



The slide features a dark blue background with abstract light blue and white streaks. In the top left corner is a circular logo with a stylized 'S'. The main title 'Grand View' is in a large, elegant script font, with 'AT ANNAPOLIS TOWNE CENTRE AT PAROLE' in a smaller, sans-serif font below it. The presenter's name 'Matt Karle' and title 'Construction Management' are centered. Below this is a photograph of a modern multi-story residential building. At the bottom, the text 'AE SENIOR THESIS PROJECT' is centered, with 'Construction Management Matt Karle April 14th 2009' in a smaller font below it.

Grand View
AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Matt Karle
Construction Management



AE SENIOR THESIS PROJECT

Construction Management Matt Karle April 14th 2009



The slide features the same dark blue background with abstract light blue and white streaks and the circular logo in the top left corner. The main title 'Grand View' and subtitle 'AT ANNAPOLIS TOWNE CENTRE AT PAROLE' are at the top. Below them is the section header 'Presentation Outline' in a bold, sans-serif font. A list of topics follows: 'Building Overview', 'Schedule & Cost', 'Overall Goals', 'Solar PV Implementation (Electrical Breadth)', 'Window Glazing', 'Solar Constructability and Future Recommendations', and 'Questions'. At the bottom, the text 'Construction Management Matt Karle April 14th 2009' is centered.

Grand View
AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Presentation Outline

- Building Overview
- Schedule & Cost
- Overall Goals
- Solar PV Implementation (Electrical Breadth)
- Window Glazing
- Solar Constructability and Future Recommendations
- Questions

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Grand View

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Project Information

- 13 Stories
- Ground: Retail
- 2-12: Residential
- 385,000 ft²
- 125 Total Units
- Top 2 Floors – Penthouse Suites

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Building Overview

- Schedule & Cost
- Overall Goals
- Solar PV Implementation
- Glazing
- Solar Constructability and Future
- Recommendations
- Questions







Grand View

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Client Information

- Greenberg Gibbons Commercial
- Sturbridge Homes
- Gilbane
- Martin Architectural Group
- Large Joint Venture
- 1 of 2 Condo Projects

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Building Overview

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GrandView
at Annapolis Towne Centre

GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Location & Layout

Demolished Strip Mall

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



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Main Office
Field Office
GrandView
Laydown
Parking
Traffic

