison

An additional payback period of **1.5 years** would be required for the double pane fiberglass windows. The triple pane windows would require an extra **2.6 years**.

A life cycle analysis of ten years gives the following CO2 impact when considering 1 kwh = 3412 BTU's and 1 kWh = 1.6 lbs of CO2 equivalent of coal burned.

[redacted]

Table 8.7: CO2 Savings

According to the Sightline Institute, based on Boeing 747 emissions and the average occupancy of USA flights, every 2,062 miles travelled accounts for 1 ton of CO2 emissions per person.

A 1200 ton CO2 savings is equivalent of a 400 Passenger Boeing 747 making a round trip from DC TO LA. Therefore, over a period of ten years, installing Design 1 would be equivalent of canceling 10 round trip flights of a 747 across the country.

(8.7) Constructability and Schedule Review

In order to determine the feasibility of construction and the impact the installation of the panels would have on the design of the building, some key areas of constructability were looked at.

Window Weight

The weight of the window weight would only affect constructability for the triple pane windows. Since they are relatively heavier than the standard double pane, a structural analysis would need to be done in order to determine load impact.

Mounting

Mounting of the double pane fiberglass windows would be identical to the current double pane aluminum windows. However, the triple pane windows have a slightly different configuration that would need to be taken into account.

Moisture Control

Glazing provides an additional moisture control system that would be paired with the Henry AIR/Moisture building skin. In a residential unit, moisture can warp and ruin many aspects. Therefore, the substitution of a Low-E window type would help protect the building and reduce maintenance costs

Schedule Impact

The only impact that this type of window substitution would have is the installation time of the triple pane windows and a possibly larger lead time. Since they are heavier and have a different mounting layout than the double pane windows, they would be expected to take longer to install due to mobility and placement detail.

Results and Recommendations

Through this analysis the following overall results were determined:

- The substitution of a fiberglass, double pane window with a LOW-E glazing reduced the cooling costs by nearly **56%** and saved an annual **$61,783**. When considering the initial cost, an additional payback period of **1.5** years would be added to the overall payback period of 30 years.
- The substitution of a fiberglass, triple pane window with a LOW-E glazing reduced the cooling cost by nearly **70%** and saved an annual **$76,579**. When considering the initial cost, and additional payback period of **2.6** years would be added to the overall payback period of 30 years.
- The double pane window design prevented **1197 tons** of CO2 from entering the atmosphere per year.
- The triple pane window design prevented **1483 tons** of CO2 from entering the atmosphere per year.

It is my recommendation that GrandView install the double pane window design with the Low-E solar glazing. However, it is not necessary to use the fiberglass frame because the conduction through a frame of this type is minimal compared to the solar energy gain. Plus, aluminum frames are lighter and less expensive. While triple pane windows provide a slightly better result, in the long run they cost more and are much heavier. These types of windows would better be suited for a harsher environment that has a vastly different inside and outside temperature difference.

The use of a Magic-Pak AHU reduces the schedule impact when coordinating partition and floor penetrations. The ease of installation and small size makes it ideal for GrandView. It is my recommendation that these units continue to be used.

After going through the all of the calculations, it would have been more advantageous to analyze one specific aspect of the window rather than 3. I would have focused specifically on just the glazing and kept the double pane window with the aluminum glazing because the solar gain was the dominant heat transfer method.

Summary and Conclusion

In the words of Niels Bohr, “An *expert* is a man who has made all the *mistakes* which can be made in a *field”.* This thesis assignment to me was largely successful in the sense of learning.

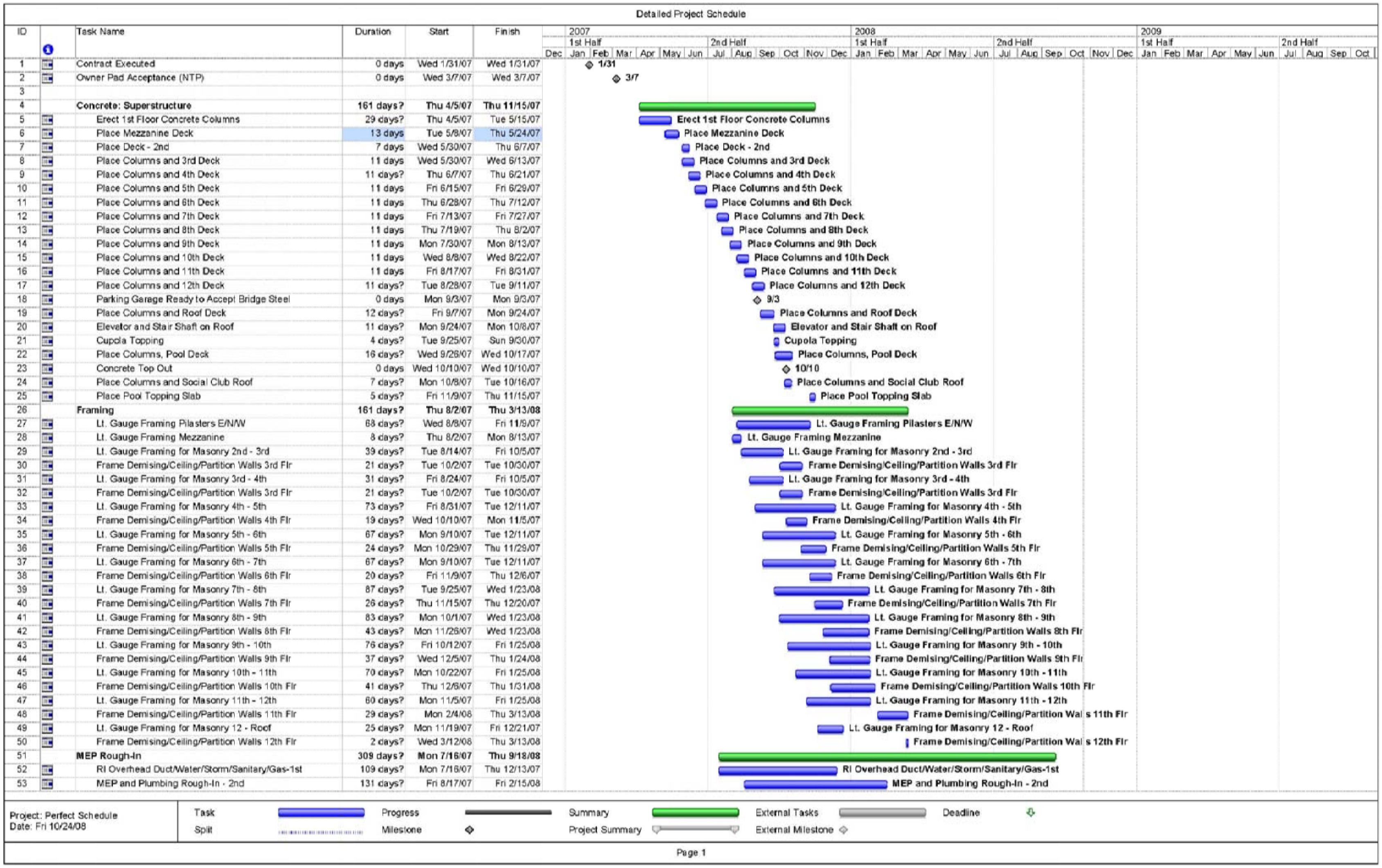
The fenestration heat gain analysis produced favorable results for the addition a Low-E, low solar gain glazing layer. Since the southern face of the building makes up a large amount of the total fenestration area, it is only logical that a total annual savings of $61,783 would be accrued. Maintaining a schedule that was not lengthened by the addition of a sustainable design was also accomplished though the glazing since it can be installed and the window manufacturer. Overall, the choice of a double pane, Low-E, low solar gain glazing is highly recommended.

The solar panel analysis on the other hand did not yield the desired results as expected. However, there was an incredible amount of information gained. A 40Kw solar panel array in Annapolis, MD can yield 49,111 kWh annually. It was determined that the support structure needed to tilt the system would add $1.50 to the overall cost of the panels and installation. It was later determined that by lying the panels flush against the roof a 17% reduction in energy absorption would occur. However, since the panels would be able to lie side by side, 150% more panel could be installed on the roof. The initial cost of $337,600 offset by an annual savings of $6,797 would yield a 49 year payback period. It was determined that at this time, installing a 40kW solar array would be financially irresponsible and could not complete with cheaper available energy. It is the hope of the industry that future advancements in solar technology and better government incentives makes it more competitive in terms of electricity cost and payback period.

APPENDICES

APPENDIX A

Detailed Project Schedule



Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
1	Contract Executed	0 days	Wed 1/31/07	Wed 1/31/07
2	Owner Pad Acceptance (NTP)	0 days	Wed 3/7/07	Wed 3/7/07
3				
4	**Concrete: Superstructure**	**161 days?**	**Thu 4/5/07**	**Thu 11/15/07**
5	Erect 1st Floor Concrete Columns	29 days?	Thu 4/5/07	Tue 5/15/07
6	Place Mezzanine Deck	13 days	Tue 5/8/07	Thu 5/24/07
7	Place Deck - 2nd	7 days	Wed 5/30/07	Thu 6/7/07
8	Place Columns and 3rd Deck	11 days	Wed 5/30/07	Wed 6/13/07
9	Place Columns and 4th Deck	11 days?	Thu 6/7/07	Thu 6/21/07
10	Place Columns and 5th Deck	11 days	Fri 6/15/07	Fri 6/29/07
11	Place Columns and 6th Deck	11 days	Thu 6/28/07	Thu 7/12/07
12	Place Columns and 7th Deck	11 days	Fri 7/13/07	Fri 7/27/07
13	Place Columns and 8th Deck	11 days	Thu 7/19/07	Thu 8/2/07
14	Place Columns and 9th Deck	11 days	Mon 7/30/07	Mon 8/13/07
15	Place Columns and 10th Deck	11 days	Wed 8/8/07	Wed 8/22/07
16	Place Columns and 11th Deck	11 days	Fri 8/17/07	Fri 8/31/07
17	Place Columns and 12th Deck	11 days?	Tue 8/28/07	Tue 9/11/07
18	Parking Garage Ready to Accept Bridge Steel	0 days	Mon 9/3/07	Mon 9/3/07
19	Place Columns and Roof Deck	12 days?	Fri 9/7/07	Mon 9/24/07
20	Elevator and Stair Shaft on Roof	11 days?	Mon 9/24/07	Mon 10/8/07
21	Cupola Topping	4 days?	Tue 9/25/07	Sun 9/30/07
22	Place Columns, Pool Deck	16 days?	Wed 9/26/07	Wed 10/17/07
23	Concrete Top Out	0 days	Wed 10/10/07	Wed 10/10/07
24	Place Columns and Social Club Roof	7 days?	Mon 10/8/07	Tue 10/16/07
25	Place Pool Topping Slab	5 days?	Fri 11/9/07	Thu 11/15/07
26	**Framing**	**161 days?**	**Thu 8/2/07**	**Thu 3/13/08**
27	Lt. Gauge Framing Pilasters E/N/W	68 days?	Wed 8/8/07	Fri 11/9/07
28	Lt. Gauge Framing Mezzanine	8 days?	Thu 8/2/07	Mon 8/13/07
29	Lt. Gauge Framing for Masonry 2nd - 3rd	39 days?	Tue 8/14/07	Fri 10/5/07
30	Frame Demising/Ceiling/Partition Walls 3rd Flr	21 days?	Tue 10/2/07	Tue 10/30/07
31	Lt. Gauge Framing for Masonry 3rd - 4th	31 days?	Fri 8/24/07	Fri 10/5/07
32	Frame Demising/Ceiling/Partition Walls 3rd Flr	21 days?	Tue 10/2/07	Tue 10/30/07
33	Lt. Gauge Framing for Masonry 4th - 5th	73 days?	Fri 8/31/07	Tue 12/11/07
34	Frame Demising/Ceiling/Partition Walls 4th Flr	19 days?	Wed 10/10/07	Mon 11/5/07
35	Lt. Gauge Framing for Masonry 5th - 6th	67 days?	Mon 9/10/07	Tue 12/11/07
36	Frame Demising/Ceiling/Partition Walls 5th Flr	24 days?	Mon 10/29/07	Thu 11/29/07
37	Lt. Gauge Framing for Masonry 6th - 7th	67 days?	Mon 9/10/07	Tue 12/11/07
38	Frame Demising/Ceiling/Partition Walls 6th Flr	20 days?	Fri 11/9/07	Thu 12/6/07
39	Lt. Gauge Framing for Masonry 7th - 8th	87 days?	Tue 9/25/07	Wed 1/23/08
40	Frame Demising/Ceiling/Partition Walls 7th Flr	26 days?	Thu 11/15/07	Thu 12/20/07
41	Lt. Gauge Framing for Masonry 8th - 9th	83 days?	Mon 10/1/07	Wed 1/23/08
42	Frame Demising/Ceiling/Partition Walls 8th Flr	43 days?	Mon 11/26/07	Wed 1/23/08
43	Lt. Gauge Framing for Masonry 9th - 10th	76 days?	Fri 10/12/07	Fri 1/25/08
44	Frame Demising/Ceiling/Partition Walls 9th Flr	37 days?	Wed 12/5/07	Thu 1/24/08
45	Lt. Gauge Framing for Masonry 10th - 11th	70 days?	Mon 10/22/07	Fri 1/25/08
46	Frame Demising/Ceiling/Partition Walls 10th Flr	41 days?	Thu 12/6/07	Thu 1/31/08
47	Lt. Gauge Framing for Masonry 11th - 12th	60 days?	Mon 11/5/07	Fri 1/25/08
48	Frame Demising/Ceiling/Partition Walls 11th Flr	29 days?	Mon 2/4/08	Thu 3/13/08
49	Lt. Gauge Framing for Masonry 12 - Roof	25 days?	Mon 11/19/07	Fri 12/21/07
50	Frame Demising/Ceiling/Partition Walls 12th Flr	2 days?	Wed 3/12/08	Thu 3/13/08
51	**MEP Rough-In**	**309 days?**	**Mon 7/16/07**	**Thu 9/18/08**
52	RI Overhead Duct/Water/Storm/Sanitary/Gas-1st	109 days?	Mon 7/16/07	Thu 12/13/07
53	MEP and Plumbing Rough-In - 2nd	131 days?	Fri 8/17/07	Fri 2/15/08

Project: Perfect Schedule
Date: Fri 10/24/08

Task	▬	Progress	▬	Summary	▬	External Tasks	▬	Deadline ⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone ◇		

