Hamad Alrahmani

Construction Management Option

Murur Mixed Use Complex

Ajman, United Arab Emirates

Final Report

Murur Mixed-use Complex | Hamad Alrahmani

Ajman, United Arab Emirates | Construction Management

Project Team:

Owner: Ajman Traffic Department
A/E: AJ Design
G/C: Ali Moosa & Sons Contracting
HVAC: AMS Contracting-MEP Division
Super-Structure Designer: Freysinnet
Landscaping Works: Lea

The Buildings:

The project has a shopping mall and 2 towers
The residential tower is 20 floors + penthouse
The office tower is 26 floors
The shopping mall is 3 floors
Total parking spaces are 1,357 spaces
3 Basement Parking + 2 upper level parking

The Project:

History: The Site was previously occupied by Ajman Traffic Department, and this is where the name comes from, since Murur means Traffic.
Size: 2,300,000 Square Feet
Delivery: Design-Bid-Build
Cost: 600 million AED = 164.4 million USD

Structural and MEP Systems:

Structure: Reinforced Concrete Building, 280 mm slabs, columns range from 300 mm to 1600 mm
Foundation: 2000 mm thick R.C.C. raft on friction pile foundation
MEP Systems: Power delivered by FEWA at 240/415V, 3 phase, 4 wires, 50 Hz.
Chilled water HVAC system

http://www.engr.psu.edu/ae/thesis/portfolios/2010/hma135/index.html

A. Executive Summary:

The senior thesis final report discusses the three analyses performed on the Murur Mixed-use Complex project. The project is about 2.3 million SF of mixed-use facilities that include a shopping mall, a residential tower, an office tower and parking floors.

Analysis 1: Photovoltaic Panels

Energy is a major issue that affects all industries including the construction industry. Energy cost is rising constantly and alternative energy sources are being developed every day. Solar energy is one of the cleanest energy sources on the planet, and with the location of the Murur Complex project, photovoltaic solar panels can be a good source of energy. A solar panels' system's simple cost payback is more than 26 years, while the discounted payback period is 75 years.

Analysis 2: Solar Shading

Due to the high solar irradiance in the region where the project is located, windows gain a huge amount of heat which enters the building and cause discomfort to the tenants. Solar louvers can keep the direct sun light off the windows and save more than 1.3 billion BTUs each year. In this analysis, a 24 inch louver shading system and an 18 inch louver system will be compared.

Analysis 3: Interior Work Prefabrication

Prefabrication has gained a lot of attention from many contractors in the past few years. Prefabrication has many benefits especially to large projects like the Murur Complex. Prefabricating the interior work will save the project more than $250,000, and will accelerate it by 100 days which gives a chance for $3.6 million worth of revenue.

B. Acknowledgments

Special thanks to my family, whom without their support and patience, I would not be able to achieve anything.

Ali Moosa and Sons:

Especially to:

Engr. Ahmad Ali Moosa

Engr. Mohammed Saleh

Penn State AE department:

Especially to:

Professor Moses Ling

Professor M. Kevin Parfitt

Professor John Messner

Professor William Bahnfleth

My Friends:

Especially to:

Jaafar Al Aidaroos

Mohamed Alali

Samir Al Azri

Ian Foster (Truland Industries)

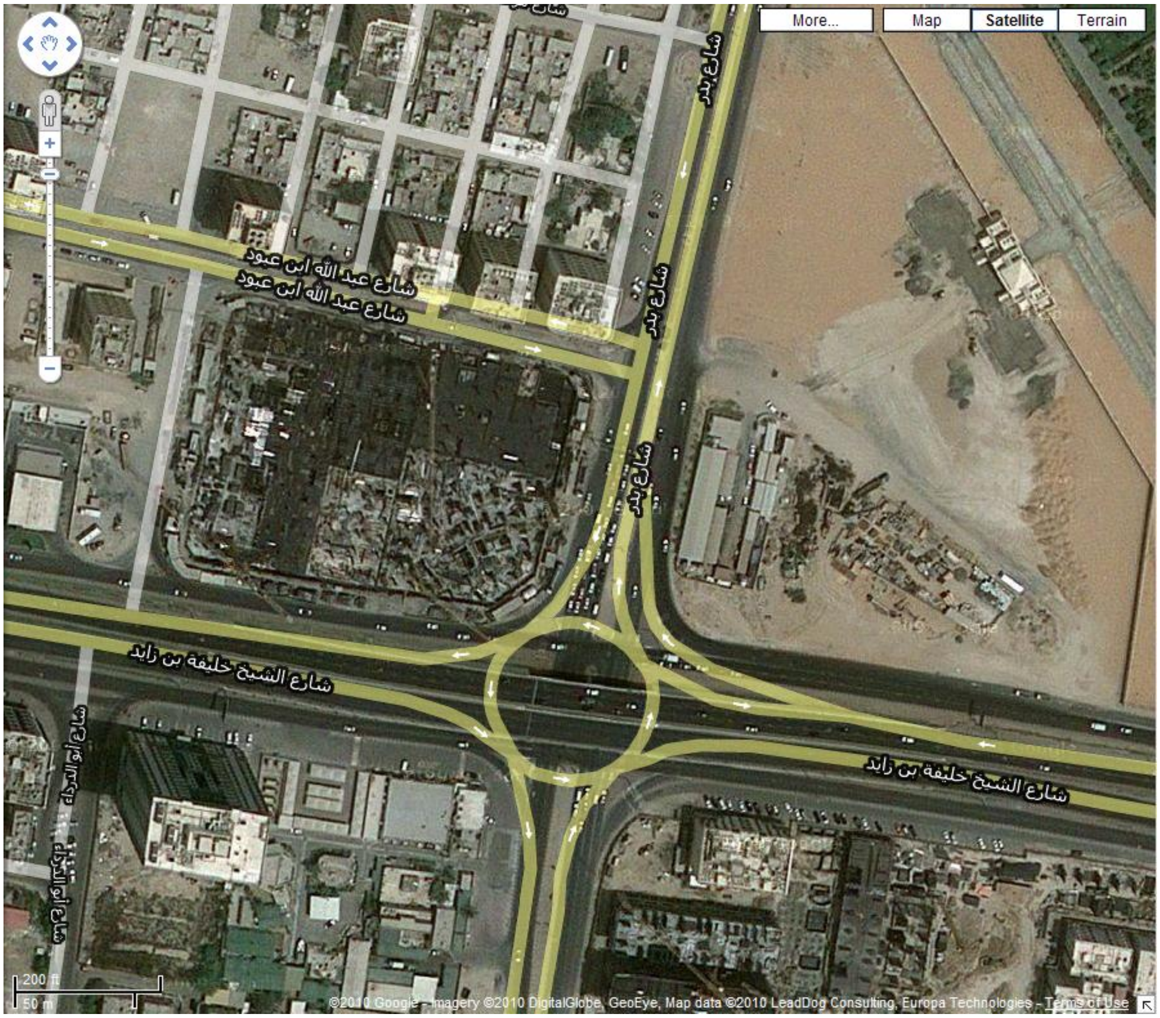
Everyone who had a part in helping me achieve what I did. Thank you

C. Project Overview

C.1 Introduction

Murur Mixed-use Complex is a huge project located in the heart of the city of Ajman in the United Arab Emirates. The project consists of a 3 story shopping mall, a 26 story office tower and a 20 floors + penthouse residential tower. The total area of the project is about 2.3 million SF. The exact cost was not provided but an estimate of 600 million Dhs ($164 million) was given. The projected completion date is November 8th, 2011.

C.2 Project Location



Google Earth view of the project site

The Site of the Murur Mixed-use Complex is located in the heart of Ajman City. It is surrounded by a populated area and main roads all around. In such cases, construction of high-rise towers is always a challenge for the contractor. Luckily, there is an empty plot on the other side of the main road that the contractor was able to lease. This plot is used for the trailers, staff parking, and for storing materials that are needed for this fast track project.

C.3 Contractor Information

Ali Moosa and Sons Contracting Company is one of the companies of Ali Moosa and Sons (AMS) Group that was found in 1978. The AMS Group includes an Aluminum and Glass Factory that complements the contracting division in the company. The Aluminum and Glass Factories help AMS Group in winning many contracts because the group owns those factories and will not need subcontractors to do Aluminum and Glass work which is needed in almost every construction job.

In addition, The AMS Group opened a Real Estate business in 2001 to satisfy the increasing demand of real estate in the UAE. The Group also established an International Trading Office in Dubai to maximize their exposure to local and international markets. All those features make The AMS Group one of the very competitive contracting companies in the United Arab Emirates.

C.4 Project Delivery Method

The contract between the client and the General contractor, Ali Moosa and Sons is a lump sum contract. The delivery system in the project is design-build. Ali Moosa and Sons only had tender drawings when they got the job; they designed the whole structural system and execution. **Figure 1** is a simple diagram of the relationship of the different parties on the project.

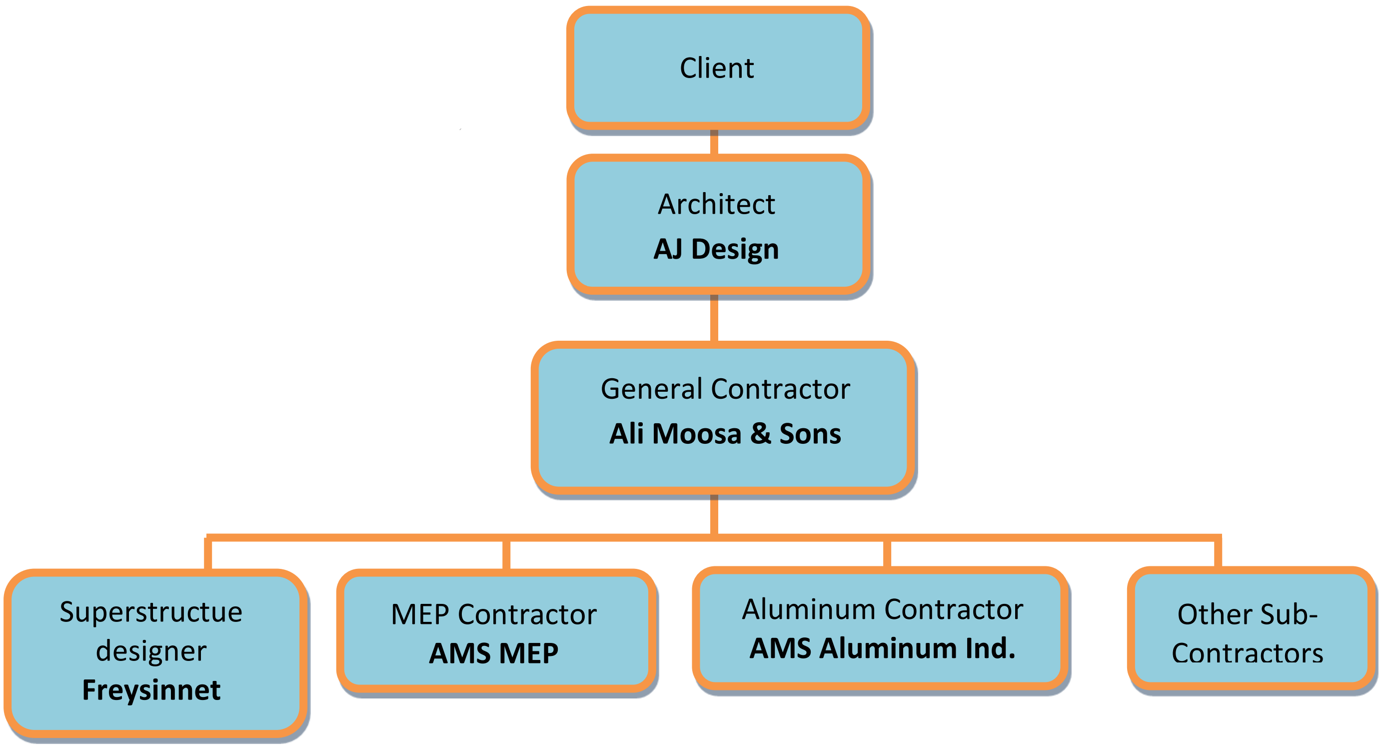


Figure 1. Murur Project Organizational Chart

The contract between Ali Moosa and Sons and the sub-contractors is a remeasurable contract, which means that the sub-contractors quote the rate of the work based on the design provided by the general contractor. This is called a remeasurable contract since the project is a huge project and many of the designs and details change while the project progresses.