Building Systems

2-Way Flat Slab
Brick Façade
Curved Glass Curtain Walls



Separate Service Utilities for Residential and Retail

GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Fiscal Projections

\$68.5 Million

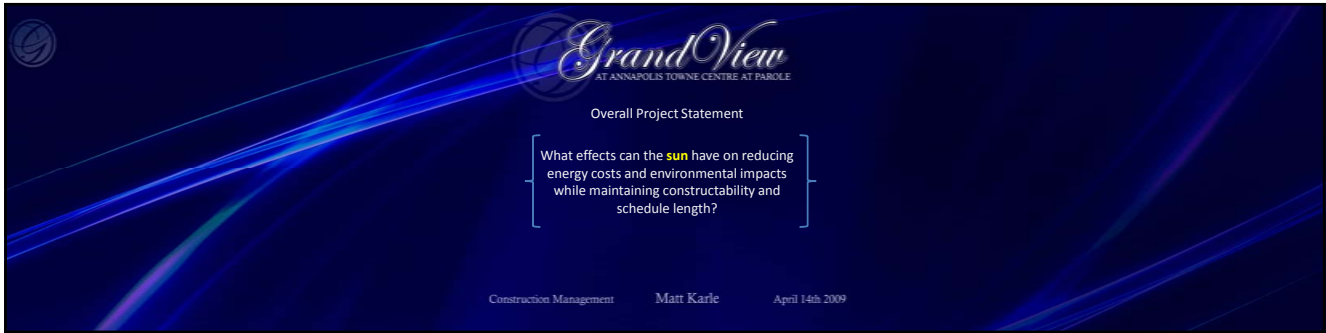
Projected : 24 Months Construction

Actual: March 07 – June 09

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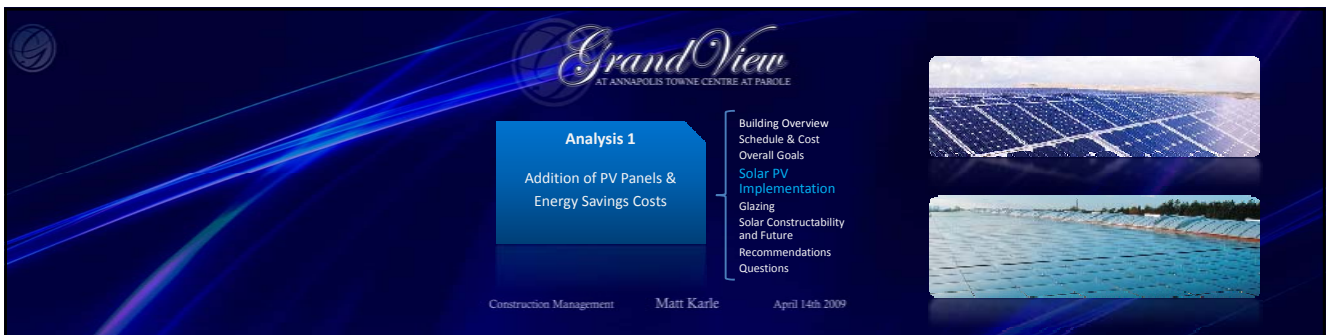


Grand View
AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Overall Project Statement

What effects can the **sun** have on reducing energy costs and environmental impacts while maintaining constructability and schedule length?



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Grand View
AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Analysis 1
Addition of PV Panels & Energy Savings Costs

- Building Overview
- Schedule & Cost
- Overall Goals
- Solar PV Implementation
- Glazing
- Solar Constructability and Future
- Recommendations
- Questions



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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	0
Max Utility Inrush Current	32.00 AM
Power Factor	>0.99
Output Characteristics	Current Source
Weight	58 lbs.
Dimensions	29" x 16" x 6"

GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Design Criteria

BP Solar s3200 200 Watt PV Module
 *34 lbs
 *66" x 33"

Xantrex GT 5.0 Grid Tie Solar Inverters
 *5000 Watt / 240 V

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Performance	
Rated Power P _{max}	200W
Power tolerance	+5%
Number of cells	100
Product Warranty	25 years

Warranty
 5 Years 0-5 years with output cables and patented MultiConnect 800 components

Electrical Characteristics	
Max. Power P _{max}	5.0 200W
Maximum power P _{opt}	200W
Voltage at P _{max} V _{mp}	24.0V
Current at P _{max} I _{mp}	8.33A
Open-circuit voltage V _{oc}	36.0V
Short-circuit current I _{sc}	9.76A
Operational voltage V _{op}	30.0V
Temperature coefficient of V _{oc}	-0.00141/°C
Temperature coefficient of I _{sc}	0.0011/°C
Temperature coefficient of power	-0.141/°C
NOCT (AM 1.5G, No. 0.6m/s wind speed)	45.1°C
Maximum series resistance	1.0Ω
Maximum system voltage	600V AC, NEC Compliant

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GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Shadow Analysis

July and December
 Uniform Layout
 Not Visible From Tenant Area

2 Arrays on East and West End of the Building

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GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Initial Design

3025 Square Feet

200 panels (10 X10)

40 kW array

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Southern Facing

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OVERVIEW Panel Array Design and Layout

- Two (2) Quarter Array locations on opposite ends of the roof
- Each Array consists of 200 panels arranged in rows of 10 (200 total panels)
- Panels are sized at 2100W and measure 66" x 33" for a total area of 615.2 SF
- The Array is faced facing directly south with the optimal 38.2 degree tilt for its location
- Nineteen (19) 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 60.0V per panel and the U.S. NEC Rating of 600V, it is determined that 33.5 panels are allowed per string which rounds to a total number of 33 panels per series.

Number of Panels in Series = 600V(33.5V/Panel) = 19.48 = 19 Panels

STEP 2 Sizing the Inverters

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

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

Based on this data the Xantrex CT 1.0 was chosen which is rated at 4000 W and has a 240 V AC output. The full specs for the CT 1.0 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 final panel count of 200 panels.