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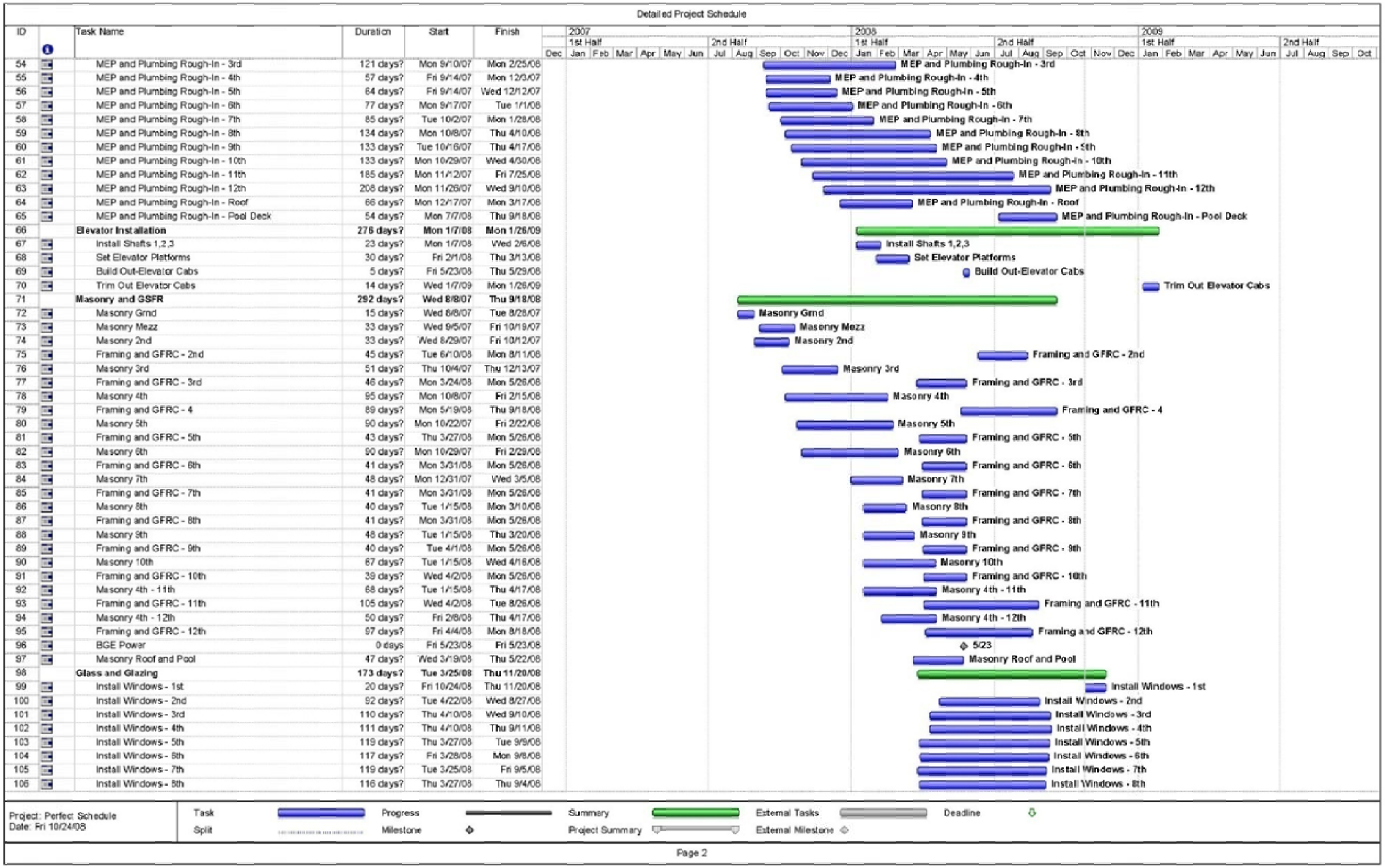

Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
54	MEP and Plumbing Rough-In - 3rd	121 days?	Mon 9/10/07	Mon 2/25/08
55	MEP and Plumbing Rough-In - 4th	57 days?	Fri 9/14/07	Mon 12/3/07
56	MEP and Plumbing Rough-In - 5th	64 days?	Fri 9/14/07	Wed 12/12/07
57	MEP and Plumbing Rough-In - 6th	77 days?	Mon 9/17/07	Tue 1/1/08
58	MEP and Plumbing Rough-In - 7th	85 days?	Tue 10/2/07	Mon 1/28/08
59	MEP and Plumbing Rough-In - 8th	134 days?	Mon 10/8/07	Thu 4/10/08
60	MEP and Plumbing Rough-In - 9th	133 days?	Tue 10/16/07	Thu 4/17/08
61	MEP and Plumbing Rough-In - 10th	133 days?	Mon 10/29/07	Wed 4/30/08
62	MEP and Plumbing Rough-In - 11th	185 days?	Mon 11/12/07	Fri 7/25/08
63	MEP and Plumbing Rough-In - 12th	208 days?	Mon 11/26/07	Wed 9/10/08
64	MEP and Plumbing Rough-In - Roof	66 days?	Mon 12/17/07	Mon 3/17/08
65	MEP and Plumbing Rough-In - Pool Deck	54 days?	Mon 7/7/08	Thu 9/18/08
66	**Elevator Installation**	**276 days?**	**Mon 1/7/08**	**Mon 1/26/09**
67	Install Shafts 1,2,3	23 days?	Mon 1/7/08	Wed 2/6/08
68	Set Elevator Platforms	30 days?	Fri 2/1/08	Thu 3/13/08
69	Build Out-Elevator Cabs	5 days?	Fri 5/23/08	Thu 5/29/08
70	Trim Out Elevator Cabs	14 days?	Wed 1/7/09	Mon 1/26/09
71	**Masonry and GSFR**	**292 days?**	**Wed 8/8/07**	**Thu 9/18/08**
72	Masonry Grnd	15 days?	Wed 8/8/07	Tue 8/28/07
73	Masonry Mezz	33 days?	Wed 9/5/07	Fri 10/19/07
74	Masonry 2nd	33 days?	Wed 8/29/07	Fri 10/12/07
75	Framing and GFRC - 2nd	45 days?	Tue 6/10/08	Mon 8/11/08
76	Masonry 3rd	51 days?	Thu 10/4/07	Thu 12/13/07
77	Framing and GFRC - 3rd	46 days?	Mon 3/24/08	Mon 5/26/08
78	Masonry 4th	95 days?	Mon 10/8/07	Fri 2/15/08
79	Framing and GFRC - 4	89 days?	Mon 5/19/08	Thu 9/18/08
80	Masonry 5th	90 days?	Mon 10/22/07	Fri 2/22/08
81	Framing and GFRC - 5th	43 days?	Thu 3/27/08	Mon 5/26/08
82	Masonry 6th	90 days?	Mon 10/29/07	Fri 2/29/08
83	Framing and GFRC - 6th	41 days?	Mon 3/31/08	Mon 5/26/08
84	Masonry 7th	48 days?	Mon 12/31/07	Wed 3/5/08
85	Framing and GFRC - 7th	41 days?	Mon 3/31/08	Mon 5/26/08
86	Masonry 8th	40 days?	Tue 1/15/08	Mon 3/10/08
87	Framing and GFRC - 8th	41 days?	Mon 3/31/08	Mon 5/26/08
88	Masonry 9th	48 days?	Tue 1/15/08	Thu 3/20/08
89	Framing and GFRC - 9th	40 days?	Tue 4/1/08	Mon 5/26/08
90	Masonry 10th	67 days?	Tue 1/15/08	Wed 4/16/08
91	Framing and GFRC - 10th	39 days?	Wed 4/2/08	Mon 5/26/08
92	Masonry 4th - 11th	68 days?	Tue 1/15/08	Thu 4/17/08
93	Framing and GFRC - 11th	105 days?	Wed 4/2/08	Tue 8/26/08
94	Masonry 4th - 12th	50 days?	Fri 2/8/08	Thu 4/17/08
95	Framing and GFRC - 12th	97 days?	Fri 4/4/08	Mon 8/18/08
96	BGE Power	0 days	Fri 5/23/08	Fri 5/23/08
97	Masonry Roof and Pool	47 days?	Wed 3/19/08	Thu 5/22/08
98	**Glass and Glazing**	**173 days?**	**Tue 3/25/08**	**Thu 11/20/08**
99	Install Windows - 1st	20 days?	Fri 10/24/08	Thu 11/20/08
100	Install Windows - 2nd	92 days?	Tue 4/22/08	Wed 8/27/08
101	Install Windows - 3rd	110 days?	Thu 4/10/08	Wed 9/10/08
102	Install Windows - 4th	111 days?	Thu 4/10/08	Thu 9/11/08
103	Install Windows - 5th	119 days?	Thu 3/27/08	Tue 9/9/08
104	Install Windows - 6th	117 days?	Fri 3/28/08	Mon 9/8/08
105	Install Windows - 7th	119 days?	Tue 3/25/08	Fri 9/5/08
106	Install Windows - 8th	116 days?	Thu 3/27/08	Thu 9/4/08

Project: Perfect Schedule
Date: Fri 10/24/08

Task ▬ | Progress ▬ | Summary ▬ | External Tasks ▬ | Deadline ⇩
Split ┈ | Milestone ◆ | Project Summary ▬ | External Milestone ◆

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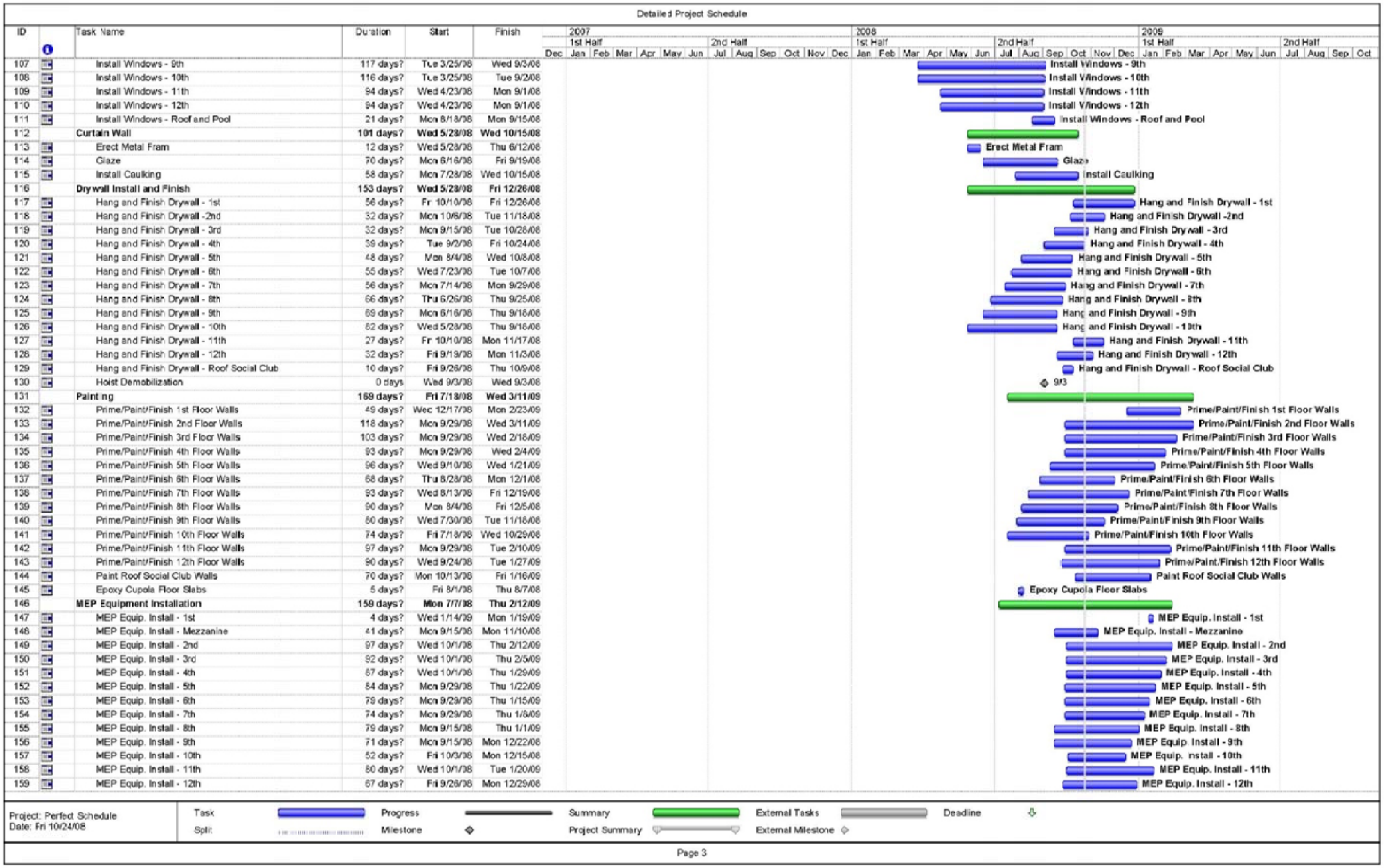

Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
107	Install Windows - 9th	117 days?	Tue 3/25/08	Wed 9/3/08
108	Install Windows - 10th	116 days?	Tue 3/25/08	Tue 9/2/08
109	Install Windows - 11th	94 days?	Wed 4/23/08	Mon 9/1/08
110	Install Windows - 12th	94 days?	Wed 4/23/08	Mon 9/1/08
111	Install Windows - Roof and Pool	21 days?	Mon 8/18/08	Mon 9/15/08
112	**Curtain Wall**	**101 days?**	**Wed 5/28/08**	**Wed 10/15/08**
113	Erect Metal Fram	12 days?	Wed 5/28/08	Thu 6/12/08
114	Glaze	70 days?	Mon 6/16/08	Fri 9/19/08
115	Install Caulking	58 days?	Mon 7/28/08	Wed 10/15/08
116	**Drywall Install and Finish**	**153 days?**	**Wed 5/28/08**	**Fri 12/26/08**
117	Hang and Finish Drywall - 1st	56 days?	Fri 10/10/08	Fri 12/26/08
118	Hang and Finish Drywall -2nd	32 days?	Mon 10/6/08	Tue 11/18/08
119	Hang and Finish Drywall - 3rd	32 days?	Mon 9/15/08	Tue 10/28/08
120	Hang and Finish Drywall - 4th	39 days?	Tue 9/2/08	Fri 10/24/08
121	Hang and Finish Drywall - 5th	48 days?	Mon 8/4/08	Wed 10/8/08
122	Hang and Finish Drywall - 6th	55 days?	Wed 7/23/08	Tue 10/7/08
123	Hang and Finish Drywall - 7th	56 days?	Mon 7/14/08	Mon 9/29/08
124	Hang and Finish Drywall - 8th	66 days?	Thu 6/26/08	Thu 9/25/08
125	Hang and Finish Drywall - 9th	69 days?	Mon 6/16/08	Thu 9/18/08
126	Hang and Finish Drywall - 10th	82 days?	Wed 5/28/08	Thu 9/18/08
127	Hang and Finish Drywall - 11th	27 days?	Fri 10/10/08	Mon 11/17/08
128	Hang and Finish Drywall - 12th	32 days?	Fri 9/19/08	Mon 11/3/08
129	Hang and Finish Drywall - Roof Social Club	10 days?	Fri 9/26/08	Thu 10/9/08
130	Hoist Demobilization	0 days	Wed 9/3/08	Wed 9/3/08
131	**Painting**	**169 days?**	**Fri 7/18/08**	**Wed 3/11/09**
132	Prime/Paint/Finish 1st Floor Walls	49 days?	Wed 12/17/08	Mon 2/23/09
133	Prime/Paint/Finish 2nd Floor Walls	118 days?	Mon 9/29/08	Wed 3/11/09
134	Prime/Paint/Finish 3rd Floor Walls	103 days?	Mon 9/29/08	Wed 2/18/09
135	Prime/Paint/Finish 4th Floor Walls	93 days?	Mon 9/29/08	Wed 2/4/09
136	Prime/Paint/Finish 5th Floor Walls	96 days?	Wed 9/10/08	Wed 1/21/09
137	Prime/Paint/Finish 6th Floor Walls	68 days?	Thu 8/28/08	Mon 12/1/08
138	Prime/Paint/Finish 7th Floor Walls	93 days?	Wed 8/13/08	Fri 12/19/08
139	Prime/Paint/Finish 8th Floor Walls	90 days?	Mon 8/4/08	Fri 12/5/08
140	Prime/Paint/Finish 9th Floor Walls	80 days?	Wed 7/30/08	Tue 11/18/08
141	Prime/Paint/Finish 10th Floor Walls	74 days?	Fri 7/18/08	Wed 10/29/08
142	Prime/Paint/Finish 11th Floor Walls	97 days?	Mon 9/29/08	Tue 2/10/09
143	Prime/Paint/Finish 12th Floor Walls	90 days?	Wed 9/24/08	Tue 1/27/09
144	Paint Roof Social Club Walls	70 days?	Mon 10/13/08	Fri 1/16/09
145	Epoxy Cupola Floor Slabs	5 days?	Fri 8/1/08	Thu 8/7/08
146	**MEP Equipment Installation**	**159 days?**	**Mon 7/7/08**	**Thu 2/12/09**
147	MEP Equip. Install - 1st	4 days?	Wed 1/14/09	Mon 1/19/09
148	MEP Equip. Install - Mezzanine	41 days?	Mon 9/15/08	Mon 11/10/08
149	MEP Equip. Install - 2nd	97 days?	Wed 10/1/08	Thu 2/12/09
150	MEP Equip. Install - 3rd	92 days?	Wed 10/1/08	Thu 2/5/09
151	MEP Equip. Install - 4th	87 days?	Wed 10/1/08	Thu 1/29/09
152	MEP Equip. Install - 5th	84 days?	Mon 9/29/08	Thu 1/22/09
153	MEP Equip. Install - 6th	79 days?	Mon 9/29/08	Thu 1/15/09
154	MEP Equip. Install - 7th	74 days?	Mon 9/29/08	Thu 1/8/09
155	MEP Equip. Install - 8th	79 days?	Mon 9/15/08	Thu 1/1/09
156	MEP Equip. Install - 9th	71 days?	Mon 9/15/08	Mon 12/22/08
157	MEP Equip. Install - 10th	52 days?	Fri 10/3/08	Mon 12/15/08
158	MEP Equip. Install - 11th	80 days?	Wed 10/1/08	Tue 1/20/09
159	MEP Equip. Install - 12th	67 days?	Fri 9/26/08	Mon 12/29/08