C.5 Project Staffing Plan

ROLE	ASSIGN PERSON	PROJECT RESPONSIBILITY	SKILLED REQUIRED	START DATE	FINISH DATE
PROJECT DIRECTOR	ENG.EHAB ANWAR SALEH	MANAGING PROJECT	PROJECT MANAGEMENT	9-Jun-08	11-Nov-11
CONSTRUCTION MANAGER	ENG.ISMAIL,ENG.NAJEEB,ENG.JAMAL	MANAGING EXECUTION WORKS	CONST. EXECUTION ,REVIEWING CONST. DRAWING, SUBMITTALS	9-Jun-08	11-Nov-11
PLANNING ENGINNER	ENG.MOHAMMED SALEH	PROJECT PLANNING MONITORING & PROJECT CONTROL	PROJECT MANGEMENT & CONTROL	9-Jun-08	11-Nov-11
ARCHITECT	ENG.MOHAMMED WALEED	ALL ARCHITECTURAL ISSUE AND DESIGN ISSUE	READING DRAWING DESIGN, ISSUING RFI, APPROVALS OF MATERIAL AND SUPPLIER	9-Jun-08	11-Nov-11
QUANTITY SURVEYOUR	Mr. SIGISH	QUANTITY TAKE MEASUREMENT	MAKING BILLS, TAKING OFF QUANTITY,CLAIMING VARIATION ETC	9-Jun-08	11-Nov-11
PROJECTS ENGINEER	ENG.SHRIEF. ENG.JAMAL.ENG.MAHMOUD	EXECUTION OF WORKS	CONSTRUCTION EXECUTION WORK, REVIEWING DRAWING ETC.	9-Jun-08	11-Nov-11
QA/QC	ENG.ABDULLAHA	QUALITY CONTROL	CONTROLLING AND ASSURING QUALITY OF WORKS	9-Jun-08	11-Nov-11

Table 1

Table 1 shows the main Ali Moosa and Sons staff working on the Murur Complex project. It briefly describes the responsibilities of each of the personnel in the project. The hardest responsibility that is not mentioned in the table but is the most important task that every single one of them needs to do is communicating with each other. In a complicated project like the Murur Complex a single change or a simple change of approach that one of them might think is negligible to mention could cost the project a big problem.

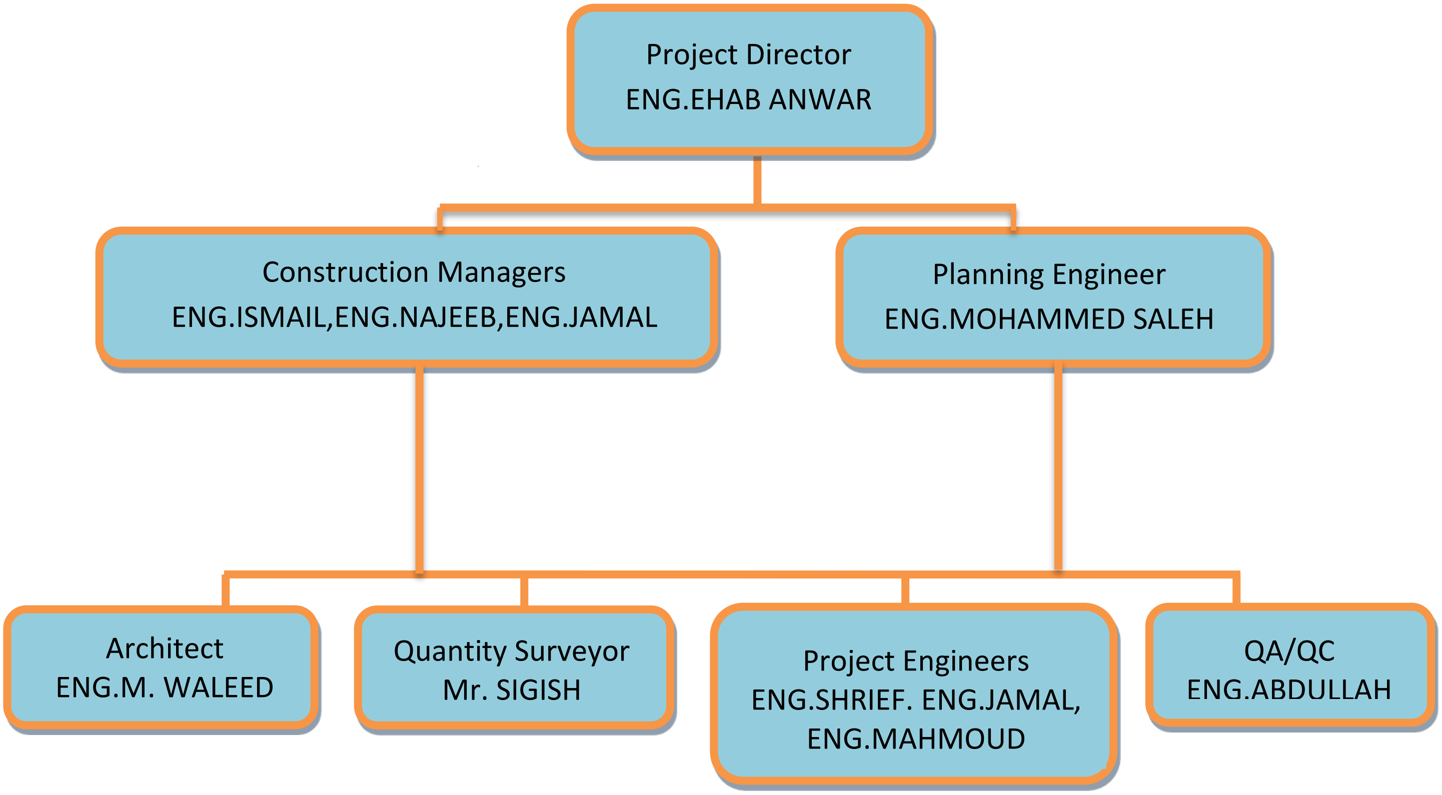


Figure 2. Staffing Chart

D. Design and Construction Overview

D.1 Building Systems Summary

- Structural System:

The whole structure of the Murur Complex project is reinforced concrete. Different grades of concrete were used which are between 40Mpa to 70Mpa in concrete strength depending upon the design of structural element.

Substructure consists of friction pile foundation over which 2000mm (2m) thick R.C.C raft foundation to support the whole super structure. RCC is roller compacted concrete; it is a special blend of concrete that has the same ingredients as the conventional concrete but with different ratios. RCC is usually used in building water Dams and for the same reason they are used in this project in both the retaining walls, and the several water tanks in the project.

- Mechanical System:

The HVAC system in the project is a central Air-Conditioning system where chilled water comes from the Federal Electricity and Water Authority's distilled cooling plant. The heat exchanger room which is located on the podium deck from where the chilled water is circulated to the mall and to both residential and office towers. All of the HVAC equipment and all chilled water and firefighting pump rooms are located on podium deck level.

There is also a firefighting system on the project. The water tank for the firefighting system is located in the basement.

- Electrical System:

Power will be delivered to the site by FEWA (Federal Electricity and Water Authority) at 240/415V, 3 phase, 4 wires, 50 Hz.

The transformers on the project are oil immersed MV/LV distribution transformers, of 2000 kVA. The transformers on this project will be provided by the client and so it will not be in the General Contactor's scope of work.

The backup power generator is an Engine Generator of 1000 kVA capacity. It works on an Automatic Transfer Switch system which connects the standby generator to the buildings electrical system once the power is cut off from FEWA.

- Cast in Place Concrete:

To support the side soil in the basement, the reinforced cement concrete shoring piles were used as well as the R.C.C retaining wall.

All the underground parking floor slabs are conventional flat slab with drop at the columns. The structural slabs above ground floor are post tensioned.

- Masonry Work:

Different sizes of masonry walls were used depending on the need at each area. All the interior walls are masonry walls, which is typical in the United Arab Emirates. The four sizes of walls are 100 mm, 150 mm, 200 mm, and 250 mm thick walls. The type of blocks used was Lightweight Thermal Insulating Clay Blocks.

- Curtain Wall:

White powder coated aluminum curtain wall frames, glazed panel system is used. The fixed double glazed aluminum curtain wall panel system consists of 6mm thick clear tempered glazing panel as an inner panel, a 12mm air gap is between the two panels, and 6mm thick High performance tinted tempered glazing panel is used as an outside panel.

- Support of Excavation:

Since water level is only about 6 feet under the ground level, the contractor carried out the dewatering for around one and half years. R.C.C shoring piles were used in order to protect the side earth from falling during the foundation work.

D.2 Project Cost Estimate

An actual construction cost was not provided to me but I was given an estimated cost of 600 million United Arab Emirates Dirhams which is approximately 164.4 United States Dollars. Actual costs of the project are not shown in this report.

D.3 Local Conditions

The Murur Mixed-use Complex is located in the heart of Ajman City. Heavy vehicular and pedestrian traffic impact the area and have to been taken into consideration. There is almost no construction parking due to the roads on all four sides. Ali Moosa and sons was able to lease the plot across the main road and use it as trailers and staff parking area, and a short term storage for needed material.

Almost all of the construction in the United Arab Emirates is reinforced concrete. And most of the towers in the past few years have curtain walls. So this project’s towers are typical UAE towers.

In many areas in the UAE, the soil has low bearing capacity and the water level is high. Murur Complex’s location is no better than any other area in the UAE; in fact, it has a very high water level. The water level in the site is around 6 feet under the ground level, which made it a big challenge for the contractors to work with.

D.4 Detailed Project Schedule

Murur Mixed-use Complex's construction started on June 9, 2008. The project will need approximately 1,248 days from start to end, that is 1,070 working days since each week has 6 working days. A detailed project schedule is attached in **Appendix A**. The detailed schedule separates the work done in each of the 3 sections of the project, the Office Tower, the Residential Tower, and the Mall section. One particular part of the schedule shows the work and durations of each job done in the first floor of the Office tower, to provide an example of time needed to finish each floor and the sequence of the different jobs done on each of them.

Due to the huge area of the project, the raft in foundation was divided into 7 stages. From basement 3 to the podium deck the area was divided into 6 stages. The office tower was not divided but the residential tower was divided into 2 phases. **Figure 3** shows the 6 stages from basement 3 up to the podium deck.