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

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AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Electrical Breadth

Panels In Series
20

Inverter Size
4 kW → 5 kW

Number of Inverters
10

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OVERVIEW Electrical Impact and System Integration

- Integrate into existing power for roofing and all of the controls lighting & both
- Electrical features on the roof and 2nd floor have to be kept in mind
- Racking is close to inverters and any system which requires critical wiring
- Inverters are mounted on the ground level and require 2" space between for the 2" pipe wires
- Each of the two separate 20 kW array systems will be fed into two separate panel boards

STEP 1 Qualify Panel Boards Name Efficient Load Capacity

Using the open circuit voltage of 60.0V per panel and the U.S. NEC Rating of 600V, it is determined that 33.5 panels are allowed per series which rounds to a total number of 33 panels per series.

Max Panel Loading = (33)(4)(200W) = 2,640W = 2.64 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 are multiplied by the load that each supply.

Total Inverter Load = (10 Inverters)(5 kW) = 50 kW

From the above calculations it is determined that 50 kW > 2.64 kW therefore the Panel Board can support the load supplied by the inverters.

The 48 kW comes from the total capacity minus the existing load (50 kW - 2.64 kW)

STEP 3 Determining Load Capacity for the Panel Board

For design purposes, it is determined that the load for each inverter needs to be double'd in order to get the load per inverter on P.B. = 10 Inverters(2) = 20 kW

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OVERVIEW *Roof Array Design and Layout*

- Two (2) Separate Array Locations at opposite ends of the roof
- Each Array consists of 20 panels arranged in rows of 10 (200 total panels)
- Panels are sized at 200W and maximum 40" x 20" for a total area of 15.11 sq'
- The Array is being hung directly south with the support 3/2 degree tilt to its location
- Karman GT20 Inverters have been chosen to convert to AC power

STEP 1 *Determining the Number of Panels in Series*

Using the open circuit voltage of 60.0V per panel and the U.S. NEC rating of 600V, it is determined that 10.5 panels are allowable per series which converts to a round number of 10 panels per series.

Number of Panels in Series = $600V / 60V / Panel = 10.00 = 10 Panels$

STEP 2 *Sizing the Inverters*

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

Size of inverter = $10 Panels \times 200W / Panel = 4000W = 4.0 kW$

Based on this data the Karman CT 5.0 was chosen which is rated at 5000 W and has a 208 V AC output. The full specs for the CT 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 = $200 Panels / 20 Panels / Series = 10 Inverters$

Electrical Breadth

Max Panel Loading
63 kW

Total Inverter Load
40 kW < 49.8 kW available

Load per Inverter
2.0 kW

PROBLEMS *Electrical Impact and System Integration*

- Integrate into existing lighting and out of the existing lighting loads
- Electrical Inverters on the roof and 12" Recess down to house the inverters
- Inverters are chosen to convert to AC power which requires minimal wiring
- Inverters are chosen to convert to AC power which requires minimal wiring
- Each of the four inverters 208 V array systems will be fed by two separate panel boards

STEP 1 *Confirm Panel Boards have Sufficient Capacity*

Using the same circuit voltage of 60.0V per panel and the U.S. NEC Rating of 600V, it is determined that 10.5 panels are allowable per series which converts to a round number of 10 panels per series.

Max Panel Loading = $10 Panels \times 60V / Panel = 600V = 63 kW$

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 are installed by the total load capacity.

Total Inverter Load = $10 Inverters \times 4.0 kW = 40 kW$

From the above calculations it is determined that $40 kW < 63 kW$ therefore the Panel Board can support the load required by the inverters.

The 63 kW comes from the total capacity minus the existing load $63 kW - 23.2 kW = 39.8 kW$

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 load of each inverter on the panel board.

Load Per Inverter on P.B. = $40 kW / 20 = 2.0 kW$

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Number of Inverters = $200 Panels / 20 Panels / Series = 10 Inverters$

Electrical Breadth

Circuit Breaker Size
25A

Open Panel Board on Roof that can accommodate all Inverters

PROBLEMS *Electrical Impact and System Integration*

- Integrate into existing lighting and out of the existing lighting loads
- Electrical Inverters on the roof and 12" Recess down to house the inverters
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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 load of each inverter on the panel board.