Project: Perfect Schedule
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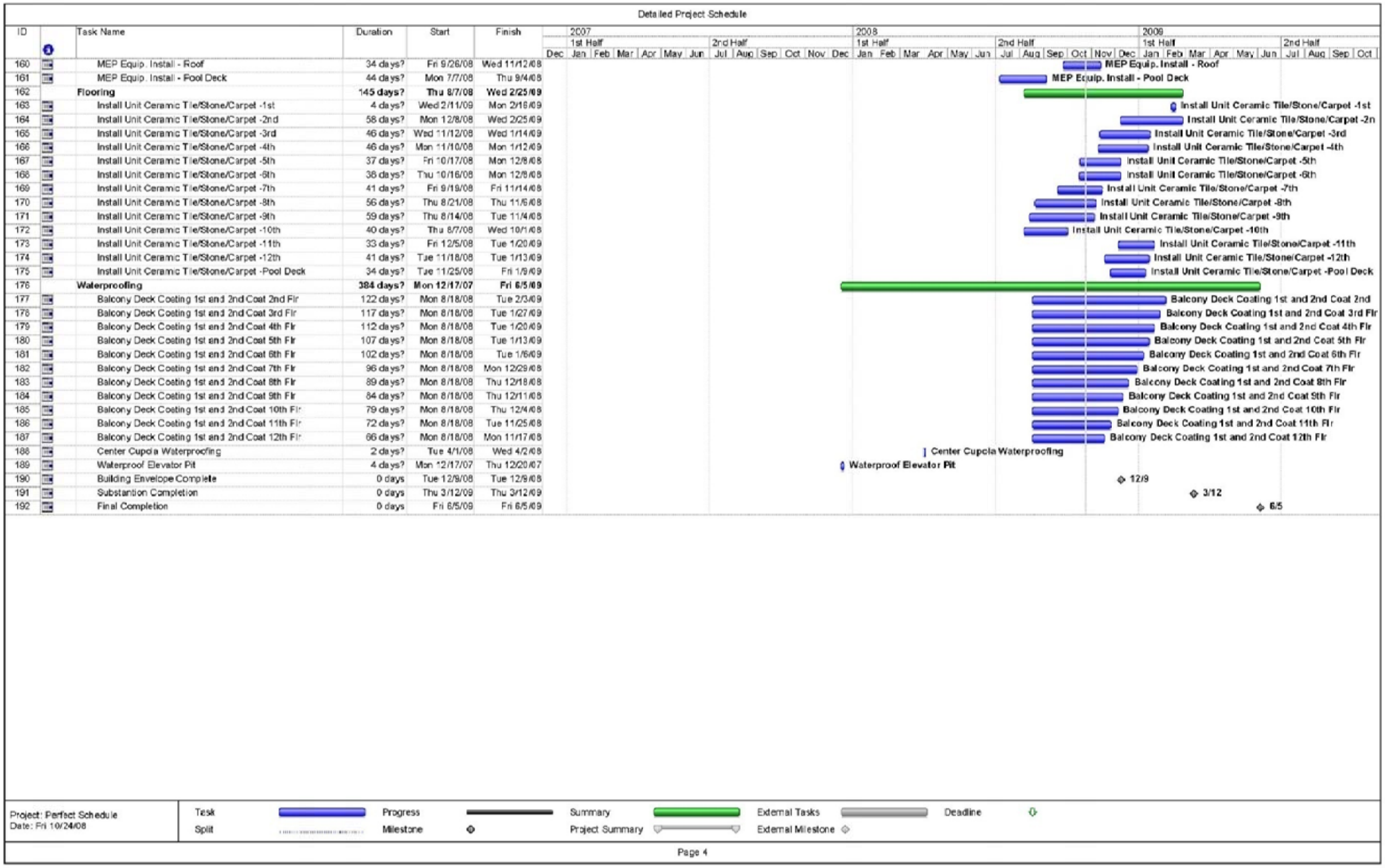

Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
160	MEP Equip. Install - Roof	34 days?	Fri 9/26/08	Wed 11/12/08
161	MEP Equip. Install - Pool Deck	44 days?	Mon 7/7/08	Thu 9/4/08
162	**Flooring**	**145 days?**	**Thu 8/7/08**	**Wed 2/25/09**
163	Install Unit Ceramic Tile/Stone/Carpet -1st	4 days?	Wed 2/11/09	Mon 2/16/09
164	Install Unit Ceramic Tile/Stone/Carpet -2nd	58 days?	Mon 12/8/08	Wed 2/25/09
165	Install Unit Ceramic Tile/Stone/Carpet -3rd	46 days?	Wed 11/12/08	Wed 1/14/09
166	Install Unit Ceramic Tile/Stone/Carpet -4th	46 days?	Mon 11/10/08	Mon 1/12/09
167	Install Unit Ceramic Tile/Stone/Carpet -5th	37 days?	Fri 10/17/08	Mon 12/8/08
168	Install Unit Ceramic Tile/Stone/Carpet -6th	38 days?	Thu 10/16/08	Mon 12/8/08
169	Install Unit Ceramic Tile/Stone/Carpet -7th	41 days?	Fri 9/19/08	Fri 11/14/08
170	Install Unit Ceramic Tile/Stone/Carpet -8th	56 days?	Thu 8/21/08	Thu 11/6/08
171	Install Unit Ceramic Tile/Stone/Carpet -9th	59 days?	Thu 8/14/08	Tue 11/4/08
172	Install Unit Ceramic Tile/Stone/Carpet -10th	40 days?	Thu 8/7/08	Wed 10/1/08
173	Install Unit Ceramic Tile/Stone/Carpet -11th	33 days?	Fri 12/5/08	Tue 1/20/09
174	Install Unit Ceramic Tile/Stone/Carpet -12th	41 days?	Tue 11/18/08	Tue 1/13/09
175	Install Unit Ceramic Tile/Stone/Carpet -Pool Deck	34 days?	Tue 11/25/08	Fri 1/9/09
176	**Waterproofing**	**384 days?**	**Mon 12/17/07**	**Fri 6/5/09**
177	Balcony Deck Coating 1st and 2nd Coat 2nd Flr	122 days?	Mon 8/18/08	Tue 2/3/09
178	Balcony Deck Coating 1st and 2nd Coat 3rd Flr	117 days?	Mon 8/18/08	Tue 1/27/09
179	Balcony Deck Coating 1st and 2nd Coat 4th Flr	112 days?	Mon 8/18/08	Tue 1/20/09
180	Balcony Deck Coating 1st and 2nd Coat 5th Flr	107 days?	Mon 8/18/08	Tue 1/13/09
181	Balcony Deck Coating 1st and 2nd Coat 6th Flr	102 days?	Mon 8/18/08	Tue 1/6/09
182	Balcony Deck Coating 1st and 2nd Coat 7th Flr	96 days?	Mon 8/18/08	Mon 12/29/08
183	Balcony Deck Coating 1st and 2nd Coat 8th Flr	89 days?	Mon 8/18/08	Thu 12/18/08
184	Balcony Deck Coating 1st and 2nd Coat 9th Flr	84 days?	Mon 8/18/08	Thu 12/11/08
185	Balcony Deck Coating 1st and 2nd Coat 10th Flr	79 days?	Mon 8/18/08	Thu 12/4/08
186	Balcony Deck Coating 1st and 2nd Coat 11th Flr	72 days?	Mon 8/18/08	Tue 11/25/08
187	Balcony Deck Coating 1st and 2nd Coat 12th Flr	66 days?	Mon 8/18/08	Mon 11/17/08
188	Center Cupola Waterproofing	2 days?	Tue 4/1/08	Wed 4/2/08
189	Waterproof Elevator Pit	4 days?	Mon 12/17/07	Thu 12/20/07
190	Building Envelope Complete	0 days	Tue 12/9/08	Tue 12/9/08
191	Substantion Completion	0 days	Thu 3/12/09	Thu 3/12/09
192	Final Completion	0 days	Fri 6/5/09	Fri 6/5/09

Project: Perfect Schedule
Date: Fri 10/24/08

Task	Progress	Summary	External Tasks
Split	Milestone ◆	Project Summary	External Milestone ◆
Deadline ⇩			

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APPENDIX B

BP Solar SX 3200 Specifications

bp solar

SX 3200

200 watt photovoltaic module

High-efficiency photovoltaic module using silicon nitride multicrystalline silicon cells

Performance

Rated power (P_{max})	200W
Power tolerance	±9%
Nominal voltage	16V
Limited Warranty[1]	25 years

Configuration

B	Bronze frame with output cables and polarized Multicontact (MC) connectors

Electrical Characteristics[2]

	SX 3200	SX 3195
Maximum power (P_{max})[3]	200W	195W
Voltage at P_{max} (V_{mp})	24.5V	24.4
Current at P_{max} (I_{mp})	8.16A	7.96A
Warranted minimum P_{max}	182.0W	177.5W
Short-circuit current (I_{sc})	8.7A	8.6A
Open-circuit voltage (V_{oc})	30.8V	30.7V
Temperature coefficient of I_{sc}	(0.065±0.015)%/°C	
Temperature coefficient of V_{oc}	-(111±10)mV/°C	
Temperature coefficient of power	-(0.5±0.05)%/°C	
NOCT (Air 20°C; Sun 0.8kW/m^2; wind 1m/s)	47±2°C	
Maximum series fuse rating	15A	
Maximum system voltage	600V (U.S. NEC rating)	

Mechanical Characteristics

Dimensions	Length: 1680mm (66.14") Width: 837mm (32.95") Depth: 50mm (1.97")
Weight	15.4 kg (33.95 pounds)
Solar Cells	50 cells (156mm x 156mm) in a 5x10 matrix connected in series
Output Cables	RHW-2 AWG# 12 (4mm^2), cable with polarized weatherproof DC rated Multicontact connectors; asymmetrical lengths - 1250mm (-) and 800mm (+)
Diodes	***IntegraBus™*** technology includes Schottky by-pass diodes integrated into the printed circuit board bus
Construction	Front: High-transmission 3mm (1/8th in) tempered glass; Back: White or BlackTedlar; Encapsulant: EVA
Frame	**B** Anodized aluminium alloy type 6063T6 Universal frame; Color: bronze

1. Module warranty: 25-year limited warranty of 80% power output; 12-year limited warranty of 90% power output; 5-year limited warranty of materials and workmanship. See your local representative for full terms of these warranties.
2. This data represents the performance of typical SX 3200 products, and is based on measurements made in accordance with ASTM E1036 corrected to SRC (STC.)
3. During the stabilization process that occurs during the first few months of deployment, module power may decrease by up to 1% from typical P_{max}.

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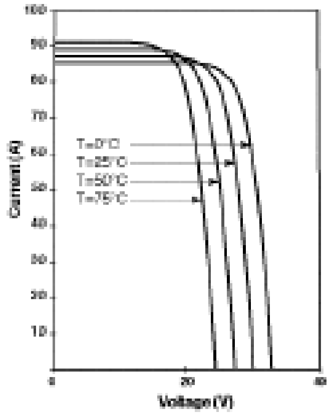
Quality and Safety

ESTI	Module power measurements calibrated to World Radiometric Reference through ESTI (European Solar Test Installation at Ispra, Italy)
UL	Listed by Underwriter's Laboratories for electrical and fire safety (Class C fire rating)

Qualification Test Parameters

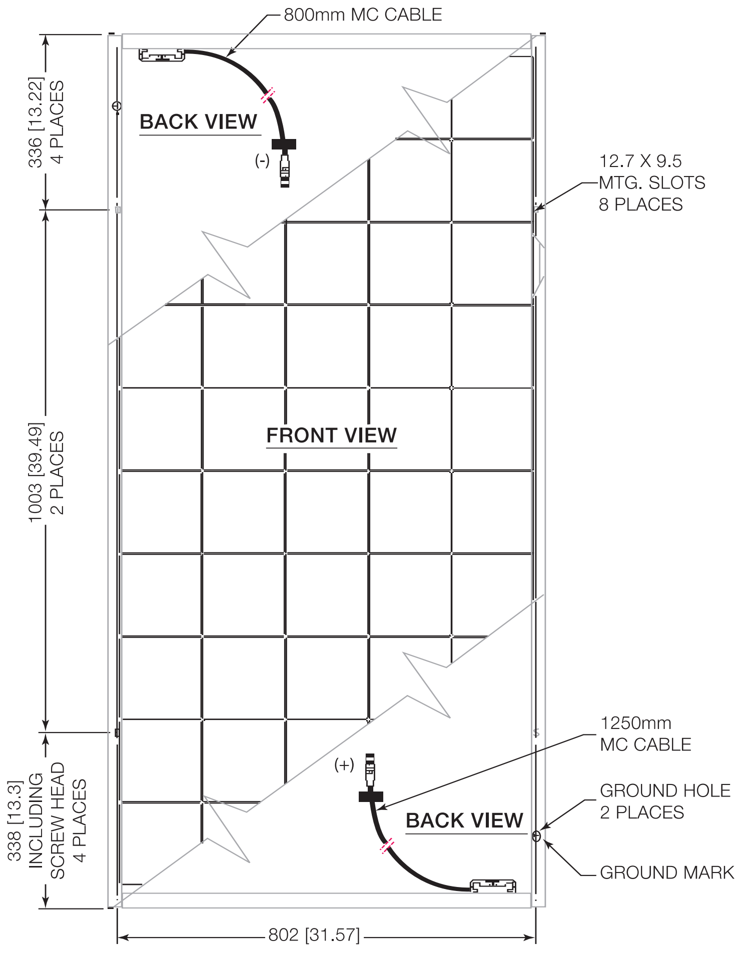
Temperature cycling range	-40°C to +85°C (-40°F to 185°F)
Humidity freeze, damp heat	85% RH
Static load front and back (e.g. wind)	2,400 pa (50psf)
Front loading (e.g. snow)	5,400 pa (113psf)
Haiilstone impact	25mm Ø (1 inch) at 23 m/s (52mph)

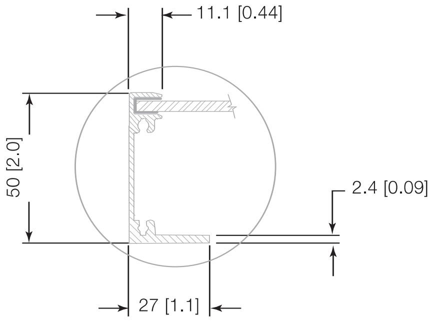
SX 3200 I-V Curves



Module Diagram

Dimensions in brackets are in inches. Un-bracketed dimensions are in millimeters. Overall tolerances ±3mm (1/8").