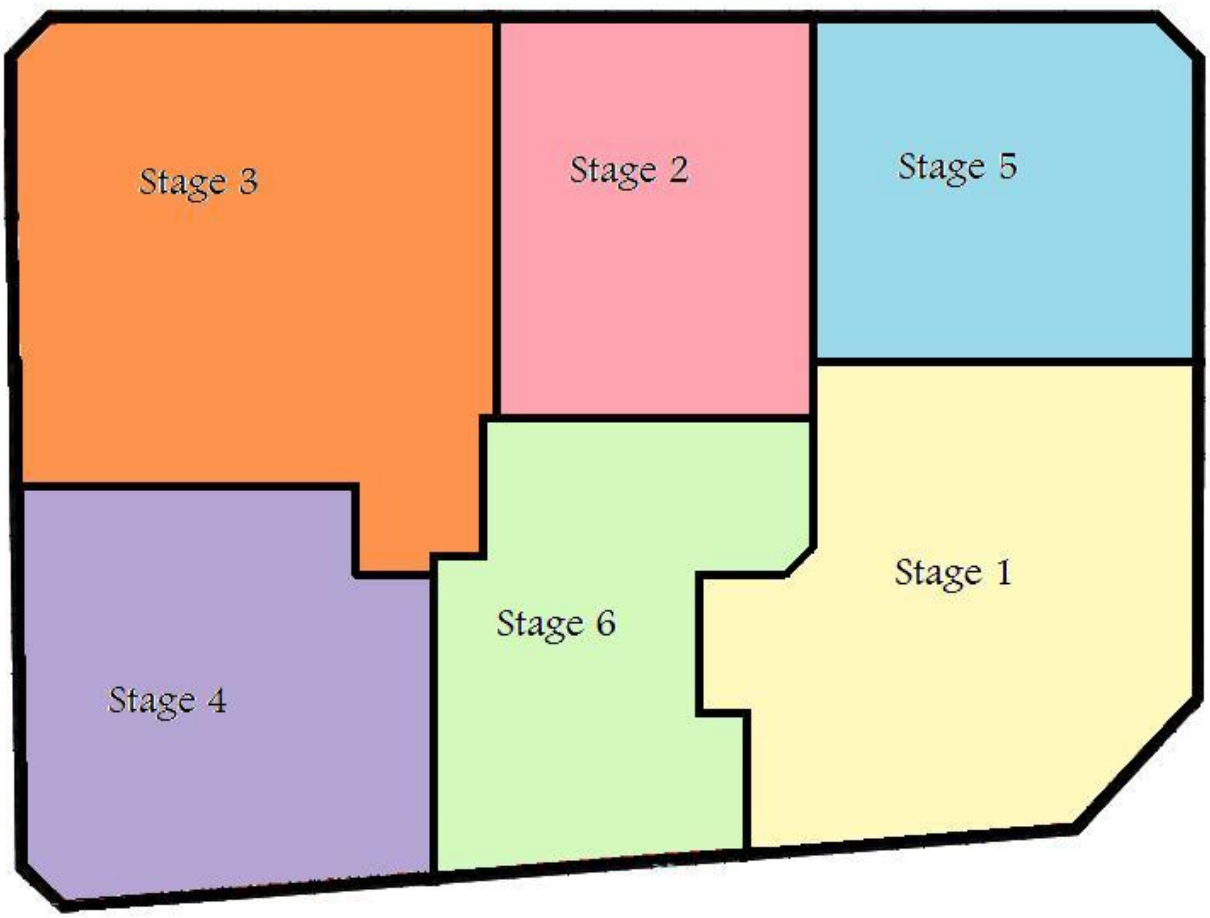


Figure 3. Parking and Shopping Mall Staging Plan

D.5 Site Layout Planning

The Murur Mixed-use Complex site is a big site covering 1 whole block. There are 2 busy main roads on the East and the South sides of the site, and 2 less active streets on the North and West sides. With the building covering the whole construction site, there is no space for material storage or delivery truck at all. This makes planning the site a very complex job due to many factors like safety of the pedestrians and vehicles, finding a place for delivery trucks to unload, and having the crane ready to finish unloading as fast as it can.

The site plan in **Appendix B** is showing the superstructure phase. In this phase of the project, the site will experience an extensive number of unloading due to the huge quantities of material needed to complete the job. Ali Moosa and Sons requested permits to close the streets on both the West and the North sides of the site to be able to get a private access for delivery trucks. The street in the West side is completely closed to public and is a perfect place for unloading material. The street on the North side is a two way two lanes' street, with an island in the middle, only the two lanes closer to the site are closed to public, while the other two lanes are used one lane each way by the public vehicles.

D.6 General Conditions Estimate

The general conditions estimate was broken up into different categories as shown in **Table 2**. The estimate was determined by using 2010 RS Means Building Construction Cost Data. The total cost estimate of the general conditions was $14,029,582 which is about 8.5% of the total project cost.

General Conditions Estimate

Description	Cost	Total
Temporary Utilities		
Lighting, Wiring and Outlets	$40/CSF-floor	$58556
Power for temp. Light	$3.14/CSF-floor/Month	$188475
Power for job Duration	$100/CSF-floor	$146390
Field Office Expenses		
Equipment rental	$171/Month	$7,011
Office supplies	$93/Month	$3813
Telephone bill	$88/Month	$3608
Lights and HVAC	$165/Month	$6765
Cleaning and Waste Management		
Clean up floor area per day during construction	$40.50/1,000SF	$93,150
Clean up after job completion	$84/1,000SF	$193,200
Final cleaning by GC at end of job	1%	$23,012
Field Personnel		
Clerk	$380/Week	$67,640
Project manager	$1,925/Week	$342,650
2 x Superintendent	$1,775/Week	$631,900
2 x Site Supervisor	$1,450/Week	$516,200
2 x Safety Inspector	$1,200/Week	$427,200
Other Fees		
Main Office Expenses	4%	$6,560,000
Protection and Safety	$3,000/Month	$123,000
Temporary Hoists and Cranes	$2,000/Day/each	$2,140,000
Temporary Fencing	$23.5/LF	$37,012
Permits	0.5%	$820,000
Insurance	0.5%	$820,000
Commissioning	0.5%	$820,000
Total		**$14,029,582**

Table 2

E. Analysis 0: A Separate Solar Powered HVAC System (Canceled)

My idea was to have an air conditioning system completely powered by solar photovoltaic panels. This air conditioning system will not substitute the existing system, but will help in reducing the need of the existing system during the hot hours of the day time.

The solar powered air conditioning system will only be providing the shopping mall area with cooled air. The shopping mall covers 3 stories and a total of 420,000 square feet.

The central air conditioner that will be working during the long lighted hours of the day and help in lowering the room temperature of the mall area. The existing air conditioning system will require much less energy to keep the area under the required conditions.

Required Dry Bulb temperatures for the mall area are 75° in the summer and 71° in the winter. The averages max temperature in the summer months is 102° and 75° in the winter months. So air conditioning the building is required all year round.

What makes the United Arab Emirates one of the greatest places to benefit from solar energy is that is has one the highest clearness index rates with an average of 82% of clear days a year. And most of those unclear days are in the winter were the need of cooling is much less. One other very important factor that helps making solar energy a highly beneficial source of energy is the long hours of daylight. The average daylight hours in December is 10.53 hours, this is the least number of hours of sunlight in a single day. In June, the average goes up to 13.47 hours of daylight a day.

The analysis will not be completed and has been cancelled due to the complexity of determining the effects that a separate HVAC system will have on the original system.

F. Analysis 1: Photovoltaic Panels

F.1 Solar Power

With energy prices rising every year and with the desire of cleaner air around the world; the search of alternative energy sources does not stop. Companies invent and develop new technologies each day to make alternative energy sources less expensive, more reliable and efficient. Many countries and governments are pushing towards green energy too, in fact, Abu Dhabi, the capital of the United Arab Emirates, is investing over $22 billion to build Masdar City, which is a city powered entirely on renewable energy sources.

Masdar City rendering

Solar power is one of the most growing renewable energy sources with about 30% growth per year. Solar energy has many applications, and it is reliable in many areas in the world. In fact, In the United Arab Emirates we rarely see clouds, which makes solar energy very effective and reliable, especially in the summer season since the sun is directly vertical to the United Arab Emirates which is located on the tropic of cancer. The area is also one of the most places in the entire world that has a very high solar irradiance average.

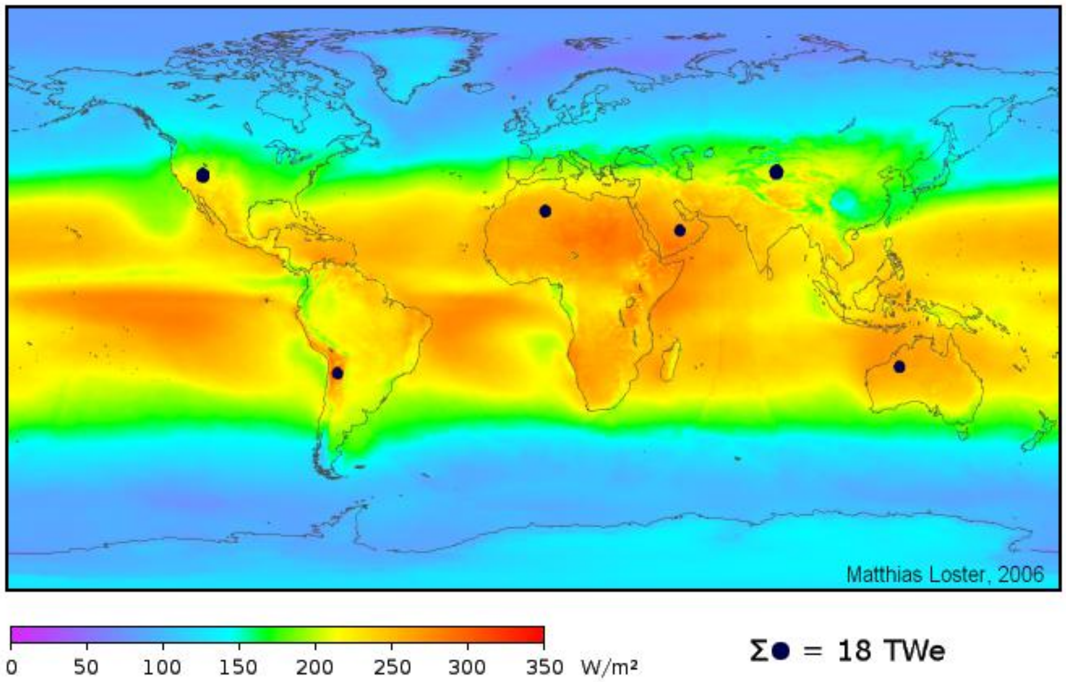


Figure 4. World Solar Irradiance

F.2 Yingli Solar

The solar panels that I will be using in this analysis are Yingli Solar Panels. Yingli is a Chinese based company that has been developing rapidly lately. The company has been successfully providing solar power systems to many European countries and to the United States. Yingli has reliable solar panels at a very competitive price, which makes it hard not to choose them.

The panel that will be used is Yingli's YL225P-29b model with a maximum power output of 225 Watts. The panel is able to operate at temperatures between -40°C and +90°C, and it can bear up to 50 psf of wind load. The solar panel's data sheet is provided in **Appendix C.**

F.3 Sizing the System

Unfortunately, the roof of both the residential and the office towers in the Murur Complex are not simply flat. Both roof tops have Helipads on them, and the residential tower has the penthouses' top floors. Those structures take a lot of the area on the roof top which could have been used for solar panels. Shading caused by the penthouses and the helipads are also taken into consideration, which makes the usable area of the roof even less. **Figure 5** shows the four areas which solar panels will be installed at in red. The dark grey areas are the helipads and the penthouse tops. The total area of the four sections is 450 m^2 which is 4,844 ft^2.