Load Per Inverter on P.B. = $40 kW / 20 = 2.0 kW$

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PANELS SELECT 2		Rating: 208V/120V/100-400V		Inverter Panel Array		Mounting System	
Panel No.	Panel Description	Panel Type	Panel Size	Panel Power	Panel Voltage	Panel Current	Panel Weight
1	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
2	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
3	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
4	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
5	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
6	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
7	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
8	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
9	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs
10	10 200W Panels	Monocrystalline	40" x 20"	200W	18V	11.11A	10.0 lbs

Structural and Schedule Impact

5-Man Crew
Install 10 Panels / Hour = **20 Hours**

Tubular Steel Inc
Quoted Support Structure
+\$4700.00
Total Panel and Support Load = 3 lb/sf



GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

PV Watts

40 kW array
Convert to AC Power
49,111 kWh per Year



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INITIAL INVESTMENT			
Item	Quantity	Cost / Unit	Total Cost
PV Panels	40000 W	\$8.0/W	\$320,000.00
Inverters	30	\$1,000	\$30,000.00
Savings	Federal \$10,000		-\$10,000.00
	State \$3,000		-\$3,000.00
Total Cost			\$337,000.00



GrandView

AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Initial Investment

Federal Incentive: **\$10,000**
Maryland Incentive: **\$3,000**

Possible: 30% Tax Cut
Carbon Tax



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 **GrandView**
AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Results

- \$337,600 Initial Investment
- 49,111 kWh annually
- \$6,797.00 Energy Savings
- \$49.00 / Apartment
- Payback Period: 49 Years
- Prevents 39.2 tons of CO2

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Shading
No Shadows
Limited Impact on
Grandview
Schedule
Huge Area

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 **GrandView**
AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Analysis 2

Thermal Window and Glazing
Substitution

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Existing Window Type

- Double Glazed
- Clear
- Aluminum Frame




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Design Methodology

Conduction:
Better Frame
Double & Triple Pane

Solar Gain:
Low Solar Gain Glazing
Low SHGC

Proposed Window Types

- Double & Triple Pane
- Low Solar Gain Glazing
- Fiberglass Frame




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Total Monthly Surface Irradiance



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Goals

Run a Fenestration Heat Analysis
Determine Energy Costs
(Cooling Load Only)

Heating Variables: Humans, Lights, Oven,
Computer...

STEP 4

Calculating Fenestration Heat Load

A fenestration is defined as the opening in a building 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 will calculate the 2005 adjusted conductance of fenestration (page 20, equation 1):

Equation	Definition of Terms
$U = U_{window} \cdot C_{glaz}$	U - Instantaneous Energy Transfer $W/(m^2 \cdot K)$
$U = U_{window} \cdot C_{glaz}$	U - Overall Coefficient of Heat Transfer $W/(m^2 \cdot K)$
$Q = A \cdot U \cdot (T_{in} - T_{out}) + SHGC \cdot I_{solar}$	A - Area of Fenestration m^2
	T_{in}, T_{out} - Indoor and Outdoor Temperatures K
	SHGC - Solar Heat Gain Factor
	I - Instant Total Irradiance W/m^2

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Monthly Cooling Load Values									
Month	Day	Total Daily (Million Btu's)			Total Monthly (Million Btu's)			Total Savings (Million Btu's)	
		Current	Design 1	Design 2	Current	Design 1	Design 2	Design 1	Design 2
JAN	31	18.8	4.2	4.1	584.5	128.0	131.1	205.5	201.1
FEB	29	15.3	7.9	5.5	555.9	230.0	159.3	330.9	401.7
MAR	31	26.2	10.2	7.1	748.8	316.1	219.9	432.5	528.8
APR	30	26.4	12.8	8.9	822.6	385.2	260.7	497.4	561.9
MAY	31	33.8	16.1	9.8	1072.0	477.1	302.8	545.7	688.3
JUN	30	34.7	15.8	10.9	1040.2	472.8	327.8	567.5	713.0
JUL	31	36.1	16.7	11.6	1119.1	518.2	358.8	600.9	760.3
AUG	31	36.4	15.6	9.9	1038.8	429.8	291.9	527.9	652.4
SEPT	30	28.8	12.0	8.3	855.1	359.1	248.6	496.0	556.5
OCT	31	21.1	9.1	6.3	654.8	282.1	195.4	372.6	458.9
NOV	30	15.9	6.7	4.7	477.4	201.7	149.7	275.6	317.7
DEC	31	13.0	5.3	3.7	402.7	161.5	113.2	241.2	289.5
Yearly Totals					5776.2	2772.4	2176.1	3003.8	3386.4
Percent Savings								52%	70%