SECTION A-A

Included with each module: self-tapping grounding screw, instruction sheet and warranty documents.

Note: This publication summarizes product warranty and specifications, which are subject to change without notice.
Additional information may be found on our web site: **www.bpsolar.us**

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APPENDIX C

Xantrex GT 5.0 Grid Tie Solar Inverter Specifications

Smart choice for power™

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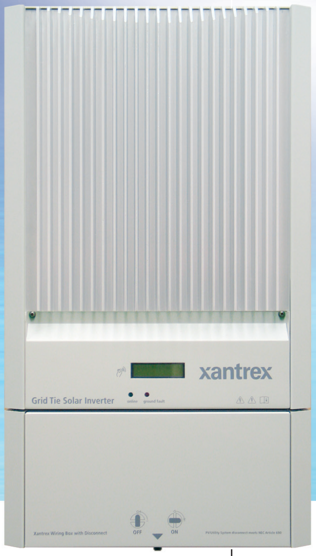
Xantrex™ GT Series Grid Tie Solar Inverters



The Xantrex™ Grid Tie Solar Inverter (GT Series) is designed to convert photovoltaic (PV) electricity produced by solar modules into utility-grade power that can be used by the home or sold to the local electrical utility. Offering high efficiency (up to 96.0 %), clean aesthetics, high reliability, and a low installed cost, through ease of installation and integrated features, the GT Series is a proven, high-frequency design in a compact enclosure.

The GT Series may be installed as a single inverter, for a single PV array, or in a multiple-inverter configuration for large PV systems.

Technology

- An NEC compliant, integrated DC/AC disconnect, standard in the GT Series, eliminates the need for external DC (PV) disconnects, and in some jurisdictions, AC disconnects
- Large heat-sink offers extraordinary heat dispersion without the need for a cooling fan
- Liquid crystal display (LCD) provides instantaneous information – power level, daily and lifetime energy production, PV array voltage and current, utility voltage and frequency, time online “selling”, fault messages, and installer-customized screens
- LCD vibration sensor allows the tap of a finger to turn backlight on and cycle through display screens

Installation

- Flexible module selection and sizing due to wide PV input MPPT tracking voltage range
- Lightweight and versatile mounting bracket
- Easy access DC (photovoltaic) and AC (utility) terminal block simplifies wiring
- Rugged NEMA 3R inverter enclosure allows reliable indoor and outdoor installations

Performance

- Best-in-class efficiency to maximize solar system return on investment
- Accurate MPPT tracking ensures maximum energy harvest under any conditions
- FCC Part B compliance provides less external electronic interference

Serviceability

- 10-year standard warranty
- Sealed inverter enclosure can be quickly separated from the wiring box allowing DC/AC connections to remain intact in the unlikely event the inverter needs to be serviced

xantrex
GT SERIES WARRANTY
10 YEARS

Standard 10-year warranty

C US
UL 1741
CSA 107.1-01
PHOTOVOLTAIC POWER INVERTER

Xantrex Technology Inc.

Customer Service/Technical Support
customerservice@xantrex.com
Toll free: 1-800-670-0707

www.xantrex.com

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Smart choice for power™

xantrex™

Xantrex™ GT Series Grid Tie Solar Inverters

Electrical Specifications - Output

Models	GT5.0		GT4.0N		GT3.8		GT3.3N		GT2.8	
Maximum AC power output	5000 W	4500 W	4000 W	3800 W	3800 W	3500 W	3300 W	3100 W	2800 W	2700 W
AC output voltage (nominal)	240 V	208 V	240 V	208 V	240 V	208 V	240 V	208 V	240 V	208 V
AC output voltage range	211-264 Vac 183-229 Vac									
AC frequency (nominal)	60 Hz									
AC frequency range	59.3 - 60.5 Hz									
Maximum continuous output current	21 A	22 A	16.7 A	18.3 A	15.8 A	16.8 A	13.8 A	14.9 A	11.7 A	13.0 A
Maximum output over-current protection	30 A		25 A		20 A	25 A	20 A		15 A	
Maximum utility backfeed current	0 A									
Total harmonic distortion (THD)	< 3 %									
Power factor	> 0.99 (at rated power), > 0.95 (full power range)									
Utility monitoring, islanding protection	UL1741-2005 / IEEE 1547									
Output characteristics	Current source									
Output current waveform	True sine wave									

Electrical Specifications - Input

Maximum array open-circuit voltage	600 Vdc									
MPPT voltage range (CEC & CSA)	240 - 550 Vdc		240 - 480 Vdc		195 - 550 Vdc		200 - 400 Vdc		195 - 550 Vdc	
MPPT operating range	235 - 550 Vdc		235 - 550 Vdc		195 - 550 Vdc		200 - 550 Vdc		193 - 550 Vdc	
Maximum input current	22.0 Adc	20.0 Adc	18.0 Adc	17.0 Adc	20.8 Adc	19.5 Adc	17.5 Adc	16.5 Adc	15.4 Adc	14.9 Adc
Maximum array short-circuit current	24.0 Adc									
Reverse-polarity protection	Short-circuit diode									
Ground-fault protection	GF detection, IDIF > 1 A									
Maximum inverter efficiency	95.9%	95.5%	96.0%	95.7%	95.9%	95.6%	95.9%	95.6%	95.0%	94.6%
CEC efficiency	95.5%	95.0%	95.5%	95.0%	95.0%	95.0%	95.5%	95.0%	94.0%	93.5%
Night-time power consumption	1 W									

Environmental Specifications

Operating temperature range	-13°F to 149°F (-25°C to 65°C)				
Enclosure type	NEMA 3R (outdoor rated)				
Inverter weight	58.0 lb (25.8 kg)	58.0 lb (25.8 kg)	58.0 lb (25.8 kg)	49.0 lb (22.2 kg)	49.0 lb (22.2 kg)
Shipping weight	65.0 lb (27.2 kg)	65.0 lb (27.2 kg)	65.0 lb (27.2 kg)	57.0 lb (25.9 kg)	57.0 lb (25.9 kg)
Inverter dimensions (H x W x D)	28 1/2 x 16 x 5 3/4" (72.4 x 40.3 x 14.5 cm)				
Shipping dimensions (H x W x D)	34 x 20 1/2 x 10 5/16" (86.6 x 51.8 x 26.2 cm)				

Mechanical Specifications

Mounting	Wall mount (mounting bracket included)				
Input and output terminal	AC and DC terminals accept wires sizes of #14 to #6 AWG				
PV / Utility disconnect	Eliminates need for external PV (DC) disconnect. Complies with NEC requirements				
Cooling	Convection cooled, fan not required				
Display	Backlit, two-line, 16-character liquid crystal display provides instantaneous power, daily and lifetime energy production, PV array voltage and current, utility voltage and frequency, time online "selling", fault messages, and installer-customizable screens				
Communications	Integrated RS232 and Xanbus™ RJ45 communication ports				
Wiring box	PV, utility, ground, and communications connections. The inverter can be separated from the wiring box.				
Warranty	10-year standard				
Model number (negative ground)	GT5.0-NA-240/208 UL-05	GT4.0N-NA-240/208 UL-05	GT3.8-NA-240-/208 UL-05	GT3.3N-NA-240/208 UL-05	GT2.8-NA-240/208 UL-05
Part number (negative ground)	864-1009	864-1008	864-1032	864-1006	864-1001
	Positive ground inverters are also available				

Regulatory Approvals

Certified to UL1741 1st Edition: 2005 version CSA 107.1-01 CSA 2 C22.2 No.107-1-01 general use power power supplies.

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APPENDIX D

Electrical Panel Schedule

PANEL LR SECT 2 | **Rating: 208/120V, 3Φ, 4W** | **General Panel Data** VOLT: 120/208V 3PH,4W | Mount: Suface BUS: 175 A

Load Description	Wire and Conduit	Kw Load			CB/Phase	Circuit No.	Φ	Circuit No.	CB/Phase	Kw Load			Wire and Conduit	Load Description
		A	B	C						A	B	C		
CU-4 Rooftop	(2)#12+(1)#12 G	2.2			35/2	1	A	2	2	1.0			(2)#12+(1)#12 G	Vending Machines
Rooftop Recep.	(2)#12+(1)#12 G		1.0		20/2	3	B	4	4		1.0		(2)#12+(1)#12 G	Vending Machines
Rooftop Recep.	(2)#12+(1)#12 G			1.0	20/2	5	C	6	6			1.0	(2)#12+(1)#12 G	Vending Machines
Rooftop Recep.	(2)#12+(1)#12 G	1.0			20/2	7	A	8	8	1.0			(2)#12+(1)#12 G	CP-2
Pool Equip Rm Recep.	(2)#12+(1)#12 G		1.0		20/2	9	B	10	10		1.0		(2)#12+(1)#12 G	Rooftop Recep.
Toilet Room Recep.	(2)#12+(1)#12 G			1.0	20/2	11	C	12	12			1.0	(2)#12+(1)#12 G	Pool Area Recep.
INVERTER 1	(2) #12 AWG	2.0			25/2	13	A	14	25/2	2.0			(2) #12 AWG	INVERTER 1
	(1) #12 WAG G		2.0			15	B	16			2.0		(1) #12 WAG G	
INVERTER 2	(2) #12 AWG			2.0	25/2	17	C	18	25/2			2.0	(2) #12 AWG	INVERTER 2
	(1) #12 WAG G	2.0				19	A	20		2.0			(1) #12 WAG G	
INVERTER 3	(2) #12 AWG		2.0		25/2	21	B	22	25/2		2.0		(2) #12 AWG	INVERTER 3
	(1) #12 WAG G			2.0		23	C	24				2.0	(1) #12 WAG G	
INVERTER 4	(2) #12 AWG	2.0			25/2	25	A	26	25/2	2.0			(2) #12 AWG	INVERTER 4
	(1) #12 WAG G		2.0			27	B	28			2.0		(1) #12 WAG G	
INVERTER 5	(2) #12 AWG			2.0	25/2	29	C	30	25/2			2.0	(2) #12 AWG	INVERTER 5
	(1) #12 WAG G	2.0				31	A	32		2.0			(1) #12 WAG G	
SPARE			X		25/1	33	B	34	25/1		X		20/1	SPARE
SPARE				X	25/1	35	C	36	25/1			X	20/1	SPARE
SPARE		X			25/1	37	A	38	25/1	X			20/1	SPARE
SPARE			X		25/1	39	B	40	25/1		X		20/1	SPARE
SPARE				X	25/1	41	C	42	25/1			X	20/1	SPARE
SPARE		X			25/1	43	A	44	25/1	X			20/1	SPARE
SPARE			X		25/1	45	B	46	25/1		X		20/1	SPARE
SPARE				X	25/1	47	C	48	25/1			X	20/1	SPARE
		11.2	8.0	8.0			TOTAL			10.0	8.0	8.0		
		27.2					53.2			26.0				

APPENDIX E

Fenestration Analysis

January 21 Fenestration Analysis

Conduction = $Q_{cond} = UA(\Delta T)$

Solar Radiation = $Q_{sol} = SHGC(A)(E_t)$

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	41	72	-31.0	-511605	-309343	-214160	0	0	0	0	0	0	0	-511605	-309343	-214160	-202263	-297445	HEATING LOAD
1:00	40	72	-32.0	-528109	-319322	-221069	0	0	0	0	0	0	0	-528109	-319322	-221069	-208787	-307040	
2:00	39	72	-33.3	-549563	-332294	-230050	0	0	0	0	0	0	0	-549563	-332294	-230050	-217269	-319514	
3:00	38	72	-34.5	-569367	-344269	-238340	0	0	0	0	0	0	0	-569367	-344269	-238340	-225099	-331028	
4:00	36	72	-35.7	-589171	-356243	-246630	0	0	0	0	0	0	0	-589171	-356243	-246630	-232928	-342542	
5:00	36	72	-36.5	-602374	-364226	-252157	0	0	0	0	0	0	0	-602374	-364226	-252157	-238148	-350218	
6:00	35	72	-37.0	-610626	-369216	-255611	0	0	0	0	0	0	0	-610626	-369216	-255611	-241410	-355015	
7:00	35	72	-36.7	-605675	-366222	-253538	0	0	0	0	0	0	0	-605675	-366222	-253538	-239453	-352137	
8:00	37	72	-35.2	-580920	-351254	-243176	6.73	86.02	6.73	54.81	946186	424152	293644	365266	72898	50468	292367	314798	COOLING LOAD
9:00	39	72	-32.7	-539661	-326307	-225905	22.32	189.16	22.32	172.80	2282968	1023399	708507	1743307	697093	482603	1046214	1260704	
10:00	43	72	-29.5	-486850	-294375	-203798	32.09	181.69	32.09	241.55	2482760	1112961	770512	1995910	818587	566714	1177323	1429196	
11:00	46	72	-26.5	-437340	-264438	-183073	38.21	133.82	38.21	283.70	2230703	999970	692287	1793363	735532	509214	1057831	1284148	
12:00	50	72	-22.0	-363075	-219534	-151985	42.93	68.28	40.97	302.54	1753506	786054	544191	1390431	566521	392207	823910	998224	
13:00	51	72	-20.8	-343271	-207559	-143695	41.41	92.24	40.37	298.46	1936948	868287	601122	1593677	660728	457427	932949	1136250	
14:00	51	72	-21.0	-346571	-209555	-145076	36.42	153.80	36.42	271.43	2356488	1056357	731324	2009917	846802	586247	1163115	1423669	
15:00	50	72	-21.7	-358124	-216540	-149912	29.07	190.75	29.07	220.48	2480048	1111745	769670	2121924	895205	619758	1226718	1502166	
16:00	49	72	-22.7	-374627	-226519	-156821	17.68	172.65	17.68	138.67	2010547	901280	623963	1635920	674761	467142	961159	1168778	
17:00	49	72	-23.5	-387830	-234502	-162347	0.37	5.59	0.37	3.12	59735	26778	18538	-328095	-207724	-143809	-120371	-184286	HEATING LOAD
18:00	47	72	-24.7	-407634	-246476	-170637	0	0	0	0	0	0	0	-407634	-246476	-170637	-161158	-236997	
19:00	46	72	-25.8	-425788	-257453	-178237	0	0	0	0	0	0	0	-425788	-257453	-178237	-168335	-247551	
20:00	45	72	-27.0	-445592	-269428	-186527	0	0	0	0	0	0	0	-445592	-269428	-186527	-176164	-259065	
21:00	44	72	-28.0	-462095	-279406	-193435	0	0	0	0	0	0	0	-462095	-279406	-193435	-182689	-268660	
22:00	43	72	-29.1	-480249	-290383	-201034	0	0	0	0	0	0	0	-480249	-290383	-201034	-189866	-279215	
23:00	42	72	-30.0	-495102	-299364	-207252	0	0	0	0	0	0	0	-495102	-299364	-207252	-195738	-287850	
	Averages			Totals							Totals			**14,649,713**	**5,968,127**	**4,131,780**	**8,681,586**	**10,517,933**	**Cooling Load**
	43	**72**	**-29**	**-11,501,219**	**-6,954,226**	**-4,814,464**	**267**	**1,274**	**264**	**1,988**	**18,539,887**	**8,310,984**	**5,753,758**	**7,611,045**	**4,611,368**	**3,192,486**	**2,999,677**	**4,418,559**	**Heating Load**