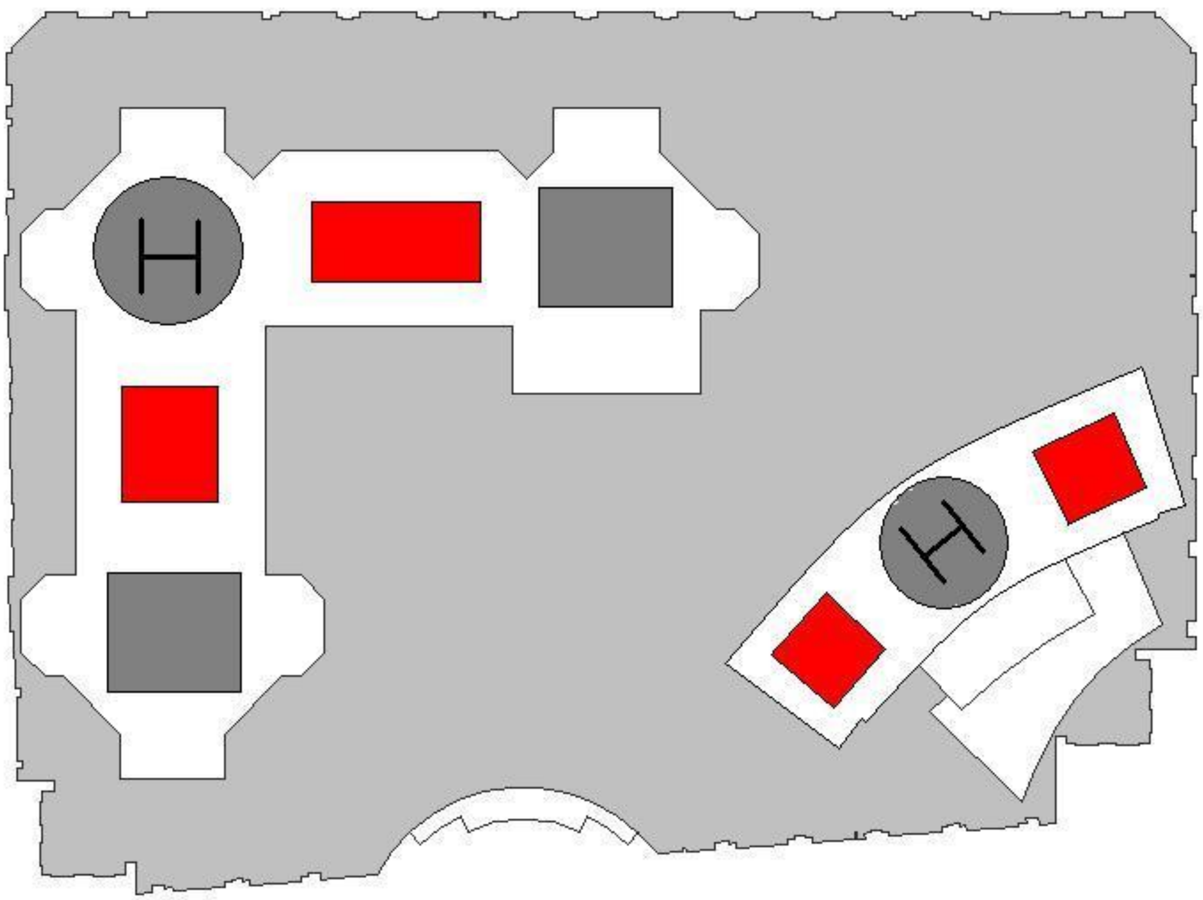


Figure 5. Solar Panels Locations

Panel Dimensions are 65"x39"x2" which makes the surface area of each panel 17.6 square feet. The area will be able to fit 275 panels, but only 240 panels will be installed to allow area for panel angles and for maintenance. Sunlight should not be blocked from the solar panels since any small shading could greatly affect the efficiency of the panel.

The panels will be distributed as the following:

48 panels will be on each on the areas on the roof of the office tower (96 total panels)

64 panels on the south wing area on the roof of the residential tower

80 panels on the north wing area of the roof of the residential tower

F.4 Sizing the Inverter

The size of the inverter is based on the open circuit voltage limit that it can handle. The inverter chosen for the photovoltaic solar system is the Solectria PVI 3000. The open circuit voltage limit for this inverter is 600V. This limit means a maximum input of 600V can be driven into the inverter from the PV arrays. Since there are 240 panels, each with a Voc of 36.5 Volts, a maximum of 16 panels can be connected to one inverter.

16 panels will produce (36.5V x 16) 584V.

The inverters' maximum recommended PV array power at 240 VAC is 3,600 Watts which is exactly the maximum output of 16 panels at 225 Watts each.

The total number of needed inverters is 15 inverters (240 panels / 16 panels per inverter). The inverters will be distributed in the following order:

3 inverters in each of the office tower PV array areas (6 total inverters)

4 inverters on the south wing, and 5 on the north wing of the residential tower PV areas (9 total inverters)

Installation of the inverters is fairly easy due to the low weight of it; each inverter only weighs 48 lbs. The Solectria inverters also have a quick-mount bracket feature, and a universal 240/208 VAC operation.

F.5 Wiring The System

The short-circuit current of each panel is 8.28A. The wire that will be connecting the panels to the inverter will be AWG 12. The inverter's output current protection is 15A so the appropriate wire size to connect the inverter to the electrical panel is AWG 9.

The maximum power output at 240 VAC is 2,900 Watts, so the total power output of the 15 inverters is 43.5 KW

F.6 System Power and Cost

To calculate the total power produced by the system, the first piece of information we need is the average solar radiation in the region that the project is taking place. Based on a study by A. Assi, M. Jama, K Al Khathairi, I. Al Shehhi and S. Fattahi, the average annual solar hours in the UAE is 3,568 hours, which equals to 9.7 hours/day. Those solar hours produce an annual solar radiation of approximately 2,285 kWh/m^2 which equals to an average of 6.3 kWh/m^2 per day. 6.3 kWh/m^2 per day is the number that we need to be able to calculate the produced power by the system.

The system is able to produce about 122.5 Mega Watts per year, calculated in **Table 3** below. With the system gaining sunlight radiation in an average of 6.3 kWh/m^2 a day. Peak sunlight hours reaching more than 13 hours per day in the summer, producing maximum power at the most time it is needed.

Solar PV Panels Power Output

Quantity and Period of use	Power Output
1 Panel	225 W
240 Panels system	54 KW
System x 6.3 kWh/m^2 per day	340.2 KWh
System x 30 days	10,206 KWh
System x 12 months	122,472 KWh

Table 3

The 122,472 kWh is the total power produced by the solar photovoltaic panels, but it is not the same amount of power tied to the electrical grid. The photovoltaic panels are connected to the 15 inverters that were sized in the previous section. Although each group of 15 panels is capable of producing a total of 3,600 Watts, the inverter's output is only 2,900 Watts. The total power than is tied to the electrical system in the building is:

2,900 Watts x 15 inverters = **43.5 kWh**

Solar System Power Output

Quantity and Period of use	Power Output
1 inverter	2,900 W
15 inverters	43.5 kW
System x 6.3 kWh/m^2 per day	274 kWh
System x 30 days	8,222 kWh
System x 12 months	98,658 kWh

Table 4

The cost of the total system is **$233,295** which is calculated in **Table 5** below. The United Arab Emirates has no government incentive programs for renewable energy yet. So there is no any type of credit or savings on installing a solar system. But there is no sales tax in the United Arab Emirates which means that the price of the system is the total price paid.

Solar System Cost

Description	Cost
12 x (20 Yingli solar panels pallet)	$124,200
15 x PVI 3000-208V inverter	$28,095
Mounting equipment at ($0.50 per Watt)	$27,000
Installation cost at ($1 per Watt)	$54,000
Total cost of the system	**$233,295**

Table 5

In addition to the solar panels and the inverters, the system will require mounting equipment that costs around $0.50 per Watt for a project of this size while installation costs $1 per Watt.

Yingli has a 25 year 80% power output warranty. It does not have an expected lifespan, but I will assume 30 years as the lifespan of the panels.

F.7 Constructability

The optimum tilt of the PV panels is 30° facing south. The project latitude is 25° north, so the sun will always be shining from the south, and it will be almost straight up in June since the location is very close to the Tropic of Cancer on the 23.5° North altitude. The optimum angle is also beneficial in cleaning the panels, since an angle flatter than 15° is not recommended, because that angle will not take advantage of the rainfall and wind to clean PVs, but the 30° angle will.

A specialty contractor will perform mounting, installing, and wiring the solar panels. Since the job is very specific, a specialized contractor is needed to make sure all the panels are mounted with the right angle, and there are no shaded areas over any of the panels since shades have dramatic effects on the panels' productivity. Wiring the panels and connecting them to the inverters and the electric panels are also a critical job to make sure no device is overloaded or misconnected; all those reasons require a specialized contractor to do this job.

The mounts will be drilled in the concrete roof top of the towers. Mounting 240 panels will need 4 crews of 3 workers. Each crew will mount 20-25 panels each day. That will allow the 4 crews to finish mounting 240 panels in 3 days. Since there are 4 PV panel areas, each crew will work on 1 area. The areas on top of the office tower are smaller and have fewer panels; the crews will finish earlier than the crews on the residential tower. Those 2 crews will help the crews on the residential tower to finish the work on time.

Figure 6. PV Panel Mount

Mounting the PV panel the way shown in **figure 6** above will allow easy access for cleaning and maintenance.

Wiring and connecting all the PV panels to the inverters, and the inverters to the electric panels will take 2 extra days. The total mounting and installation process will need 5 days to complete.

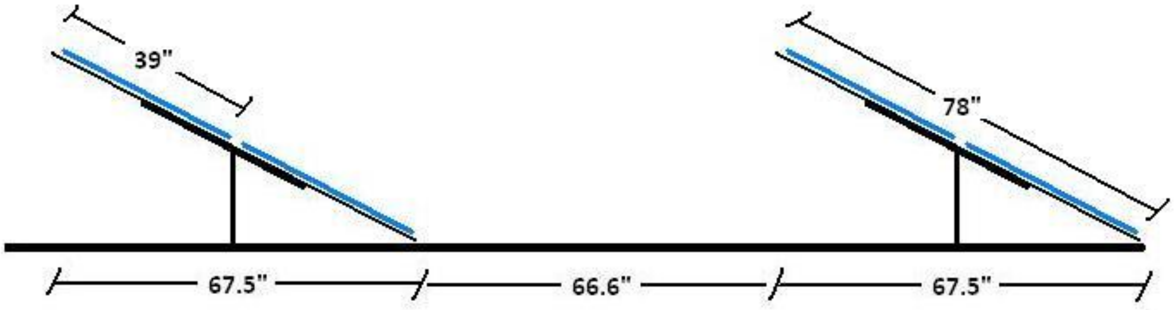


Figure 7. Panel Spacing and layout

Figure 7 shows the panels spacing and layout. Each panel is 65 inch long and 39 inch wide. The panels will be mounted so the long side is horizontal. Two panels will be on each mount and their total depth will be 67.5 inches due to their tilt. This will allow about 66 inches between each row of panels, which is enough to avoid any shades on the panels, and for easy cleaning and maintenance. **Figure 8** shows the layout of the panels facing south on the roof of each tower.

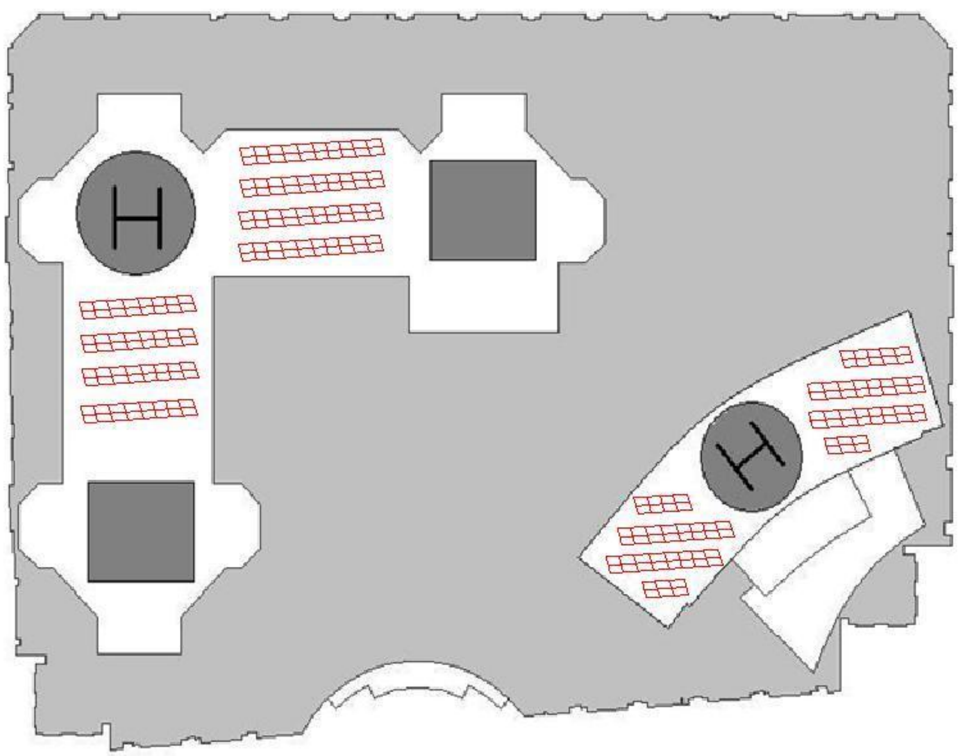


Figure 8. Solar panels layout

F.8 System Payback

Simple Payback Method:

The cost of electricity per KW is about $0.09 in the United Arab Emirates for large commercial buildings.