Findings

Design 1: Saved **56%** Cooling Load
 Design 2: Saved **70%** Cooling Load

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Month	Day	Total Daily (Million Btu's)			Total Monthly (Million Btu's)			Total Savings (Million Btu's)	
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SEPT	30	28.8	12.0	8.3	855.1	359.1	248.6	496.0	556.5
OCT	31	21.1	9.1	6.3	654.8	282.1	195.4	372.6	458.9
NOV	30	15.9	6.7	4.7	477.4	201.7	149.7	275.6	317.7
DEC	31	13.0	5.3	3.7	402.7	161.5	113.2	241.2	289.5
Yearly Totals					5776.2	2772.4	2176.1	3003.8	3386.4
Percent Savings								52%	70%

Life Cycle and Energy

Annually:
 Design 1: Saved **\$61,783** Electricity
1200 TONS of CO2
 Design 2: Saved **\$76,579** Electricity
1480 TONS of CO2

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Cost Comparison						
Design	Difference in Cost	Area (SF)	Initial Cost Difference	Energy Use (\$/yr)	Annual Cooling Savings	Percent Savings
Design 1	\$ 2,421	18,176	\$ 11,488.16	11.4	\$ 46,367.00	80%
Design 2	\$ 5,222	18,936	\$ 200,922.72	11.4	\$ 93,912.00	70%

Yearly CO2 Savings Impact				
Design	Window Type	Million BTU's	lb/ton	Tons of CO2
Design 1	Double Pane Low E	5324	1429.782	7.6
Design 2	Triple Pane Low E	6216	1754.020	10.8

FUN FACT:
 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 cancelling 10 round trip flights of a 747 across the country.

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AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Schedule and Constructability

Only Schedule Impact Lead Time

Constructability:
Double Pane: Same Weight and Design
Triple Pane: Heavier Different Design
 **Require Structure Modifications

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Construction Management

Matt Karle

April 14th 2009





AT ANNAPOLIS TOWNE CENTRE AT PAROLE



Energy Consumption

	USA	CHINA
Land Area	6,150,000	9,520,410 (Square Kilometers)
Population	300,540,000	1,322,410,000 (2007 Estimate)
Energy Consumption	2,300 (million metric tons of oil equivalent)	1,800 (million metric tons of oil equivalent)
Energy Per Capita	7.66 (thousand tons of oil equivalent per person)	1.38 (thousand tons of oil equivalent per person)

How does **America** compare?

China

Building Overview
 Schedule & Cost
 Overall Goals
 Solar PV
 Implementation
 Glazing
Solar Constructability
 and Future
 Recommendations
 Questions

Residential and Commercial Make Up Bulk of Energy Usage:
 Tells us that we need to build smarter!!

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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.

Solar Growth and Constructability

40 Respondents in the Construction Industry, mainly Contractors in the D.C. area, were asked their views on Solar Energy.

- Building Overview
- Schedule & Cost
- Overall Goals
- Solar PV Implementation
- Glazing
- Solar Constructability and Future
- Recommendations
- Questions

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.

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

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What would make you more willing to install a system?

TOP 3:

- Lower Initial Cost
- Higher Incentives
- Better Efficiency

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PV PANELS IMPLEMENTATION

While photovoltaic panels seem to be the way of the future, it is my recommendation that at this point in time GrandView does not add PV's to the roof.

The low energy gain as compared to each apartment does not seem financially smart when a 49 year payback period exists.

It would be smart to wait 5 years to see what type of new and cheaper PV technology comes out that would allow a much smaller payback period.

GrandView
AT ANNAPOLIS TOWNE CENTRE AT PAROLE

Conclusions and Recommendations

THERMAL WINDOW SUBSTITUTION

From an economic, financial, and comfort point of view, I would highly recommend upgrading to a low solar gain glazing on the windows.

However, I would keep the windows double pane as they already are and keep the aluminum frames. These only add to the cost of the units and do not provide substantial enough energy savings in the long run as compared to radiation.

SOLAR PANELS AND THE ECONOMY

I recommend that the government provide better funding for renewable energy research as well as provide better federal and state tax cuts and grants for installing energy saving technology.

It is my hope that we one day surpass China.

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GrandView
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Thank You

I wld b plsd to nswr qustns t ths tm

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