February 21 Fenestration Analysis

Conduction = $Q_{cond} = UA(\Delta T)$

Solar Radiation = $Q_{sol} = SHGC(A)(E_t)$

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	37	72	-35.5	-585871	-354247	-245248	0	0	0	0	0	0	0	-585871	-354247	-245248	-231623	-340623	HEATING LOAD
1:00	35	72	-36.7	-605675	-366222	-253538	0	0	0	0	0	0	0	-605675	-366222	-253538	-239453	-352137	
2:00	34	72	-38.0	-627129	-379194	-262519	0	0	0	0	0	0	0	-627129	-379194	-262519	-247935	-364610	
3:00	32	72	-39.6	-653535	-395160	-273573	0	0	0	0	0	0	0	-653535	-395160	-273573	-258374	-379962	
4:00	32	72	-40.4	-666737	-403144	-279099	0	0	0	0	0	0	0	-666737	-403144	-279099	-263594	-387638	
5:00	31	72	-41.3	-681590	-412124	-285317	0	0	0	0	0	0	0	-681590	-412124	-285317	-269466	-396274	
6:00	32	72	-40.5	-668388	-404141	-279790	0	0	0	0	0	0	0	-668388	-404141	-279790	-264246	-388598	
7:00	34	72	-38.3	-632080	-382188	-264592	0	0	0	0	0	0	0	-632080	-382188	-264592	-249892	-367489	
8:00	37	72	-35.5	-585871	-354247	-245248	17.14	191.74	17.14	95.45	2073459	929482	643487	1487588	575234	398239	912354	1089349	COOLING LOAD
9:00	39	72	-33.0	-544612	-329300	-227977	30.53	253.43	30.53	175.77	2940914	1318341	912697	2396302	989040	684720	1407261	1711582	
10:00	42	72	-30.3	-500053	-302358	-209325	39.90	210.74	39.90	233.98	2806646	1258152	871028	2306593	955794	661704	1350799	1644890	
11:00	45	72	-27.5	-453844	-274417	-189981	46.03	154.18	46.03	272.68	2471494	1107911	767016	2017651	833494	577035	1184157	1440616	
12:00	46	72	-25.7	-424137	-256455	-177546	50.80	81.01	48.92	291.00	1927571	864084	598212	1503434	607629	420666	895805	1082768	
13:00	47	72	-25.4	-419186	-253462	-175473	49.61	101.46	48.47	288.17	2086734	935433	647607	1667548	681971	472134	985577	1195414	
14:00	46	72	-25.8	-425788	-257453	-178237	44.72	171.34	44.72	264.33	2587003	1159691	802863	2161215	902238	624626	1258977	1536589	
15:00	46	72	-26.5	-437340	-264438	-183073	37.73	221.27	37.73	220.39	2843086	1274487	882337	2405746	1010048	699264	1395697	1706481	
16:00	44	72	-27.7	-457144	-276413	-191363	27.44	233.21	27.44	156.90	2688007	1204968	834209	2230862	928556	642846	1302307	1588016	
17:00	43	72	-28.7	-473648	-286392	-198271	12.46	154.84	12.46	68.42	1639375	734892	508772	1165728	448501	310501	717227	855227	
18:00	42	72	-30.0	-495102	-299364	-207252	0	0	0	0	0	0	0	-495102	-299364	-207252	-195738	-287850	HEATING LOAD
19:00	41	72	-31.2	-514906	-311339	-215542	0	0	0	0	0	0	0	-514906	-311339	-215542	-203568	-299364	
20:00	41	72	-31.2	-514906	-311339	-215542	0	0	0	0	0	0	0	-514906	-311339	-215542	-203568	-299364	
21:00	40	72	-32.4	-534710	-323313	-223832	0	0	0	0	0	0	0	-534710	-323313	-223832	-211397	-310878	
22:00	39	72	-33.5	-552864	-334290	-231431	0	0	0	0	0	0	0	-552864	-334290	-231431	-218574	-321433	
23:00	38	72	-34.5	-569367	-344269	-238340	0	0	0	0	0	0	0	-569367	-344269	-238340	-225099	-331028	
	Averages			Totals							Totals			**19,342,667**	**7,932,506**	**5,491,735**	**11,410,162**	**13,850,933**	**Cooling Load**
	39	**72**	**-33**	**-13,024,483**	**-7,875,269**	**-5,452,109**	**356**	**1,773**	**353**	**2,067**	**24,064,290**	**10,787,440**	**7,468,228**	**8,302,861**	**5,020,334**	**3,475,616**	**3,282,526**	**4,827,245**	**Heating Load**

March 21 Fenestration Analysis

Conduction = $Q_{cond} = UA(\Delta T)$

Solar Radiation = $Q_{sol} = SHGC(A)(E_t)$

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	46	72	-25.8	-425788	-257453	-178237	0	0	0	0	0	0	0	-425788	-257453	-178237	-168335	-247551	HEATING LOAD
1:00	45	72	-27.2	-448892	-271423	-187908	0	0	0	0	0	0	0	-448892	-271423	-187908	-177469	-260984	
2:00	43	72	-29.0	-478599	-289385	-200344	0	0	0	0	0	0	0	-478599	-289385	-200344	-189213	-278255	
3:00	42	72	-30.5	-503354	-304353	-210706	0	0	0	0	0	0	0	-503354	-304353	-210706	-199000	-292648	
4:00	40	72	-32.0	-528109	-319322	-221069	0	0	0	0	0	0	0	-528109	-319322	-221069	-208787	-307040	
5:00	39	72	-33.2	-547913	-331296	-229359	0	0	0	0	0	0	0	-547913	-331296	-229359	-216617	-318554	
6:00	38	72	-33.7	-556165	-336286	-232813	0	0	0	0	0	0	0	-556165	-336286	-232813	-219879	-323352	
7:00	39	72	-33.0	-544612	-329300	-227977	12.03	154.64	12.79	30.39	1548994	694376.6544	480722	1004382	365076	252745	639306	751637	COOLING LOAD
8:00	41	72	-31.4	-518207	-313334	-216924	28.23	256.23	28.23	98.74	2766671	1240232	858622	2248464	926897	641698	1321566	1606766	
9:00	43	72	-28.8	-475298	-287389	-198962	39.89	260.31	39.89	160.62	3072821	1377471	953634	2597523	1090082	754672	1507441	1842851	
10:00	46	72	-26.0	-429088	-259449	-179618	48.52	221.61	48.52	210.23	2945566	1320426	914141	2516477	1060977	734523	1455500	1781955	
11:00	49	72	-23.5	-387830	-234502	-162347	54.16	158.17	54.16	243.76	2533523	1135717	786266	2145693	901216	623918	1244478	1521775	
12:00	51	72	-20.9	-344921	-208557	-144386	58.96	81.11	56.64	258.72	1947821	873161	604496	1602900	664604	460111	938296	1142789	
13:00	54	72	-17.8	-293761	-177623	-122970	56.74	119.13	55.86	253.98	2244931	1006348	696703	1951170	828726	573733	1122445	1377437	
14:00	56	72	-15.6	-257453	-155669	-107771	51.84	190.89	51.85	229.88	2760376	1237410	856668	2502923	1081741	748897	1421182	1754025	
15:00	57	72	-14.6	-240950	-145690	-100863	44.75	244.08	44.75	188.25	3048796	1366702	946178	2807847	1221011	845316	1586835	1962531	
16:00	57	72	-14.8	-244250	-147686	-102244	34.71	256.44	34.71	132.21	2916882	1307568	905239	2672632	1159882	802995	1512750	1869637	
17:00	56	72	-15.6	-257453	-155669	-107771	21.29	227.04	21.29	66.21	2361628	1058661	732919	2104175	902992	625148	1201184	1479027	
18:00	55	72	-17.0	-280558	-169640	-117443	1.62	25.21	1.82	2.83	244039	109396.7082	75736	-36519	-60243	-41707	23724	5188	HEATING LOAD
19:00	54	72	-18.3	-302012	-182612	-126424	0	0	0	0	0	0	0	-302012	-182612	-126424	-119400	-175589	
20:00	52	72	-19.8	-326767	-197580	-136786	0	0	0	0	0	0	0	-326767	-197580	-136786	-129187	-189981	
21:00	51	72	-21.5	-354823	-214544	-148531	0	0	0	0	0	0	0	-354823	-214544	-148531	-140279	-206293	
22:00	49	72	-23.0	-379578	-229512	-158893	0	0	0	0	0	0	0	-379578	-229512	-158893	-150066	-220685	
23:00	48	72	-24.3	-401033	-242485	-167874	0	0	0	0	0	0	0	-401033	-242485	-167874	-158548	-233159	
	Averages			Totals							Totals			**24,154,186**	**10,203,203**	**7,063,756**	**13,950,983**	**17,090,430**	**Cooling Load**
	48	**72**	**-24**	**-9,527,413**	**-5,760,761**	**-3,988,219**	**453**	**2,195**	**451**	**1,876**	**28,392,048**	**12,727,470**	**8,811,325**	**5,289,551**	**3,236,495**	**2,240,650**	**2,053,056**	**3,048,901**	**Heating Load**

April 21 Fenestration Analysis

Conduction = $Q_{cond} = UA(\Delta T)$

Solar Radiation = $Q_{sol} = SHGC(A)(E_t)$

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	57	72	-14.6	-240950	-145690	-100863	0	0	0	0	0	0	0	-240950	-145690	-100863	-95259	-140087	HEATING LOAD
1:00	56	72	-16.4	-270656	-163652	-113298	0	0	0	0	0	0	0	-270656	-163652	-113298	-107003	-157358	
2:00	54	72	-18.5	-305313	-184608	-127805	0	0	0	0	0	0	0	-305313	-184608	-127805	-120705	-177508	
3:00	52	72	-20.2	-333369	-201572	-139550	0	0	0	0	0	0	0	-333369	-201572	-139550	-131797	-193819	
4:00	50	72	-22.0	-363075	-219534	-151985	0	0	0	0	0	0	0	-363075	-219534	-151985	-143541	-211090	
5:00	49	72	-22.7	-374627	-226519	-156821	0	0	0	0	0	0	0	-374627	-226519	-156821	-148108	-217807	
6:00	50	72	-22.3	-368026	-222527	-154057	6.36	82.82	20.37	6.64	831995	372963	258205	463970	150436	104148	313533	359821	COOLING LOAD
7:00	51	72	-21.0	-346571	-209555	-145076	24.56	237.01	30.32	26.83	2407653	1079293	747203	2061082	869738	602126	1191344	1458955	
8:00	53	72	-18.8	-310264	-187601	-129878	37.67	274.01	39.07	76.13	2980022	1335872	924834	2669758	1148270	794956	1521487	1874801	
9:00	56	72	-16.0	-264054	-159661	-110534	47.97	259.97	47.97	127.49	3087245	1383937	958110	2823190	1224276	847576	1598914	1975614	
10:00	58	72	-13.8	-227747	-137707	-95336	55.68	215.13	55.68	169.42	2879032	1290601	893493	2651286	1152893	798157	1498392	1853129	
11:00	60	72	-11.7	-193090	-116752	-80828	60.59	150.56	60.59	197.22	2436070	1092031	756022	2242980	975279	675193	1267701	1567787	
12:00	63	72	-9.0	-148531	-89809	-62176	65.53	75.15	62.49	208.21	1856077	832034	576024	1707546	742225	513848	965321	1193698	
13:00	66	72	-6.3	-103971	-62866	-43523	61.31	133.38	61.39	201.37	2304443	1033026	715172	2200471	970160	671649	1230312	1528822	
14:00	68	72	-4.0	-66014	-39915	-27634	57.09	201.45	57.09	177.32	2793877	1252428	867065	2727863	1212512	839432	1515351	1888432	
15:00	69	72	-2.7	-44559	-26943	-18653	50.01	251.77	50.01	138.00	3062673	1372922	950485	3018114	1345980	931832	1672134	2086282	
16:00	70	72	-2.2	-36307	-21953	-15198	40.31	274.27	41.41	88.65	3039686	1362618	943351	3003378	1340664	928152	1662714	2075226	
17:00	69	72	-3.0	-49510	-29936	-20725	27.94	252.24	30.31	35.30	2591003	1161484	804104	2541492	1131548	783379	1409945	1758113	
18:00	68	72	-4.2	-69314	-41911	-29015	11.33	137.1	29.71	11.97	1379742	618505	428196	1310427	576594	399180	733833	911247	
19:00	66	72	-5.7	-94069	-56879	-39378	0	0	0	0	0	0	0	-94069	-56879	-39378	-37190	-54692	
20:00	64	72	-7.6	-125426	-75839	-52504	0	0	0	0	0	0	0	-125426	-75839	-52504	-49587	-72922	
21:00	63	72	-9.4	-155132	-93801	-64939	0	0	0	0	0	0	0	-155132	-93801	-64939	-61331	-90193	
22:00	61	72	-11.5	-189789	-114756	-79447	0	0	0	0	0	0	0	-189789	-114756	-79447	-75033	-110343	
23:00	59	72	-13.0	-214544	-129724	-89809	0	0	0	0	0	0	0	-214544	-129724	-89809	-84820	-124735	
	Averages			Totals			Totals							**29,421,558**	**12,840,577**	**8,889,630**	**16,580,982**	**20,531,928**	Cooling Load
	60	**72**	**-12**	**-4,894,908**	**-2,959,712**	**-2,049,031**	**546**	**2,545**	**586**	**1,465**	**31,649,517**	**14,187,715**	**9,822,264**	**2,666,949**	**1,612,574**	**1,116,397**	**1,054,375**	**1,550,552**	Heating Load