The System will be saving:

98,658 kWh/year x $0.10/KW = $8,879.2 each year

$233,295 total cost / $8,879.2/year = **26.3 years**

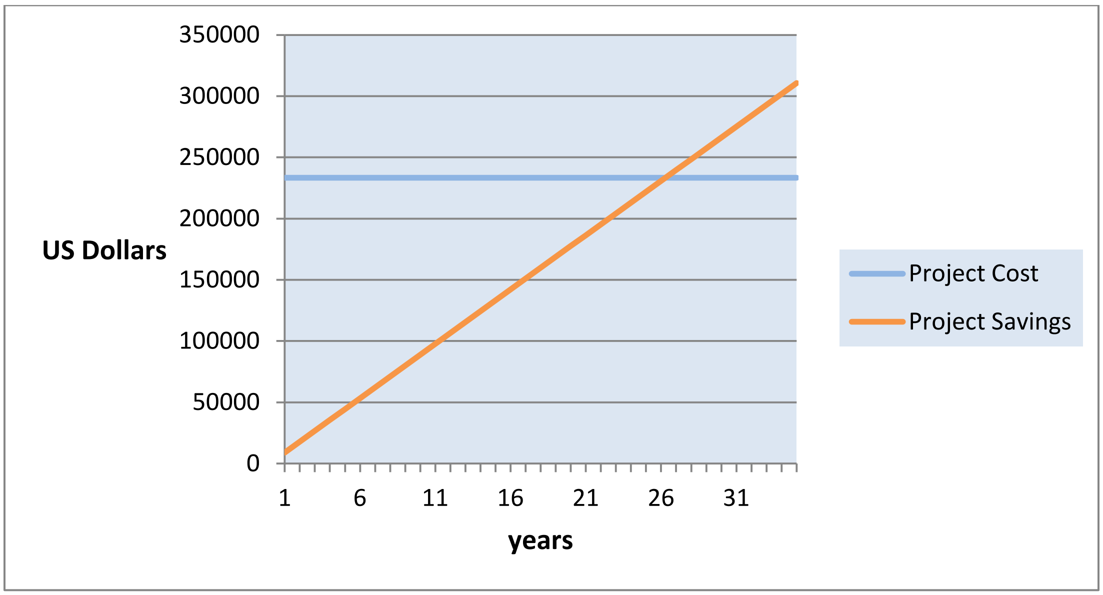


Figure 9. Simple Payback

The simple payback period of the system is about 26 years. It seems a long period of time but it is reasonable for such systems to payback in this number of years. Simple payback method does not take into account the inflation rates, so it is not an accurate method for calculating payback. And since the payback period is long, inflation will have a huge effect on the period of time.

Discounted Payback Method:

Simple payback is not the best way to calculate the payback period. So instead, I am calculating the discounted payback period which takes into account the inflation and interest rates, because time always affects the value of money. I have not found an interest rate for the

United Arab Emirates central bank but I assumed the number is 4%. **Table 6** below shows the savings of 100 years using the discounted payback method.

100 years discounted payback savings

Number of Years	Value of Savings at each Year	Total Value of Savings up to the Specific Year
1	9486.346	9486.346
2	9121.487	18607.83
3	8770.66	27378.49
4	8433.327	35811.82
5	8108.968	43920.79
6	7797.085	51717.87
7	7497.197	59215.07
8	7208.843	66423.91
9	6931.58	73355.49
10	6664.981	80020.48
11	6408.636	86429.11
12	6162.15	92591.26
13	5925.144	98516.4
14	5697.254	104213.7
15	5478.129	109691.8
16	5267.431	114959.2
17	5064.838	120024.1
18	4870.036	124894.1
19	4682.727	129576.8
20	4502.622	134079.4
21	4329.445	138408.9
22	4162.927	142571.8
23	4002.815	146574.6
24	3848.86	150423.5
25	3700.827	154124.3
26	3558.488	157682.8
27	3421.623	161104.4
28	3290.022	164394.4
29	3163.483	167557.9
30	3041.81	170599.7
31	2924.818	173524.6
32	2812.325	176336.9
33	2704.158	179041

34	2600.152	181641.2
35	2500.146	184141.3
36	2403.987	186545.3
37	2311.526	188856.9
38	2222.621	191079.5
39	2137.136	193216.6
40	2054.938	195271.5
41	1975.902	197247.5
42	1899.906	199147.4
43	1826.832	200974.2
44	1756.57	202730.8
45	1689.009	204419.8
46	1624.047	206043.8
47	1561.584	207605.4
48	1501.523	209106.9
49	1443.772	210550.7
50	1388.243	211938.9
51	1334.849	213273.8
52	1283.508	214557.3
53	1234.143	215791.4
54	1186.676	216978.1
55	1141.034	218119.1
56	1097.148	219216.3
57	1054.95	220271.2
58	1014.375	221285.6
59	975.3608	222261
60	937.8469	223198.8
61	901.7759	224100.6
62	867.0922	224967.7
63	833.7425	225801.4
64	801.6755	226603.1
65	770.8418	227374
66	741.194	228115.1
67	712.6866	228827.8
68	685.2755	229513.1
69	658.9188	230172
70	633.5758	230805.6
71	609.2075	231414.8
72	585.7764	232000.6
73	563.2465	232563.8
74	541.5832	233105.4
75	520.7531	233626.2

76	500.7241	234126.9
77	481.4655	234608.4
78	462.9476	235071.3
79	445.1419	235516.5
80	428.0211	235944.5
81	411.5587	236356
82	395.7296	236751.8
83	380.5092	237132.3
84	365.8742	237498.1
85	351.8021	237849.9
86	338.2713	238188.2
87	325.2608	238513.5
88	312.7508	238826.2
89	300.7219	239127
90	289.1557	239416.1
91	278.0343	239694.1
92	267.3407	239961.5
93	257.0584	240218.5
94	247.1715	240465.7
95	237.6649	240703.4
96	228.524	240931.9
97	219.7346	241151.6
98	211.2832	241362.9
99	203.157	241566.1
100	195.3432	241761.4
Number of Years	**Value of Savings at each Year**	**Total Value of Savings up to the Specific Year**

Table 6

As shown in the table above, the system will need 75 years to payback the original cost. This period is way over the average payback time of similar solar systems. 75 years is also more than the expected life time of the system components. If the panels needed replacement after 30 years, the system will never payback its cost. Although the sunshine in the United Arab Emirates is perfect for a solar system, but the initial high cost of the system and the lack of government incentives makes the system way over any reasonable cost. At the rate the solar panels are developing, and if their prices keep dropping in the next few years as they were in the last couple of years, such systems will be at a great cost and efficiency very soon, but as for now, the cost is not worth the payback.

G. Analysis 2: Solar Shading (Aluminum Louvers)

G.1 Solar Shading

Due to the location of the Murur Mixed-use Complex, photovoltaic solar panels are very beneficial. And due to the same reason, solar shading has a great impact on the building. The extremely high sun radiance and the high number of clear days can cause windows to gain a huge amount of heat. The heat gained by those windows will increase the interior temperature and will require more energy to keep the interior area comfortable for the tenants. Solar shading will help in reducing the amount of heat gained by the windows due to the direct sun.

Solar Shaded Facade

G.2 Nysan Aerofoil Louvers

The aluminum louvers used in this analysis are the Nysan Aerofoil Louvers. Nysan Solar Control Solutions is a well-known Canadian based company that provides exceptional products for more sustainable buildings. The louvers direct the sun shine away from the building, helping in reducing the heat gained by the windows. The louvers also control the light entering the building, for a more controllable work environment inside the building. The louvers are also aesthetically pleasing and can create an attractive modern look to the building.

I chose 2 different louver lengths and I will study and compare both of them in this analysis. The louvers chosen are exactly the same shape but one is the 24 inch (600mm) louver, and the other is the 18 inch (450mm) louver.

Appendix D contains data about the Nysan Aerofoil Louvers.

Figure 10. Nysan Aerofoil Louver

G.3 The Right Location

Solar shading will not be beneficial for any area on the project. The residential tower's exterior walls are not all glass, and many of the windows are protected from the direct sun by balconies. This makes the residential tower a bad section to invest in solar shading. The office tower on the other hand has a glass curtain wall, where solar shading is most beneficial.

Figure 11. Murur Complex viewed from the West

The project being on the northern hemisphere, the South façade is the most façade getting sunshine all year around. The East and West facades mainly get sunshine in the early morning and late in the afternoon when the sun is not intense and at a lower unavoidable angle. And the North façade is the least to get sunshine, the residential tower also helps in keeping the direct sun off this side of the office tower during the late afternoon hours.

Figure 12 shows the area of the façade chosen to place solar louvers on by an orange line. This location gives the best value for the solar louvers.

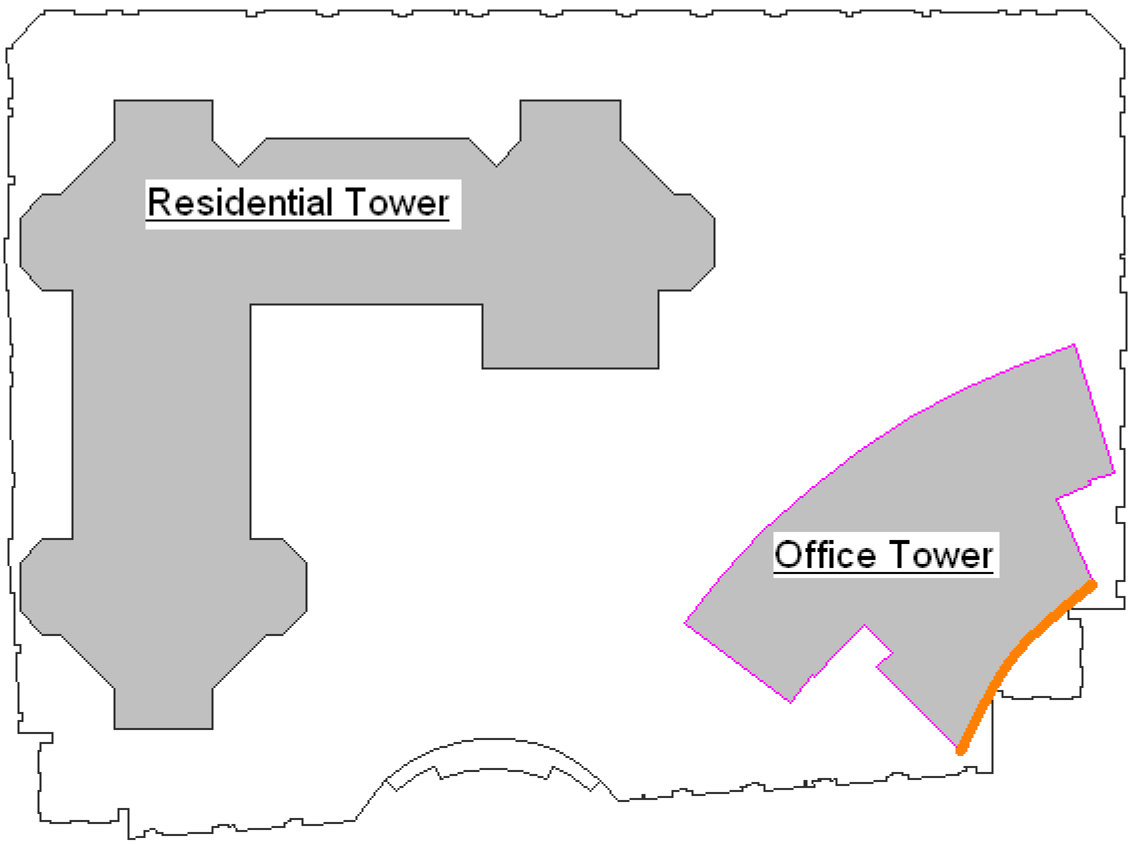


Figure 12. Solar Louvers Location

G.4 Windows Heat Gain Calculations

To calculate the heat gained by the windows, first we need to know what the area of the windows is. The height of the windows in the office tower is 7 feet. The length of the section that solar louvers will be installed at is 94 feet. And solar louvers will be added on all 26 floors.

7 feet x 94 feet x 26 floors = **17,108 ft^2**

I have used a window heat gain tool from the website susdesign.com to calculate the solar heat gain. The tool takes into account:

- the location of the project
- the sky clearness
- ground surface type and reflectance
- windows type, solar heat gain coefficient, and orientation

The output units are Btu / ft^2 / month, **Appendix E** has the average windows heat gain for double glazed windows per month. The average per month is multiplied by the area of the windows to calculate the total heat gained per month in BTUs. **Table 7** shows the total BTU's gained.

South façade windows solar heat gain

Month	Solar Heat Gain (BTUs)
January	472,659,824
February	361,594,688
March	266,508,428
April	145,503,540
May	122,082,688
June	119,294,084
July	123,092,060
August	153,219,248
September	269,143,056
October	414,543,948
November	471,017,456
December	495,516,112
Total BTUs per year	**3,414,175,132**

Table 7

G.5 BTUs Saved by the 24 inch Louvers

The 24 inch solar louvers will be spaced 8.4 inches above the windows to maximize the shadow while allowing an acceptable amount of indirect light to enter the building. **Table 8** shows the percentage of the direct sunlight on the windows after installing the louvers at the desired location. This is specifically calculated for the office tower façade that is facing 10° East of South. The grey boxes indicate that the sun is in the sky, but away from this side of the façade, so the direct light cannot hit the building. The 0% boxes indicate that no direct sunlight hitting the windows because it is blocked by the louvers.

Sunlight percentage on shaded windows by 24 inch louvers

	Morning							Afternoon					
	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00
Jan		100%	98%	91%	86%	83%	81%	79%	80%	82%	88%	100%	
Feb		100%	91%	84%	78%	74%	70%	68%	66%	65%	68%	79%	
Mar		89%	77%	68%	62%	56%	50%	42%	32%	14%	0%		
Apr	14%	35%	32%	27%	20%	9%	0%	0%	0%				
May			0%	0%	0%	0%	0%	0%					
Jun				0%	0%	0%	0%						
Jul				0%	0%	0%	0%						
Aug		0%	0%	0%	0%	0%	0%	0%	0%				
Sep	100%	76%	64%	56%	48%	41%	32%	19%	0%	0%			
Oct		97%	86%	78%	73%	68%	64%	60%	56%	52%	47%	37%	
Nov		100%	96%	89%	84%	80%	78%	76%	76%	78%	83%	97%	
Dec		100%	99%	93%	88%	85%	83%	82%	82%	85%	91%	100%	

Table 8

The average of the sun light percentage per day of each month is shown in **Table 9**

Using the percentage of the sunlight from **Table 9**, the heat gained by the windows with the louvers installed can be calculated. And by subtracting that number from the total BTUs gained which was calculated previously, the BTUs saved can be calculated. **Table 10** shows the BTUs gained after installing the louvers, and the BTUs saved by using them.

Sunlight monthly average

For 24 inch system

Month	Average Sun
January	88%
February	76.6%
March	49%
April	15.2%
May	0%
June	0%
July	0%
August	0%
September	43.6%
October	65.3%
November	85.2%
December	89.8%

Table 9

24 inch system energy savings

Month	BTUs Gained with Louvers on	BTUs Saved by Louvers
January	415,940,645	56,719,179
February	276,981,531	84,613,157
March	130,589,130	135,919,298
April	22,116,538	123,387,002
May	0	122,082,688
June	0	119,294,084
July	0	123,092,060
August	0	153,219,248
September	117,346,372	151,796,683
October	270,697,198	143,846,750
November	401,306,872	69,710,583
December	444,973,468	50,542,643
Total	**2,079,951,754**	**1,334,223,375**

Table 10

The total number of BTUs saved per year by the solar louvers is **1,334,223,375** BTUs. Calculating the energy saved in terms of electricity:

1 KWh = 3,413 BTUs

1,334,223,375 BTUs / (3,413 BTUs/KWh) = **390,924 KWh**

With the electricity cost of $0.09/KWh, 390,924 KWh will cost **$35,183** per year.

G.6 BTUs Saved by the 18 inch Louvers

Similar to the 24 inch louvers, the 18 inch louvers are located 8.4 inches above the windows to minimize the sunshine entering the building through the windows. **Table 11** below shows the percentage of the direct sunlight entering the building after installing the 18 inch louvers.

Sunlight percentage on shaded windows by 24 inch louvers

	Morning							Afternoon					
	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00
Jan		100%	100%	97%	93%	91%	89%	88%	88%	90%	95%	100%	
Feb		100%	96%	91%	87%	84%	82%	80%	79%	79%	80%	89%	
Mar		95%	86%	80%	76%	72%	68%	63%	56%	45%	7%		
Apr	40%	57%	55%	52%	48%	41%	30%	10%	0%	0%			
May			0%	0%	0%	0%	0%	0%					
Jun				0%	0%	0%	0%						
Jul			0%	0%	0%	0%	0%	0%					
Aug		0%	20%	27%	24%	16%	0%	0%	0%				
Sep	100%	86%	77%	71%	67%	62%	56%	48%	34%	0%	0%		
Oct		100%	93%	87%	83%	80%	77%	75%	72%	69%	66%	61%	
Nov		100%	100%	95%	91%	89%	87%	86%	86%	87%	91%	100%	
Dec		100%	100%	98%	94%	92%	91%	90%	90%	92%	97%	100%	

Table 11

18 inch system average sunlight

Table 12 on the right shows the average sunlight entering the building per month.

The BTUs gained with the 18 inch louver installed and the BTUs saved by those louvers are in **Table 13** below.

Month	Average Sun
January	91.5%
February	83.4%
March	61.9%
April	31%
May	0%
June	0%
July	0%
August	9.6%
September	52.5%
October	75.8%
November	89.5%
December	92.7%

Table 12

18 inch system energy savings

Month	BTUs Gained with Louvers on	BTUs Saved by Louvers
January	432,247,409	40,412,415
February	301,425,332	60,169,356
March	164,968,717	101,539,711
April	45,106,098	100,397,442
May	0	122,082,688
June	0	119,294,084
July	0	123,092,060
August	14,739,692	138,479,556
September	141,407,762	127,735,294
October	314,265,767	100,278,181
November	421,749,031	49,268,425
December	459,442,539	36,073,573
Total	**2,295,352,347**	**1,118,822,785**

Table 13

The total number of BTUs saved per year by the 18 inch louvers is **1,118,822,785 BTUs**

The energy saved is 1,118,822,785 BTUs / (3,413 BTUs / KWh) = **327,812.1 KWh**

The dollar amount of the saved energy is 327,812.1 KWh x $0.09/KWh = **$29,503** per year

G.7 Solar Shading System Cost:

The cost of the material for the 24 inch louver is way over the cost the material for the 18 inch one. The cost estimate that I received from the distributer includes the louvers and the mounting equipment. The 24 inch louver costs $107.5 per foot while the 18 inch costs $41.5 per foot. This huge difference in the cost is mainly due to the difference in weight, since the 24 inch louver weighs 8.7 lbs/ft while the 18 inch louver weighs 5.7 lbs/ft.

- 24 inch louvers cost:

- louvers and mounting equipment cost:

  2,444 ft x 107.5 $/ft = $262,730

- Labor and installation cost estimate:

  12 $/ft x 2,444 ft = $29,328

- Total cost = **$292,328**

-18 inch louvers cost:

- louvers and mounting equipment cost:

  2,444 ft x 41.5 $/ft = $101,426

- Labor and installation cost estimate:

  11 $/ft x 2,444 ft = $26,884

- Total cost = **$128,310**

G.8 System Payback:

Table 14 and **Table 15** below are the discounted savings values for 24 inch and 18 inch louvers respectively. As calculated previously, the savings per year for the 24 inch system is **$35,183**, while the savings for the 18 inch system is **$29,503** per year.

24 inch system discounted payback

Number of Years	Value of Savings at each Year	Total Value of Savings up to the Specific Year
1	35,183	35,183
2	33829.81	69,013
3	32528.66	101,541
4	31277.56	132,819
5	30074.58	162,894
6	28917.86	191,811
7	27805.64	219,617
8	26736.19	246,353
9	25707.87	272,061
10	24719.11	296,780
11	23768.37	320,549
12	22854.21	343,403
13	21975.2	365,378
14	21130	386,508
15	20317.31	406,825
Number of Years	Value of Savings at each Year	Total Value of Savings up to the Specific Year

Table 14

The 24 inch system will need **10 years** until it can pay off the original cost of the system. 10 years is not a bad period of time to payback a project like this one. But since the system's cost of $292,328 is way higher than the 18 inch system's cost, the 18 inch system might have a shorter payback period.

18 inch system discounted payback

Number of Years	Value of Savings at each Year	Total Value of Savings up to the Specific Year
1	29503	29503
2	28368.27	57871.27
3	27277.18	85148.45
4	26228.06	111376.5
5	25219.29	136595.8
6	24249.32	160845.1
7	23316.65	184161.8
8	22419.86	206581.6
9	21557.55	228139.2
10	20728.42	248867.6
11	19931.17	268798.8
12	19164.59	287963.3
13	18427.49	306390.8
14	17718.74	324109.6
15	17037.25	341146.8
Number of Years	**Value of Savings at each Year**	**Total Value of Savings up to the Specific Year**

Table 15

Although the 18 inch system has a lower savings value of only $29,503 compared to the $35,183 of the 24 inch system, but it was still able to payback in **less than five year.** This advantage is due to the huge difference in the original cost of the two systems.

Due to the short payback period, and the small difference in the energy savings, the 18 inch system is a better choice and will be the one used for the Murur Project.

G.9 Constructability:

The solar shading louvers will be installed floor by floor, from the bottom to the top of the office tower. The installation of the louvers will start at the same time the glass curtain walls are being installed on each floor. Installing the systems this way will not cause delays to the project since both installations will occur at the same time.

The louvers required for each floor will be stored at the floor above it since the louvers should be installed above the window of each floor. Coordination is always an important part of any construction project. Coordinating with the curtain wall installer is the most important coordination the solar louvers' installer should take into consideration.

The louvers' carriers will be mounted between the glass windows of the curtain wall in the floor above. The mounts will be suspended from the floor to the desired height of the louvers which is 0.7 feet above the windows. The mounts will hold the racks which the louvers will be fitted on.

Installing the louvers will be done by the general contractor since the job does not require a specialty contractor. Having the job done by the general contractor will also eliminate further coordination between the different contractors.

Since the chosen louver for the project is the 18 inch louver, the suspended platform will still be usable to clean the glass. 1.5 feet away from the glass is not too far to be able to clean the glass, and the glass suction cups can be used to hold the suspended platform in place in order to clean the glass safely.

Solar louvers are a great way to save energy cost and keep away sunshine heat. The 18 inch system that was examined and analyzed in this report has a reasonable cost and a great payback period of less than 5 years. Maintaining the solar louvers will add a very small extra cost. The same equipment that is already used to clean and maintain the glass curtain wall will be used to maintain the solar louvers, and since they are made of aluminum, they are very durable, with a long life span, and require almost no work to keep it in good condition. Solar louvers can also keep out the annoying direct sunlight which will provide better lighting for the occupied areas. All those advantages make solar shading by aluminum louvers a must do for this project.

H. Analysis 4: Interior Work Prefabrication

H.1 Prefabrication

Prefabrication is gaining a lot of interest in the construction industry lately. Prefabrication has many benefits for any construction project. The main points that can be improved via prefabrication are:

- Time saving
- Labor saving
- Cost saving
- Better quality
- Waste management

Exact time or labor saved, or quality improved through prefabrication cannot be determined for any project. A great example of prefabrication benefits in given by Ian Foster from Truland Industries, one of the items that were prefabricated on the project was the wall rough-in. The total project was 80,000 hours while the wall rough-in accounted for 25% of the project with 20,000 hours. The receptacle boxes were prefabricated and accounted for only 5,000 hours which is 50% of the original time to complete the job. That also resulted in an overall labor saving of about 3%.