May 21 Fenestration Analysis

Conduction = $Q_{cond} = UA(\Delta T)$

Solar Radiation = $Q_{sol} = SHGC(A)(E_t)$

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	63	72	-9.0	-148531	-89809	-62176	0	0	0	0	0	0	0	-148531	-89809	-62176	-58721	-86355	HEATING LOAD
1:00	61	72	-11.0	-181537	-109767	-75992	0	0	0	0	0	0	0	-181537	-109767	-75992	-71771	-105545	
2:00	59	72	-13.0	-214544	-129724	-89809	0	0	0	0	0	0	0	-214544	-129724	-89809	-84820	-124735	
3:00	56	72	-16.0	-264054	-159661	-110534	0	0	0	0	0	0	0	-264054	-159661	-110534	-104394	-153520	
4:00	55	72	-17.0	-280558	-169640	-117443	0	0	0	0	0	0	0	-280558	-169640	-117443	-110918	-163115	
5:00	55	72	-17.0	-280558	-169640	-117443	0	0	0	0	0	0	0	-280558	-169640	-117443	-110918	-163115	
6:00	56	72	-16.0	-264054	-159661	-110534	15.66	162.38	59.4	15.66	1703124	763470	528556	1439070	603809	418021	835261	1021049	COOLING LOAD
7:00	58	72	-14.0	-231048	-139703	-96718	30.74	250.35	62.51	32.15	2653131	1189334	823385	2422083	1049631	726668	1372452	1695415	
8:00	60	72	-12.0	-198041	-119746	-82901	42.59	270.73	45.59	50.60	2953048	1323780	916463	2755007	1204035	833562	1550973	1921445	
9:00	62	72	-10.0	-165034	-99788	-69084	52.11	252.51	53.65	96.01	3001689	1345585	931559	2836655	1245797	862475	1590858	1974181	
10:00	64	72	-8.0	-132027	-79830	-55267	59.26	208.17	59.26	133.35	2778374	1245478	862254	2646346	1165647	806987	1480699	1839360	
11:00	66	72	-6.0	-99020	-59873	-41450	63.78	146.43	63.78	158.03	2348586	1052815	728872	2249566	992942	687421	1256624	1562145	
12:00	68	72	-4.0	-66014	-39915	-27634	68.84	75.09	65.47	167.44	1801163	807418	558981	1735149	767502	531348	967646	1203801	
13:00	70	72	-2.0	-33007	-19958	-13817	64.24	135.42	64.24	160.62	2263966	1014881	702610	2230959	994924	688793	1236035	1542166	
14:00	72	72	0.0	0	0	0	60.17	199.22	60.17	138.25	2721919	1220171	844733	2721919	1220171	844733	1501748	1877185	
15:00	74	72	2.0	33007	19958	13817	53.43	246.90	54.70	102.70	2982406	1336941	925574	3015413	1356898	939391	1658515	2076022	
16:00	75	72	3.0	49510	29936	20725	44.27	269.99	47.02	58.18	2982176	1336837	925503	3031686	1366774	946228	1664912	2085458	
17:00	74	72	2.0	33007	19958	13817	32.82	257.04	59.09	34.53	2730065	1223822	847261	2763072	1243780	861078	1519292	1901993	
18:00	73	72	1.0	16503	9979	6908	18.41	183.62	63.43	18.41	1927285	863955	598123	1943788	873934	605031	1069854	1338757	
19:00	72	72	0.0	0	0	0	0.36	4.66	2.27	0.36	48863	21904	15164	48863	21904	15164	26959	33698	
20:00	70	72	-1.9	-31356	-18960	-13126	0	0	0	0	0	0	0	-31356	-18960	-13126	-12397	-18231	
21:00	68	72	-4.0	-66014	-39915	-27634	0	0	0	0	0	0	0	-66014	-39915	-27634	-26098	-38380	
22:00	66	72	-6.0	-99020	-59873	-41450	0	0	0	0	0	0	0	-99020	-59873	-41450	-39148	-57570	
23:00	64	72	-8.0	-132027	-79830	-55267	0	0	0	0	0	0	0	-132027	-79830	-55267	-52197	-76760	
	Averages			Totals			Totals							**31,839,576**	**14,107,747**	**9,766,902**	**17,731,829**	**22,072,674**	Cooling Load
	65	**72**	**-7**	**-2,754,417**	**-1,665,462**	**-1,153,012**	**607**	**2,663**	**761**	**1,166**	**32,895,794**	**14,746,390**	**10,209,039**	**1,369,782**	**828,240**	**573,397**	**541,542**	**796,385**	Heating Load

June 21 Fenestration Analysis

Conduction = $Q_{cond} = UA(\Delta T)$

Solar Radiation = $Q_{sol} = SHGC(A)(E_t)$

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	73	72	0.6	9902	5987	4145	0	0	0	0	0	0	0	9902	5987	4145	3915	5757	HEATING LOAD
1:00	71	72	-1.2	-19804	-11975	-8290	0	0	0	0	0	0	0	-19804	-11975	-8290	-7830	-11514	
2:00	69	72	-3.3	-54461	-32930	-22798	0	0	0	0	0	0	0	-54461	-32930	-22798	-21531	-31664	
3:00	67	72	-5.0	-82517	-49894	-34542	0	0	0	0	0	0	0	-82517	-49894	-34542	-32623	-47975	
4:00	66	72	-6.2	-102321	-61869	-42832	0	0	0	0	0	0	0	-102321	-61869	-42832	-40453	-59489	
5:00	66	72	-6.2	-102321	-61869	-42832	0.19	2.27	1.33	0.19	24385	10931.1228	7568	-77936	-50937	-35264	-26999	-42672	
6:00	67	72	-5.3	-87468	-52888	-36615	17.3	166	71.48	17.3	1775955	796118	551158	1688487	743230	514544	945257	1173943	COOLING LOAD
7:00	68	72	-4.0	-66014	-39915	-27634	31.76	244.95	76.68	32.64	2642976	1184782	820234	2576962	1144867	792600	1432095	1784362	
8:00	70	72	-2.1	-34657	-20955	-14508	43.31	264.95	57.79	46.06	2921869	1309803	906787	2887212	1288848	892279	1598364	1994933	
9:00	72	72	-0.2	-3301	-1996	-1382	52.66	248.94	55.07	78.63	2939587	1317746	912286	2936286	1315750	910904	1620536	2025382	
10:00	74	72	1.5	24755	14968	10363	59.75	207.69	60.96	114.69	2740187	1228360	850403	2764943	1243328	860766	1521614	1904177	
11:00	75	72	3.0	49510	29936	20725	64.33	149.33	64.33	139.13	2337685	1047928	725488	2387195	1077864	746214	1309331	1640981	
12:00	77	72	4.9	80867	48896	33851	69.37	81.25	66.18	149.24	1820248	815973	564905	1901115	864869	598756	1036245	1302359	
13:00	79	72	6.9	113873	68854	47668	65.21	128.44	65.21	143.97	2177044	975916	675634	2290917	1044770	723302	1246147	1567615	
14:00	81	72	8.7	143580	86816	60103	61.49	190.67	61.49	123.87	2630410	1179149	816334	2773989	1265965	876437	1508025	1897552	
15:00	82	72	10.2	168335	101784	70466	55.17	238.18	57.15	91.09	2901684	1300755	900523	3070019	1402539	970988	1667480	2099030	
16:00	83	72	11.2	184838	111763	77374	46.51	263.18	50.30	49.94	2931861	1314283	909888	3116700	1426045	987262	1690654	2129437	
17:00	83	72	11.2	184838	111763	77374	35.67	256.16	71.98	37.09	2778847	1245690	862401	2963685	1357453	939775	1606233	2023910	
18:00	82	72	10.4	171635	103780	71847	22.33	200.05	78.04	22.33	2142786	960559	665003	2314421	1064339	736850	1250083	1577571	
19:00	81	72	9.0	148531	89809	62176	4.63	51.45	27.34	4.63	551347	247156	171108	699877	336965	233283	362913	466594	
20:00	80	72	7.5	123776	74841	51813	0	0	0	0	0	0	0	123776	74841	51813	48935	71963	
21:00	78	72	5.5	90769	54883	37996	0	0	0	0	0	0	0	90769	54883	37996	35885	52773	
22:00	76	72	3.5	57762	34926	24179	0	0	0	0	0	0	0	57762	34926	24179	22836	33583	
23:00	74	72	2.0	33007	19958	13817	0	0	0	0	0	0	0	33007	19958	13817	13049	19190	
	Averages			Totals			Totals							**34,677,121**	**15,761,439**	**10,911,766**	**18,915,682**	**23,765,356**	Cooling Load
	75	**72**	**3**	**1,033,113**	**624,673**	**432,466**	**630**	**2,694**	**865**	**1,051**	**33,316,871**	**14,935,149**	**10,339,718**	**327,138**	**201,617**	**139,581**	**125,520**	**187,556**	Heating Load

July 21 Fenestration Analysis

Conduction = Q_{cond} = UA(ΔT)
Solar Radiation = Q_{sol} = SHGC(A)(E_t)

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	**T_o**	**T_i**	**ΔT**	**Current**	**Design 1**	**Design 2**	**North**	**South**	**East**	**West**	**Current**	**Design 1**	**Design 2**	**Current**	**Design 1**	**Design 2**	**Design 1**	**Design 2**	
0:00	79	72	6.7	110573	66858	46286	0	0	0	0	0	0	0	110573	66858	46286	43715	64287	COOLING LOAD
1:00	77	72	5.4	89118	53886	37305	0	0	0	0	0	0	0	89118	53886	37305	35233	51813	
2:00	76	72	3.7	61063	36922	25561	0	0	0	0	0	0	0	61063	36922	25561	24141	35502	
3:00	74	72	2.0	33007	19958	13817	0	0	0	0	0	0	0	33007	19958	13817	13049	19190	
4:00	73	72	0.8	13203	7983	5527	0	0	0	0	0	0	0	13203	7983	5527	5220	7676	
5:00	72	72	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6:00	72	72	0.2	3301	1996	1382	13.11	134.86	53.68	13.11	1423667	638195	441828	1426968	640191	443209	786776	983758	
7:00	73	72	1.3	21454	12972	8981	28.91	236.28	65.77	30	2514690	1127275	780421	2536144	1140247	789402	1395897	1746743	
8:00	75	72	3.0	49510	29936	20725	41.10	264.86	47.56	44.24	2877272	1289812	892947	2926782	1319748	913672	1607034	2013111	
9:00	77	72	5.2	85818	51890	35924	50.91	252.70	52.84	86.19	2968464	1330691	921248	3054282	1382581	957171	1671701	2097111	
10:00	79	72	7.3	120475	72845	50431	58.38	213.14	58.38	124.28	2791260	1251254	866253	2911734	1324100	916684	1587635	1995050	
11:00	81	72	9.0	148531	89809	62176	63.27	155.12	63.27	150.62	2401695	1076622	745354	2550226	1166431	807529	1383795	1742696	
12:00	83	72	11.1	183188	110765	76683	68.29	86.45	65.40	162.31	1882995	844101	584378	2066183	954866	661061	1111317	1405122	
13:00	86	72	13.5	222796	134714	93263	65.78	123.20	64.64	158.14	2167632	971697	672713	2390428	1106411	765977	1284017	1624451	
14:00	88	72	15.5	255803	154671	107080	61.05	187.26	61.05	138.54	2628655	1178363	815790	2884458	1333034	922870	1551424	1961588	
15:00	89	72	16.8	277257	167644	116061	54.78	236.64	56.09	105.58	2915109	1306773	904689	3192366	1474417	1020750	1717949	2171616	
16:00	89	72	17.2	283858	171635	118824	46.07	263.14	48.78	63.14	2954109	1324256	916792	3237967	1495891	1035617	1742076	2202350	
17:00	89	72	16.7	275607	166646	115370	35.06	256.26	66.20	36.14	2761203	1237781	856925	3036810	1404427	972295	1632383	2064514	
18:00	88	72	15.6	257453	155669	107771	21.28	196.16	15.8	37.05	2017948	904597	626260	2275401	1060267	734031	1215134	1541370	
19:00	86	72	14.4	237649	143695	99481	2.87	33.35	6.3	21.28	376144	168616	116734	613793	312311	216215	301482	397578	
20:00	85	72	12.9	212894	128727	89118	0	0	0	0	0	0	0	212894	128727	89118	84167	123776	
21:00	83	72	11.2	184838	111763	77374	0	0	0	0	0	0	0	184838	111763	77374	73076	107464	
22:00	82	72	9.5	156782	94799	65630	0	0	0	0	0	0	0	156782	94799	65630	61984	91153	
23:00	80	72	8.2	135328	81826	56649	0	0	0	0	0	0	0	135328	81826	56649	53502	78679	
	Averages			Totals			Totals							**36,100,347**	**16,717,640**	**11,573,751**	**19,382,707**	**24,526,596**	**Cooling Load**
	81	**72**	**9**	**3,419,504**	**2,067,607**	**1,431,420**	**611**	**2,639**	**726**	**1,171**	**32,680,843**	**14,650,033**	**10,142,330**	**0**	**0**	**0**	**0**	**0**	**Heating Load**

August 21 Fenestration Analysis

Conduction = Q_{cond} = UA(ΔT)
Solar Radiation = Q_{sol} = SHGC(A)(E_t)

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	**T_o**	**T_i**	**ΔT**	**Current**	**Design 1**	**Design 2**	**North**	**South**	**East**	**West**	**Current**	**Design 1**	**Design 2**	**Current**	**Design 1**	**Design 2**	**Design 1**	**Design 2**	
0:00	66	72	-5.6	-92419	-55881	-38687	0	0	0	0	0	0	0	-92419	-55881	-38687	-36538	-53732	HEATING LOAD
1:00	65	72	-7.0	-115524	-69852	-48359	0	0	0	0	0	0	0	-115524	-69852	-48359	-45672	-67165	
2:00	64	72	-8.0	-132027	-79830	-55267	0	0	0	0	0	0	0	-132027	-79830	-55267	-52197	-76760	
3:00	62	72	-10.0	-165034	-99788	-69084	0	0	0	0	0	0	0	-165034	-99788	-69084	-65246	-95950	
4:00	61	72	-11.0	-181537	-109767	-75992	0	0	0	0	0	0	0	-181537	-109767	-75992	-71771	-105545	
5:00	61	72	-11.0	-181537	-109767	-75992	0	0	0	0	0	0	0	-181537	-109767	-75992	-71771	-105545	
6:00	61	72	-11.0	-181537	-109767	-75992	23.94	64.28	17.26	5.49	829699	371934	257493	648162	262167	181500	385994	466661	COOLING LOAD
7:00	62	72	-10.0	-165034	-99788	-69084	37.36	220.7	33.18	36.06	2413498	1081913	749017	2248464	982125	679933	1266339	1568531	
8:00	65	72	-7.0	-115524	-69852	-48359	47.81	263.63	39.04	69.53	2971359	1331989	922146	2855836	1262137	873787	1593698	1982048	
9:00	67	72	-5.0	-82517	-49894	-34542	55.62	254.23	47.81	119.61	3092125	1386125	959625	3009608	1336231	925083	1673377	2084525	
10:00	68	72	-4.0	-66014	-39915	-27634	60.66	213.28	55.62	161.10	2891534	1296205	897372	2825520	1256290	869739	1569230	1955781	
11:00	71	72	-1.0	-16503	-9979	-6908	65.75	152.11	60.66	189.14	2480590	1111988	769838	2464086	1102010	762930	1362077	1701157	
12:00	73	72	1.0	16503	9979	6908	61.73	79.73	62.72	200.88	1843764	826515	572203	1860268	836494	579111	1023774	1281157	
13:00	74	72	2.0	33007	19958	13817	57.72	127.57	61.73	195.20	2206676	989200	684831	2239683	1009157	698647	1230526	1541036	
14:00	75	72	3.0	49510	29936	20725	50.85	193.64	57.72	172.65	2657453	1191272	824727	2706963	1221208	845452	1485755	1861511	
15:00	74	72	2.0	33007	19958	13817	41.32	242.79	50.85	135.44	2897920	1299068	899354	2930927	1319025	913171	1611902	2017755	
16:00	74	72	2.0	33007	19958	13817	29.06	264.86	42.85	87.64	2851447	1278235	884932	2884453	1298192	898749	1586261	1985705	
17:00	73	72	1.0	16503	9979	6908	12.65	244.01	31.60	36.25	2378753	1066337	738234	2395256	1076316	745142	1318940	1650114	
18:00	71	72	-1.0	-16503	-9979	-6908	10.12	139.02	31.25	13.36	1390858	623488	431646	1374354	613509	424737	760845	949617	
19:00	70	72	-2.0	-33007	-19958	-13817	0	0	0	0	0	0	0	-33007	-19958	-13817	-13049	-19190	HEATING LOAD
20:00	70	72	-2.0	-33007	-19958	-13817	0	0	0	0	0	0	0	-33007	-19958	-13817	-13049	-19190	
21:00	68	72	-4.0	-66014	-39915	-27634	0	0	0	0	0	0	0	-66014	-39915	-27634	-26098	-38380	
22:00	67	72	-5.0	-82517	-49894	-34542	0	0	0	0	0	0	0	-82517	-49894	-34542	-32623	-47975	
23:00	66	72	-6.0	-99020	-59873	-41450	0	0	0	0	0	0	0	-99020	-59873	-41450	-39148	-57570	
	Averages			Totals			Totals							**30,443,580**	**13,574,862**	**9,397,981**	**16,868,718**	**21,045,599**	**Cooling Load**
	68	**72**	**-4**	**-1,643,739**	**-993,888**	**-688,077**	**555**	**2,460**	**592**	**1,422**	**30,905,675**	**13,854,268**	**9,591,416**	**1,181,643**	**714,482**	**494,641**	**467,161**	**687,002**	**Heating Load**

September 21 Fenestration Analysis

Conduction = Q_{cond} = UA(ΔT)
Solar Radiation = Q_{sol} = SHGC(A)(E_t)

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	**T_o**	**T_i**	**ΔT**	**Current**	**Design 1**	**Design 2**	**North**	**South**	**East**	**West**	**Current**	**Design 1**	**Design 2**	**Current**	**Design 1**	**Design 2**	**Design 1**	**Design 2**	
0:00	66	72	-5.6	-92419	-55881	-38687	0	0	0	0	0	0	0	-92419	-55881	-38687	-36538	-53732	HEATING LOAD
1:00	65	72	-6.7	-110573	-66858	-46286	0	0	0	0	0	0	0	-110573	-66858	-46286	-43715	-64287	
2:00	64	72	-8.0	-132027	-79830	-55267	0	0	0	0	0	0	0	-132027	-79830	-55267	-52197	-76760	
3:00	63	72	-9.2	-151831	-91805	-63557	0	0	0	0	0	0	0	-151831	-91805	-63557	-60026	-88274	
4:00	62	72	-10.3	-169985	-102782	-71157	0	0	0	0	0	0	0	-169985	-102782	-71157	-67203	-98829	
5:00	61	72	-11.1	-183188	-110765	-76683	0	0	0	0	0	0	0	-183188	-110765	-76683	-72423	-106505	
6:00	61	72	-11.3	-186488	-112760	-78065	0	0	0	0	0	0	0	-186488	-112760	-78065	-73728	-108424	
7:00	61	72	-10.6	-174936	-105775	-73229	16.22	179.68	16.92	44.22	1844838	826996	572536	1669902	721221	499307	948681	1170595	COOLING LOAD
8:00	63	72	-9.1	-150181	-90807	-62866	31.13	249.80	31.13	110.17	2769280	1241401	859432	2619099	1150594	796565	1468505	1822534	
9:00	65	72	-7.0	-115524	-69852	-48359	42.00	244.09	42.00	168.21	2972841	1332653	922606	2857318	1262801	874247	1594516	1983070	
10:00	67	72	-5.0	-82517	-49894	-34542	49.85	201.00	49.85	213.24	2788359	1249954	865353	2705842	1200060	830811	1505782	1875031	
11:00	69	72	-3.0	-49510	-29936	-20725	54.67	136.36	54.67	241.79	2345448	1051408	727898	2295938	1021471	707172	1274466	1588765	
12:00	71	72	-1.0	-16503	-9979	-6908	59.72	60.57	56.32	251.69	1760300	789100	546300	1743797	779121	539392	964675	1204405	
13:00	73	72	1.0	16503	9979	6908	54.74	134.89	54.74	242.19	2334368	1046441	724459	2350872	1056420	731368	1294452	1619504	
14:00	74	72	2.4	39608	23949	16580	49.98	199.92	49.98	214.01	2782175	1247182	863434	2821783	1271131	880014	1550652	1941770	
15:00	75	72	2.9	47860	28939	20034	42.20	243.51	42.24	169.29	2972562	1332528	922519	3020422	1361466	942554	1658955	2077868	
16:00	75	72	2.7	44559	26943	18653	31.39	250.23	31.39	111.47	2778872	1245701	862409	2823432	1272644	881061	1550787	1942370	
17:00	74	72	1.9	31356	18960	13126	16.95	182.53	17.29	45.60	1880297	842892	583540	1911653	861851	596666	1049802	1314987	
18:00	73	72	1.0	16503	9979	6908	0	0	0	0	0	0	0	16503	9979	6908	6525	9595	
19:00	72	72	-0.2	-3301	-1996	-1382	0	0	0	0	0	0	0	-3301	-1996	-1382	-1305	-1919	HEATING LOAD
20:00	71	72	-1.3	-21454	-12972	-8981	0	0	0	0	0	0	0	-21454	-12972	-8981	-8482	-12474	
21:00	70	72	-2.5	-41259	-24947	-17271	0	0	0	0	0	0	0	-41259	-24947	-17271	-16312	-23988	
22:00	68	72	-3.7	-61063	-36922	-25561	0	0	0	0	0	0	0	-61063	-36922	-25561	-24141	-35502	
23:00	67	72	-4.6	-75916	-45902	-31779	0	0	0	0	0	0	0	-75916	-45902	-31779	-30013	-44137	
	Averages			Totals			Totals							**26,836,559**	**11,968,760**	**8,286,065**	**14,867,799**	**18,550,494**	**Cooling Load**
	68	**72**	**-4**	**-1,622,284**	**-980,916**	**-679,096**	**449**	**2,083**	**447**	**1,812**	**27,229,340**	**12,206,256**	**8,450,485**	**1,229,503**	**743,421**	**514,676**	**486,083**	**714,828**	**Heating Load**

October 21 Fenestration Analysis

Conduction = Q_{cond} = UA(ΔT)

Solar Radiation = Q_{sol} = SHGC(A)(E_t)

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	56	72	-16.5	-272306	-164650	-113989	0	0	0	0	0	0	0	-272306	-164650	-113989	-107656	-158318	HEATING LOAD
1:00	54	72	-17.8	-293761	-177623	-122970	0	0	0	0	0	0	0	-293761	-177623	-122970	-116138	-170791	
2:00	53	72	-19.1	-315215	-190595	-131950	0	0	0	0	0	0	0	-315215	-190595	-131950	-124620	-183265	
3:00	51	72	-20.6	-339970	-205563	-142313	0	0	0	0	0	0	0	-339970	-205563	-142313	-134407	-197657	
4:00	50	72	-22.0	-363075	-219534	-151985	0	0	0	0	0	0	0	-363075	-219534	-151985	-143541	-211090	
5:00	49	72	-23.0	-379578	-229512	-158893	0	0	0	0	0	0	0	-379578	-229512	-158893	-150066	-220685	
6:00	49	72	-23.5	-387830	-234502	-162347	0	0	0	0	0	0	0	-387830	-234502	-162347	-153328	-225483	
7:00	49	72	-23.3	-384529	-232506	-160966	7.26	95.31	7.26	37.28	993629	445420	308368	609100	212914	147402	396186	461698	COOLING LOAD
8:00	50	72	-21.6	-356473	-215542	-149221	24.13	217.13	24.13	131.86	2454749	1100405	761819	2098276	884863	612597	1213413	1485679	
9:00	53	72	-19.0	-313565	-189597	-131260	35.36	222.06	35.36	199.55	2776421	1244602	861648	2462856	1055005	730388	1407851	1732468	
10:00	56	72	-15.7	-259103	-156667	-108462	43.12	181.63	43.12	247.75	2621122	1174986	813452	2362018	1018318	704990	1343700	1657029	
11:00	59	72	-13.0	-214544	-129724	-89809	47.65	117.71	47.65	276.34	2181268	977810	676945	1966724	848085	587136	1118638	1379588	
12:00	63	72	-9.5	-156782	-94799	-65630	51.65	61.40	48.91	284.29	1750268	784603	543187	1593486	689804	477557	903682	1115929	
13:00	65	72	-7.0	-115524	-69852	-48359	46.85	134.65	46.85	271.26	2307968	1034606	716266	2192444	964755	667907	1227690	1524537	
14:00	66	72	-5.8	-95720	-57877	-40069	41.53	194.18	41.53	237.81	2689854	1205796	834782	2594134	1147919	794713	1446215	1799421	
15:00	66	72	-6.0	-99020	-59873	-41450	32.98	226.31	32.98	184.98	2753737	1234434	854608	2654717	1174561	813158	1480156	1841559	
16:00	64	72	-7.8	-128727	-77835	-53886	20.74	203.68	20.74	112.02	2255075	1010896	699851	2126348	933061	645965	1193287	1480383	
17:00	63	72	-9.0	-148531	-89809	-62176	31.26	31.26	2.15	10.78	596589	267437	185148	448059	177627	122973	270431	325086	
18:00	62	72	-10.2	-168335	-101784	-70466	0	0	0	0	0	0	0	-168335	-101784	-70466	-66551	-97869	
19:00	61	72	-11.5	-189789	-114756	-79447	0	0	0	0	0	0	0	-189789	-114756	-79447	-75033	-110343	
20:00	59	72	-13.0	-214544	-129724	-89809	0	0	0	0	0	0	0	-214544	-129724	-89809	-84820	-124735	
21:00	58	72	-14.3	-235999	-142697	-98790	0	0	0	0	0	0	0	-235999	-142697	-98790	-93302	-137209	
22:00	57	72	-15.4	-254152	-153674	-106389	0	0	0	0	0	0	0	-254152	-153674	-106389	-100479	-147763	
23:00	56	72	-16.0	-264054	-159661	-110534	0	0	0	0	0	0	0	-264054	-159661	-110534	-104394	-153520	
	Averages			Totals							Totals			**21,108,162**	**9,106,914**	**6,304,786**	**12,001,248**	**14,803,375**	**Cooling Load**
	57	**72**	**-15**	**-5,951,126**	**-3,598,355**	**-2,491,169**	**383**	**1,685**	**351**	**1,994**	**23,380,680**	**10,480,994**	**7,256,073**	**3,678,608**	**2,224,275**	**1,539,882**	**1,454,333**	**2,138,726**	**Heating Load**

November 21 Fenestration Analysis

Conduction = Q_{cond} = UA(ΔT)

Solar Radiation = Q_{sol} = SHGC(A)(E_t)

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	48	72	-23.6	-389480	-235500	-163038	0	0	0	0	0	0	0	-389480	-235500	-163038	-153981	-226442	HEATING LOAD
1:00	47	72	-24.6	-405984	-245478	-169947	0	0	0	0	0	0	0	-405984	-245478	-169947	-160505	-236037	
2:00	46	72	-26.0	-429088	-259449	-179618	0	0	0	0	0	0	0	-429088	-259449	-179618	-169640	-249470	
3:00	45	72	-27.0	-445592	-269428	-186527	0	0	0	0	0	0	0	-445592	-269428	-186527	-176164	-259065	
4:00	44	72	-28.0	-462095	-279406	-193435	0	0	0	0	0	0	0	-462095	-279406	-193435	-182689	-268660	
5:00	43	72	-29.0	-478599	-289385	-200344	0	0	0	0	0	0	0	-478599	-289385	-200344	-189213	-278255	
6:00	43	72	-29.0	-478599	-289385	-200344	0	0	0	0	0	0	0	-478599	-289385	-200344	-189213	-278255	
7:00	44	72	-28.0	-462095	-279406	-193435	0	0	0	0	0	0	0	-462095	-279406	-193435	-182689	-268660	
8:00	46	72	-26.0	-429088	-259449	-179618	14.39	151.19	14.39	111.57	1726172	773801	535709	1297084	514353	356090	782731	940994	COOLING LOAD
9:00	49	72	-23.0	-379578	-229512	-158893	26.99	191.31	26.99	202.26	2420538	1085069	751202	2040960	855557	592308	1185404	1448652	
10:00	52	72	-20.0	-330068	-199576	-138168	35.13	163.57	35.13	258.61	2398023	1074976	744214	2067955	875400	606046	1192555	1461909	
11:00	56	72	-16.0	-264054	-159661	-110534	39.81	106.85	39.81	290.64	2030113	910050	630035	1766058	750390	519501	1015669	1246558	
12:00	58	72	-14.0	-231048	-139703	-96718	43.82	50.92	41.17	299.85	1605513	719713	498263	1374466	580010	401545	794456	972921	
13:00	58	72	-14.0	-231048	-139703	-96718	39.18	118.96	39.81	286.34	2119686	950204	657834	1888639	810501	561116	1078138	1327523	
14:00	58	72	-14.0	-231048	-139703	-96718	33.86	171.71	33.86	249.91	2434853	1091486	755644	2203805	951783	658926	1252023	1544879	
15:00	58	72	-14.4	-238309	-144094	-99757	25.02	190.99	25.02	188.37	2364329	1059871	733757	2126019	915778	634000	1210242	1492020	
16:00	55	72	-17.0	-280558	-169640	-117443	11.20	127.14	11.20	87.66	1427578	639949	443041	1147020	470309	325599	676711	821421	
17:00	54	72	-18.0	-297061	-179618	-124351					0	0	0	-297061	-179618	-124351	-117443	-172710	HEATING LOAD
18:00	53	72	-19.0	-313565	-189597	-131260	0	0	0	0	0	0	0	-313565	-189597	-131260	-123967	-182305	
19:00	52	72	-20.0	-330068	-199576	-138168	0	0	0	0	0	0	0	-330068	-199576	-138168	-130492	-191900	
20:00	51	72	-21.0	-346571	-209555	-145076	0	0	0	0	0	0	0	-346571	-209555	-145076	-137017	-201495	
21:00	50	72	-22.0	-363075	-219534	-151985	0	0	0	0	0	0	0	-363075	-219534	-151985	-143541	-211090	
22:00	49	72	-23.0	-379578	-229512	-158893	0	0	0	0	0	0	0	-379578	-229512	-158893	-150066	-220685	
23:00	48	72	-24.0	-396082	-239491	-165802	0	0	0	0	0	0	0	-396082	-239491	-165802	-156590	-230280	
	Averages			Totals							Totals			**15,912,007**	**6,724,079**	**4,655,131**	**9,187,928**	**11,256,875**	**Cooling Load**
	50	**72**	**-22**	**-8,592,330**	**-5,195,362**	**-3,596,789**	**269**	**1,273**	**267**	**1,975**	**18,526,805**	**8,305,120**	**5,749,698**	**5,977,531**	**3,614,321**	**2,502,222**	**2,363,210**	**3,475,309**	**Heating Load**

December 21 Fenestration Analysis

Conduction = Q_{cond} = UA(ΔT)

Solar Radiation = Q_{sol} = SHGC(A)(E_t)