Receptacle boxes are a great example for prefabrication. Although it is small in size, it is complicated and need a lot of time. The box itself should be at the exact size needed. There are bolts and wires that need to be fitted. And in the end, the length from the ground to the exact area that the receptacle box should be placed must be measured by the worker. If all that work was done on-site, the worker responsible for this job will need a long time doing them perfectly, and usually the tools are not in hand's reach so the worker has to look for them which wastes more time. Due to the nature of the site, the quality of the work will not be at its best, since many factors will be affecting the site and the worker. After finishing the job on-site, waste will be all around the area, which will affect negatively on the worker himself, and on all the other workers in the same area. The height of the receptacle is already measured in the shop and it will have an extra piece that will be exactly the height intended and the worker will literally only need to kick the receptacle box in its place.

Recycling materials will be very simple when prefabrication is done in a controlled area. Since in a prefabrication shop each item is prefabricated in its own station, different materials will not be mixed with each other and that will make collecting the unused material for recycling easily done. On the other hand, if the same job was done on-site, different unused or unwanted materials will be mixed with each other and they will soon become waste that cannot be useful anymore. Separating all the waste in a job site is almost impossible and the chance of recycling all that material is lost.

H.2 Trip and Experience

In spring 2010 semester, I went on a trip to Washington DC with AE 476 class. We visited both Truland and Southland Prefabrication shops. There are many areas in a construction project that prefabrication can be applied on. On Truland's prefabrication shop there were some small items like receptacle boxes and cables that were cut and prepared exactly for the areas needed on the project. There were also some larger prefabricated items like a 12' trailer that was a temporary transformer ready for any job.

After prefabrication of the several items for a project is completed in the shop, all the items are organized in boxes or trolleys that have their location on the project written on them. Each box or trolley has the floor number, the area, the section, and the exact location where each item has to go to. This makes the whole process of prefabrication and installation much easier and faster since the worker on the site will have all the items needed for the area he is working in and every single item will be exactly the size it should be to fit the intended area.

H.3 Hospital Prefabrication Example

The cover story of ENR September 13, 2010 edition was about prefabricating patient rooms and corridor racks for a hospital in Ohio State. The prefabrication consisted of 178 patient rooms and 120 corridor utility racks which were all prefabricated in a prefab shop of only 18 workers.

The foundation work of the hospital started in May 2008, but stopped on June 1 for 14 weeks due to a discovery of a soil snag that was missed in the soil tests. The prefabrication process did not start until February 2, 2009. Although the prefabrication operation did not start from the beginning of the project, but it was still successful in cutting 2 months off the schedule and save about 2% of the project’s cost.

The workers in the prefab shop were able to work from the floor at bench-height instead of assembling racks from ladders on site. Prefabricating led to a safer work zone with zero injuries among the 18 workers in the prefab shop. Prefabricating also led to better product quality due to the controlled environment in the prefab shop.

Figure 13. Bench-height work

The only problem that this project had is that the prefabrication was faster than expected. The original plan was for just-in-time delivery from the three miles away warehouse that the contractor leased for the prefab units. But the workers produced 8-10 racks per week instead of the expected 3-5 racks per week. The steel structure was still not ready to be received when the warehouse was filled. The company had to lease another warehouse to keep all the units stored in.

If Prefabrication was planned since the start of the project, the savings in time and cost would have been maximized. Members of the project team said that they hope to apply prefabrication on future jobs, and that they learned 2 lessons from this first-time prefabrication experience. The first is that prefabrication should be planned from the onset of the project, not midway through the design development. The second lesson is timing prefabrication production so the product can be shipped to the construction site just-in-time, in order to avoid the cost of storages spaces like what happened in this project with the second warehouse.

H.4 Murur Complex Prefabrication

As previously mentioned, the cost or time saved cannot be known before the project has ended. Ian Foster, from Truland Industries, said that the typical labor savings for the specific activity being prefabricated is 20%-30%. And the time saving can reach up to 50% of the original duration of the single activity that has been prefabricated. I will use an average savings percentage of 25% and will apply that number to the Murur Mixed-use Complex project.

Since Murur Complex is a huge project, and has many repetitive activities, prefabricating items will be very beneficial for the project. In prefabrication, the bigger and more repetitive the work is, the less cost per unit.

The parts that will be prefabricated for the Murur Complex are:

- Receptacle boxes, fully assembled and ready to install
- Raceways and conduit racks for electrical wiring that are preassembled in one piece
- Ducts for ventilation, exactly measured so they can fit with no on-site adjustments
- Plumbing pipes, designed to fit perfectly taking ducts and raceways into consideration
- Conduits that are cut exactly as needed
- Pre-mounted electrical panels

All those different parts will be organized in trolleys while they are in the prefabrication shop. They will be organized based on the location they are going to. Each trolley will have a certain number and letter indicating the floor and section it is going to. Each piece will be numbered so the workers on-site know the exact location that piece should be installed.

H.5 Prefabrication Calculations

In all 3 sections of the project, the Office tower, the Residential tower, and the Mall area, the interior work has the longest activity period of time. The interior work includes wiring, cables, firefighting system, A/C ducts and other activities that can benefit from prefabrication. In each part of the project, the interior work takes more than 400 days to complete. With saving more than 100 days on the job site, and with the interior work being on the critical path, the project completion date can be much sooner.

100 days sooner mean 100 days less work for laborers. Prefabrication itself needs labor to get it done, but prefabrication in the shop needs less than half of the time that was going to be spent on the site to do the same job. Since prefabrication of the items can be done before they are needed, the saving in time would not change, but the savings in labor will. The job in the prefabrication shop needs less than half the time to get the job done, so I will use 50 days. That gives us 50 days of savings in labor. I will assume that about 50 laborers are needed for the different items that will be prefabricated. With that number of workers, the savings are a good percentage.

Prefabrication also takes away a huge amount of waste, which makes less cleaning management required and can save about 30% of the cleaning and waste management bill. The revenue of 100 days has also been calculated assuming 8% per year revenue. All those savings are summarized in **table 16** below

Prefabrication savings estimate

Description	Savings
Time (25% of total time of 400 days)	100 days
Labor (50 x 50 days x 8hr/day x $8/hr)	$160,000
Cleaning and waste management (30% of $309,362 from GC estimate)	$92,808
More recycling material	No $ value
Expected revenue (100 days assuming 8% per year revenue)	3,594,520
Total	**$3,847,328**

Table 16

Murur Project is a 6 working days per week project. 100 less working days mean that the project's completion date will be July 31, 2011 instead of the original November 8, 2011.

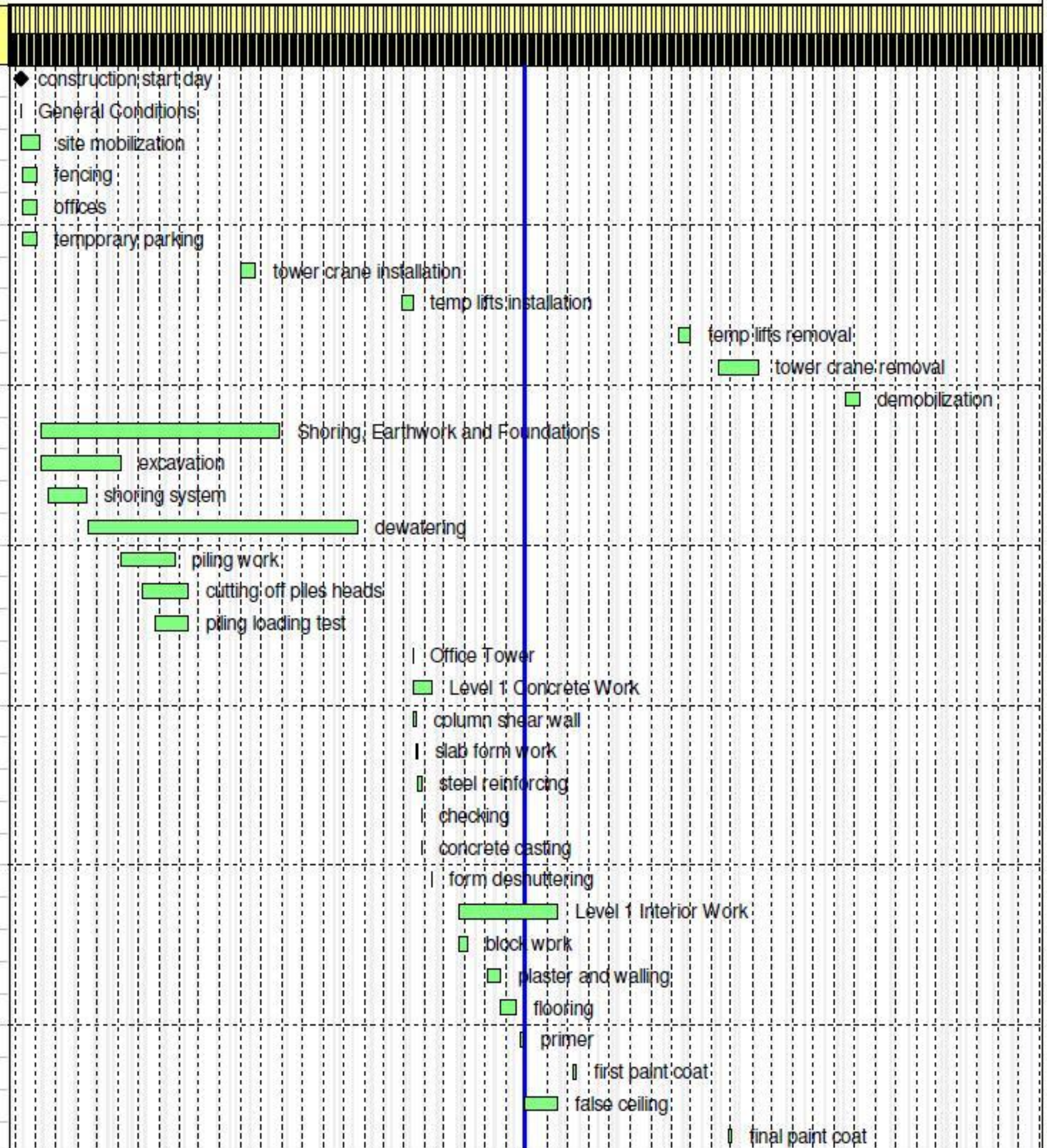
With accelerating the schedule 100 days, and saving more than $3.8 million, prefabrication is a must do for any General Contractor working on a big project such as the Murur Complex. Usually owners are expected to pay a huge number of dollars to expedite the construction process. But in this case, an acceleration of more than 9% is possible with no money spent; in fact, it is done with some savings.