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Savings (btu)		
Time	T_o	T_i	ΔT	Current	Design 1	Design 2	North	South	East	West	Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2	
0:00	42	72	-30.1	-496752	-300362	-207943	0	0	0	0	0	0	0	-496752	-300362	-207943	-196390	-288810	HEATING LOAD
1:00	41	72	-31.2	-514906	-311339	-215542	0	0	0	0	0	0	0	-514906	-311339	-215542	-203568	-299364	
2:00	40	72	-32.5	-536361	-324311	-224523	0	0	0	0	0	0	0	-536361	-324311	-224523	-212050	-311838	
3:00	38	72	-33.7	-556165	-336286	-232813	0	0	0	0	0	0	0	-556165	-336286	-232813	-219879	-323352	
4:00	37	72	-35.0	-577619	-349258	-241794	0	0	0	0	0	0	0	-577619	-349258	-241794	-228361	-335825	
5:00	36	72	-36.0	-594122	-359237	-248702	0	0	0	0	0	0	0	-594122	-359237	-248702	-234886	-345420	
6:00	36	72	-36.3	-599073	-362230	-250775	0	0	0	0	0	0	0	-599073	-362230	-250775	-236843	-348299	
7:00	36	72	-36.0	-594122	-359237	-248702	0	0	0	0	0	0	0	-594122	-359237	-248702	-234886	-345420	
8:00	38	72	-33.9	-559465	-338281	-234195	5.94	73.31	5.94	54.53	826206	370368	256409	266740	32087	22214	234654	244527	COOLING LOAD
9:00	42	72	-30.0	-495102	-299364	-207252	21.00	170.53	21.00	179.19	2120497	950568	658085	1625395	651204	450833	974191	1174562	
10:00	46	72	-26.5	-437340	-264438	-183073	30.18	160.96	30.18	248.04	2295586	1029056	712423	1858246	764617	529351	1093628	1328895	
11:00	50	72	-22.0	-363075	-219534	-151985	35.62	112.86	35.62	287.24	2027218	908753	629137	1664144	689219	477152	974924	1186992	
12:00	52	72	-20.0	-330068	-199576	-138168	40.18	48.00	37.67	301.77	1543455	691894	479003	1213387	492318	340835	721070	872552	
13:00	53	72	-19.2	-316865	-191593	-132641	36.35	99.68	36.35	292.44	1932653	866362	599789	1615788	674769	467148	941019	1148640	
14:00	52	72	-19.6	-323467	-195584	-135405	31.66	152.77	31.66	258.55	2264755	1015235	702855	1941288	819650	567450	1121638	1373838	
15:00	52	72	-20.5	-338320	-204565	-141622	23.36	173.63	23.36	197.35	2214836	992857	687363	1876516	788292	545741	1088224	1330775	
16:00	51	72	-21.4	-353173	-213546	-147840	9.95	111.63	9.95	89.46	1282722	575013	398086	929549	361467	250246	568082	679303	
17:00	50	72	-22.5	-371327	-224523	-155439	0	0	0	0	0	0	0	-371327	-224523	-155439	-146804	-215888	HEATING LOAD
18:00	48	72	-23.7	-391131	-236498	-163729	0	0	0	0	0	0	0	-391131	-236498	-163729	-154633	-227402	
19:00	47	72	-24.8	-409284	-247474	-171328	0	0	0	0	0	0	0	-409284	-247474	-171328	-161810	-237956	
20:00	46	72	-25.6	-422487	-255457	-176855	0	0	0	0	0	0	0	-422487	-255457	-176855	-167030	-245632	
21:00	45	72	-27.1	-447242	-270425	-187218	0	0	0	0	0	0	0	-447242	-270425	-187218	-176817	-260025	
22:00	44	72	-28.2	-465396	-281402	-194817	0	0	0	0	0	0	0	-465396	-281402	-194817	-183994	-270579	
23:00	43	72	-29.2	-481899	-291381	-201725	0	0	0	0	0	0	0	-481899	-291381	-201725	-190518	-280174	
	Averages			Totals							Totals			**12,991,053**	**5,273,623**	**3,650,970**	**7,717,430**	**9,340,083**	**Cooling Load**
	44	**72**	**-28**	**-10,974,761**	**-6,635,902**	**-4,594,086**	**234**	**1,103**	**232**	**1,909**	**16,507,928**	**7,400,105**	**5,123,150**	**7,457,886**	**4,509,420**	**3,121,906**	**2,948,467**	**4,335,981**	**Heating Load**

Daily Cooling Load Values (for the 21st day of Each Month)

Conduction = $Q_{cond} = UA(\Delta T)$

Solar Radiation = $Q_{sol} = SHGC(A)(E_t)$

	Temperature (F)			Total Conduction (Btu)			E_t				Total Solar Radiation (Btu)			Total Energy Transfer (Btu)			Cooling Only Savings (btu)	
Time	**T_o**	**T_i**	**ΔT**	**Current**	**Design 1**	**Design 2**	**North**	**South**	**East**	**West**	**Current**	**Design 1**	**Design 2**	**Current**	**Design 1**	**Design 2**	**Design 1**	**Design 2**
JAN	*43*	72	-29.0	-11,501,219	-6,954,226	-4,814,464	267	1,274	264	1,988	18,539,887	8,310,984	5,753,758	14,649,713	5,968,127	4,131,780	**8,681,586**	**10,517,933**
FEB	*39*	72	-32.9	-13,024,483	-7,875,269	-5,452,109	356	1,773	353	2,067	24,064,290	10,787,440	7,468,228	19,342,667	7,932,506	5,491,735	**11,410,162**	**13,850,933**
MAR	*48*	72	-24.1	-9,527,413	-5,760,761	-3,988,219	453	2,195	451	1,876	28,392,048	12,727,470	8,811,325	24,154,186	10,203,203	7,063,756	**13,950,983**	**17,090,430**
APR	*60*	72	-12.4	-4,894,908	-2,959,712	-2,049,031	546	2,545	586	1,465	31,649,517	14,187,715	9,822,264	29,421,558	12,840,577	8,889,630	**16,580,982**	**20,531,928**
MAY	*65*	72	-7.0	-2,754,417	-1,665,462	-1,153,012	607	2,663	761	1,166	32,895,794	14,746,390	10,209,039	31,839,576	14,107,747	9,766,902	**17,731,829**	**22,072,674**
JUN	*75*	72	2.6	1,033,113	624,673	432,466	630	2,694	865	1,051	33,316,871	14,935,149	10,339,718	34,677,121	15,761,439	10,911,766	**18,915,682**	**23,765,356**
JUL	*81*	72	8.6	3,419,504	2,067,607	1,431,420	611	2,639	726	1,171	32,680,843	14,650,033	10,142,330	36,100,347	16,717,640	11,573,751	**19,382,707**	**24,526,596**
AUG	*68*	72	-4.2	-1,643,739	-993,888	-688,077	555	2,460	592	1,422	30,905,675	13,854,268	9,591,416	30,443,580	13,574,862	9,397,981	**16,868,718**	**21,045,599**
SEPT	*68*	72	-4.1	-1,622,284	-980,916	-679,096	449	2,083	447	1,812	27,229,340	12,206,256	8,450,485	26,836,559	11,968,760	8,286,065	**14,867,799**	**18,550,494**
OCT	*57*	72	-15.0	-5,951,126	-3,598,355	-2,491,169	383	1,685	351	1,994	23,380,680	10,480,994	7,256,073	21,108,162	9,106,914	6,304,786	**12,001,248**	**14,803,375**
NOV	*50*	72	-21.7	-8,592,330	-5,195,362	-3,596,789	269	1,273	267	1,975	18,526,805	8,305,120	5,749,698	15,912,007	6,724,079	4,655,131	**9,187,928**	**11,256,875**
DEC	*44*	72	-27.7	-10,974,761	-6,635,902	-4,594,086	234	1,103	232	1,909	16,507,928	7,400,105	5,123,150	12,991,053	5,273,623	3,650,970	**7,717,430**	**9,340,083**
													Total Savings	**297,476,530**	**130,179,477**	**90,124,253**	**167,297,053**	**207,352,277**
															Percent Savings		**56%**	**70%**

COOLING LOAD

Monthly Cooling Load Values

		Total Daily (Million Btu's)			Total Monthy (Million Btu's)			Total Savings (Million Btu's)	
Time	**Days**	**Current**	**Design 1**	**Design 2**	**Current**	**Design 1**	**Design 2**	**Design 1**	**Design 2**
JAN	31	14.6	6.0	4.1	454.1	185.0	128.1	269.1	326.1
FEB	29	19.3	7.9	5.5	560.9	230.0	159.3	330.9	401.7
MAR	31	24.2	10.2	7.1	748.8	316.3	219.0	432.5	529.8
APR	30	29.4	12.8	8.9	882.6	385.2	266.7	497.4	616.0
MAY	31	31.8	14.1	9.8	987.0	437.3	302.8	549.7	684.3
JUN	30	34.7	15.8	10.9	1040.3	472.8	327.4	567.5	713.0
JUL	31	36.1	16.7	11.6	1119.1	518.2	358.8	600.9	760.3
AUG	31	30.4	13.6	9.4	943.8	420.8	291.3	522.9	652.4
SEPT	30	26.8	12.0	8.3	805.1	359.1	248.6	446.0	556.5
OCT	31	21.1	9.1	6.3	654.4	282.3	195.4	372.0	458.9
NOV	30	15.9	6.7	4.7	477.4	201.7	139.7	275.6	337.7
DEC	31	13.0	5.3	3.7	402.7	163.5	113.2	239.2	289.5
			Yearly Totals		**9076.2**	**3972.4**	**2750.1**	**5103.8**	**6326.1**
			Percent Savings			**Percent Savings**		**56%**	**70%**

Monthly Cooling Savings

Cumulative Savings (Million BTU's)

Design 1	**Design 2**
269	326
600	728
1033	1258
1530	1873
2080	2558
2647	3271
3248	4031
3771	4683
4217	5240
4589	5699
4865	6037
5104	6326

June Surface Irradiance

Time	North	South	East	West
5:00	0.19	2.27	1.33	0.19
6:00	17.3	166	71.48	17.3
7:00	31.76	244.95	76.68	32.64
8:00	43.31	264.95	57.79	46.06
9:00	52.66	248.94	55.07	78.63
10:00	59.75	207.69	60.96	114.69
11:00	64.33	149.33	64.33	139.13
12:00	69.37	81.25	66.18	149.24
13:00	65.21	128.44	65.21	143.97
14:00	61.49	190.67	61.49	123.87
15:00	55.17	238.18	57.15	91.09
16:00	46.51	263.18	50.30	49.94
17:00	35.67	256.16	71.98	37.09
18:00	22.33	200.05	78.04	22.33
19:00	4.63	51.45	27.34	4.63

December Surface Irradiance

Time	North	South	East	West
8:00	5.94	73.31	5.94	54.53
9:00	21.00	170.53	21.00	179.19
10:00	30.18	160.96	30.18	248.04
11:00	35.62	112.86	35.62	287.24
12:00	40.18	48.00	37.67	301.77
13:00	36.35	99.68	36.35	292.44
14:00	31.66	152.77	31.66	258.55
15:00	23.36	173.63	23.36	197.35
16:00	9.95	111.63	9.95	89.46

APPENDIX F

Magic-Pak AHU Specifications

Thru-The-Wall Heating & Cooling Units

magic-pak®

www.magic-pak.com • 1-866-282-7257

Designed and built for designers and builders

Simple installation makes Magic-Pak heating and cooling systems compatible with any building design with multi-units. Our combination, through-the-wall units come in a completely self-contained package, eliminating complicated installation procedures associated with conventional systems. Building management is simplified with Magic-Pak systems' reliability and practical maintenance features. Service downtime is minimized, and central-system shutdowns are entirely eliminated. Tenants have the option of convenient individual controls. Building industry professionals such as architects, engineers and builders have been requesting Magic-Pak heating and cooling products for over forty years. We have a proven track record of successful and innovative products that keep customers satisified. Magic-Pak units are well designed and prove that multi-unit heating and cooling can be simple, easy and reliable.

GAS ALTERNATIVE

Magic-Pak Advantages

The MGE, MCE and MHP Magic-Pak units boast an extensive array of features and product innovations, and offer many valuable benefits to your customers:

- Unobtrusive design – small footprint and wall-opening requirement
- Low operating sound levels
- Standard and high-efficiency cooling models
- Wide variety of louver colors – with custom colors available
- Robust heating, cooling and air-side performance
- Antimicrobial insulation in air handling compartment (MCE & MHP)
- Fully insulated cabinet
- Drain connection in chassis base for easy cleaning
- Large access panels – unit is serviced with chassis in place
- Low installed, maintenance and life-cycle costs

MGE
Gas Heating & Electric Cooling

Maximizes energy-cost efficiency in applications where gas is available. Uses only outside air for combustion. Built-in power vent eliminates need for chimney.

Easy To Install, Simple To Service

Magic-Pak units come pre-wired and pre-charged with refrigerant. Simply place the self-contained combination unit, attach the condensate drain, hook up power and thermostat connections (and gas line on our MGE). There are no complications – no outdoor condenser units, no separate cooling coils, no external refrigerant lines, and no chimneys.

Once they're in place, building managers can virtually forget about them. Maintenance problems practically disappear with the reliable design of Magic-Pak.

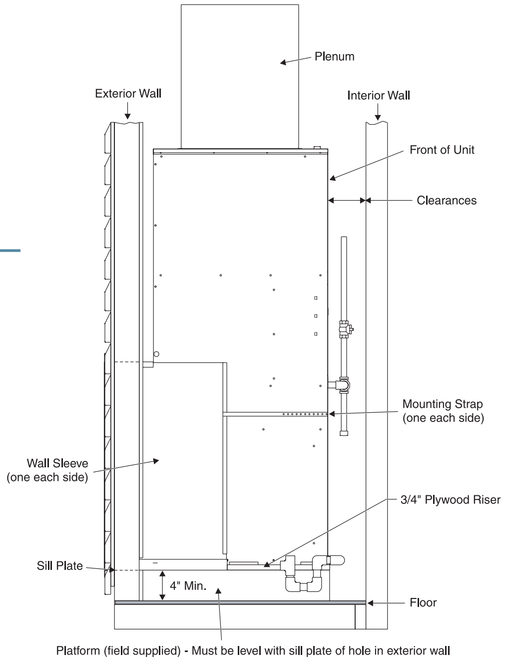
ELECTRIC ALTERNATIVES

MCE
Electric Heating & Electric Cooling

Provides the best alternative to a heat pump in all-electric applications. A highly efficient design.

MHP
Electric Heat Pump

The energy-efficient option for heating and cooling where gas is not available.



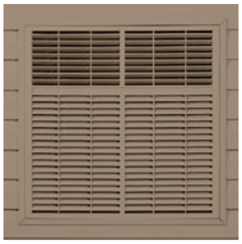
Louvers

Polypropylene or aluminum styles are available in four standard colors, or can be custom-painted to match your exterior.


BONE WHITE


SANDSTONE


TAUPESTONE


SURREY BEIGE

Unit Specifications

Model	**MGE**	**MCE**	**MHP**
Heating Capacities	36 – 48 – 60 Mbtu	3 – 5 – 7 – 10 kW	3 – 5 – 7 – 10 kW
Heating Efficiency	80% AFUE	100% AFUE	3.2 – 3.5 COP 7.2 – 7.6 HSPF
Cooling Capacities (Nominal Tons)	1, 1.5, 2, 2.5	1, 1.5, 2, 2.5	1, 1.5, 2, 2.5
Cooling Efficiency (EER)	9.5 - 11.2	9.4 - 11.2	9.2 - 10.7
Outdoor Sound Power (Decibels)	72 - 76	72 - 76	72 - 76
Air Volume Range (CFM @ .4" ESP)	400 - 1030	400 - 1030	400 - 1030
Wall Opening	29-1/8" W x 29-1/8" H 29-1/8" W x 32-7/8" H	29-1/8" W x 29-1/8" H 29-1/8" W x 32-7/8" H	29-1/8" W x 29-1/8" H 29-1/8" W x 32-7/8" H
Footprint	28-1/16" W x 24-3/8" D x 58-7/8" H 28-1/16" W x 24-3/8" D x 59-7/8" H 28-1/16" W x 24-3/8" D x 64" H	28-1/16" W x 21-1/2" D x 43-7/8" H 28-1/16" W x 24-3/8" D x 47-13/16" H 28-1/16" W x 24-3/8" D x 55-13/16" H	28-1/16" W x 21-1/2" D x 43-7/8" H 28-1/16" W x 24-3/8" D x 47-13/16" H 28-1/16" W x 24-3/8" D x 55-13/16" H
Weight	220 - 300 lbs.	165 - 235 lbs.	185 - 255 lbs.
Limited Warranty	5 Year Parts 10 Year Heat Exchanger	5 Year Parts	5 Year Parts

All specifications are subject to change without notice.

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