Appendix A

Detailed Project Schedule

Murur

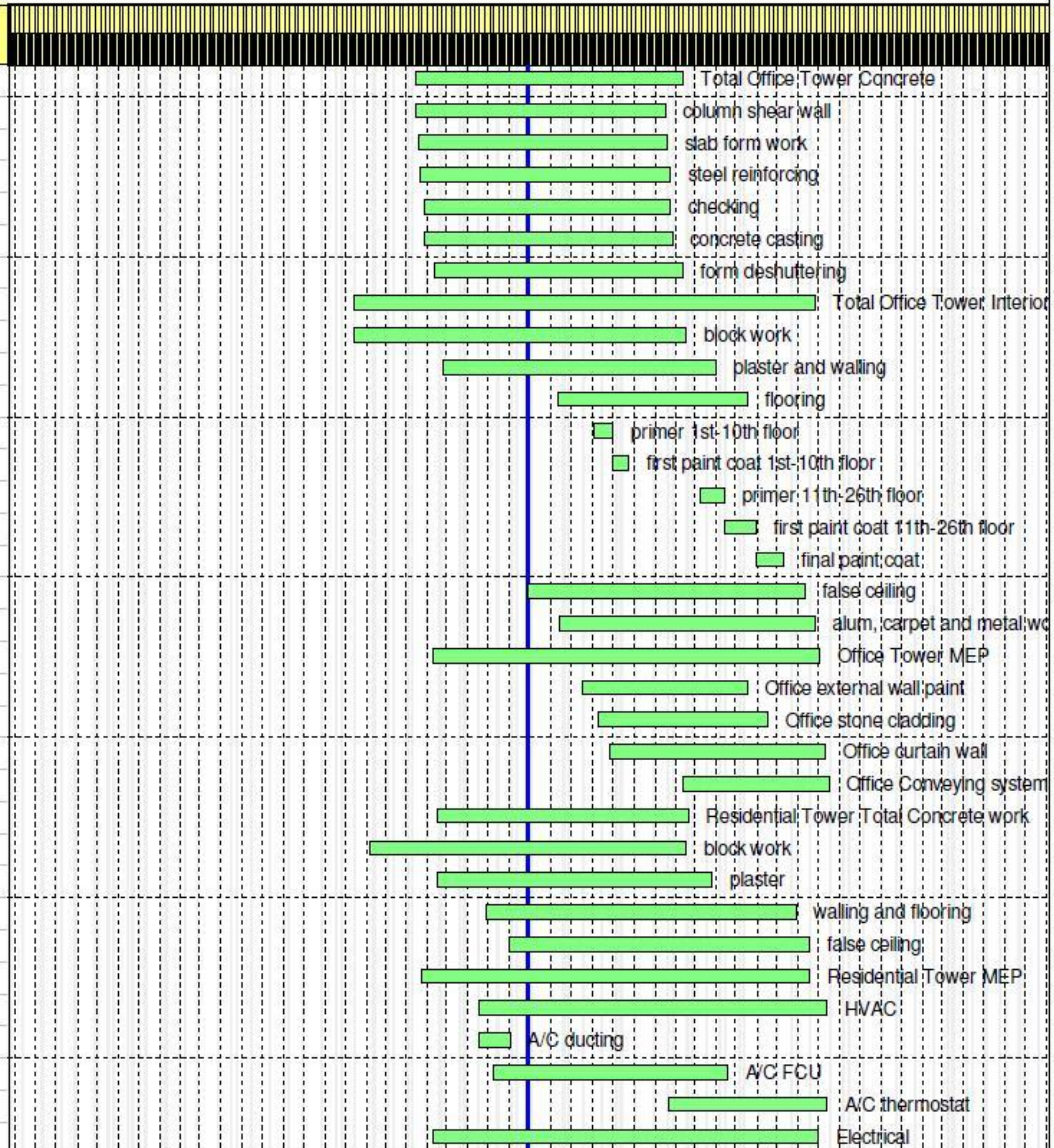
Activity Name	Original Duration	Start	Finish
construction start day	0	09-Jun-08	
General Conditions	0	09-Jun-08	09-Jun-08
site mobilization	26	09-Jun-08	08-Jul-08
fencing	20	11-Jun-08	03-Jul-08
offices	20	11-Jun-08	03-Jul-08
temporary parking	20	11-Jun-08	03-Jul-08
tower crane installation	20	02-May-09	24-May-09
temp lifts installation	15	28-Dec-09	13-Jan-10
temp lifts removal	15	12-Feb-11*	28-Feb-11
tower crane removal	50	12-Apr-11*	08-Jun-11
demobilization	18	19-Oct-11*	08-Nov-11
Shoring, Earthwork and Foundat	299	09-Jul-08	29-Jun-09
excavation	99	10-Jul-08	04-Nov-08
shoring system	51	19-Jul-08	15-Sep-08
dewatering	400	16-Sep-08	23-Oct-09
piling work	64	05-Nov-08	22-Jan-09
cutting off piles heads	57	06-Dec-08	12-Feb-09
piling loading test	42	25-Dec-08	12-Feb-09
Office Tower	0	13-Jan-10	13-Jan-10
Level 1 Concrete Work	25	13-Jan-10	10-Feb-10
column shear wall	3	13-Jan-10	16-Jan-10
slab form work	3	17-Jan-10	19-Jan-10
steel reinforcing	4	20-Jan-10	24-Jan-10
checking	1	25-Jan-10	25-Jan-10
concrete casting	1	26-Jan-10	26-Jan-10
form deshuttering	2	09-Feb-10	10-Feb-10
Level 1 Interior Work	126	23-Mar-10	16-Aug-10
block work	11	23-Mar-10	04-Apr-10
plaster and walling	18	03-May-10	23-May-10
flooring	19	24-May-10	14-Jun-10
primer	6	20-Jun-10	26-Jun-10
first paint coat	6	07-Sep-10*	13-Sep-10
false ceiling	44	27-Jun-10*	16-Aug-10
final paint coat	5	27-Apr-11*	02-May-11



Actual Work | Critical Remaining Work | Sum... | Remaining Work | Milestone

TASK filter: 2 Week Lookahead.

Activity Name	Original Duration	Start	Finish
Total Office Tower Concrete	338	13-Jan-10	10-Feb-11
column shear wall	316	13-Jan-10	16-Jan-11
slab form work	316	17-Jan-10	19-Jan-11
steel reinforcing	317	20-Jan-10	24-Jan-11
checking	314	25-Jan-10	25-Jan-11
concrete casting	314	26-Jan-10	26-Jan-11
form deshuttering	315	09-Feb-10	10-Feb-11
Total Office Tower Interior	581	15-Oct-09	24-Aug-11
block work	420	15-Oct-09	17-Feb-11
plaster and walling	346	22-Feb-10	31-Mar-11
flooring	242	10-Aug-10*	18-May-11
primer 1st-10th floor	25	03-Oct-10*	31-Oct-10
first paint coat 1st-10th floor	20	01-Nov-10*	23-Nov-10
primer 11th-26th floor	30	10-Mar-11*	13-Apr-11
first paint coat 11th-26th floor	40	14-Apr-11*	30-May-11
final paint coat	35	31-May-11*	10-Jul-11
false ceiling	352	27-Jun-10	10-Aug-11
alum, carpet and metal work	323	14-Aug-10*	24-Aug-11
Office Tower MEP	491	08-Feb-10	03-Sep-11
Office external wall paint	211	15-Sep-10*	18-May-11
Office stone cladding	216	09-Oct-10*	16-Jun-11
Office curtain wall	274	26-Oct-10*	10-Sep-11
Office Conveying system	185	12-Feb-11*	14-Sep-11
Residential Tower Total Concrete	316	16-Feb-10	19-Feb-11
block work	400	08-Nov-09	17-Feb-11
plaster	348	15-Feb-10	27-Mar-11
walling and flooring	392	27-Apr-10	27-Jul-11
false ceiling	381	01-Jun-10	18-Aug-11
Residential Tower MEP	490	24-Jan-10	17-Aug-11
HVAC	441	17-Apr-10	12-Sep-11
A/C ducting	41	17-Apr-10	02-Jun-10
A/C FCU	299	08-May-10	20-Apr-11
A/C thermostat	201	22-Jan-11*	12-Sep-11
Electrical	489	07-Feb-10	30-Aug-11

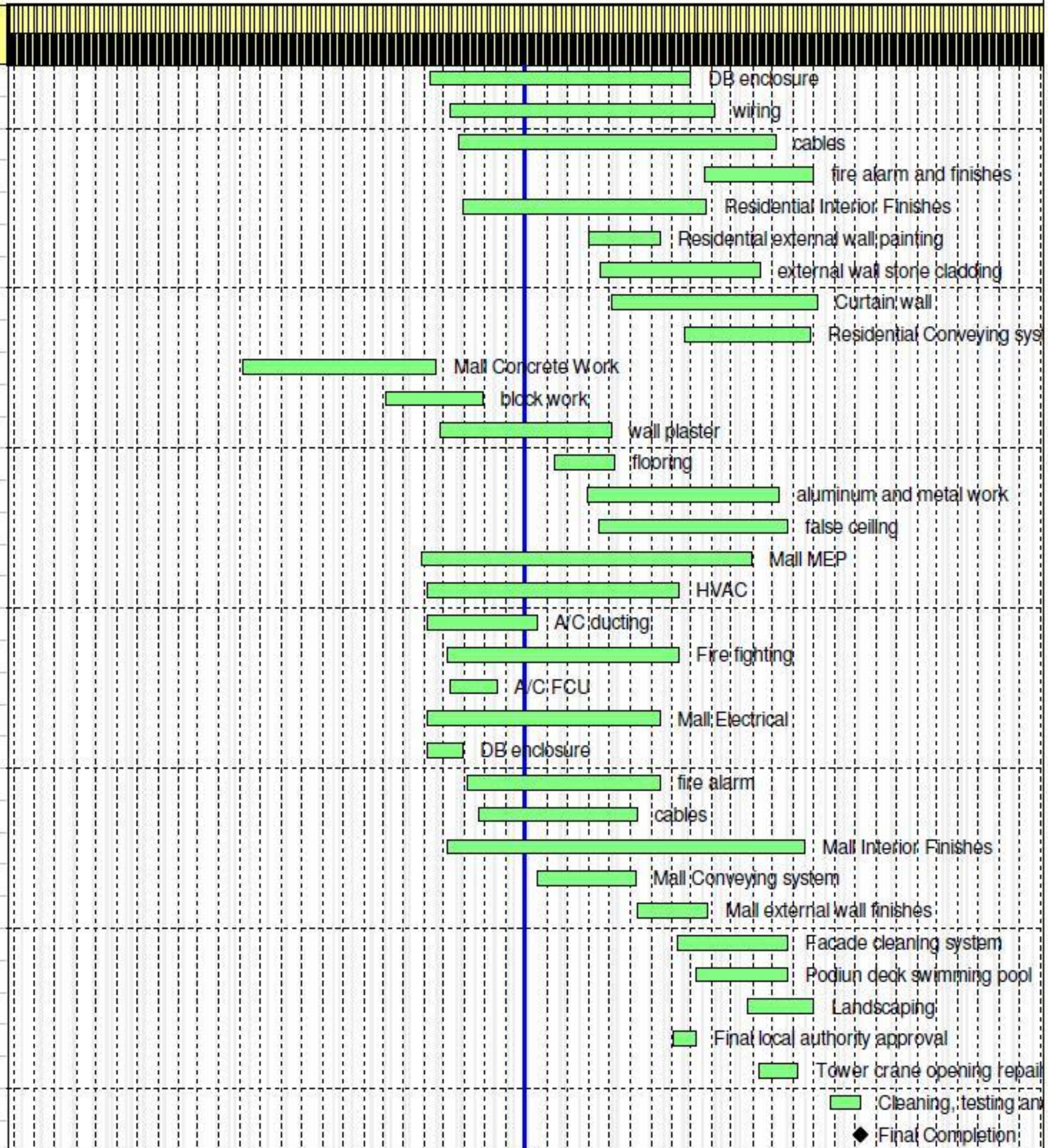


Actual Work | Critical Remaining Work | Sum...
Remaining Work | Milestone

TASK filter: 2 Week Lookahead.

Murur

Activity Name	)riginal uration	Start	Finish
DB enclosure	333	07-Feb-10	01-Mar-11
wiring	336	10-Mar-10	05-Apr-11
cables	402	24-Mar-10	05-Jul-11
fire alarm and finishes	140	21-Mar-11*	30-Aug-11
Residential Interior Finishes	311	28-Mar-10	24-Mar-11
Residential external wall painting	91	30-Sep-10*	13-Jan-11
external wall stone cladding	203	18-Oct-10*	11-Jun-11
Curtain wall	261	04-Nov-10*	04-Sep-11
Residential Conveying system	160	20-Feb-11*	24-Aug-11
Mall Concrete Work	246	06-May-09	17-Feb-10
block work	125	05-Dec-09	28-Apr-10
wall plaster	220	22-Feb-10	04-Nov-10
flooring	78	10-Aug-10*	08-Nov-10
aluminum and metal work	243	29-Sep-10*	09-Jul-11
false ceiling	241	16-Oct-10*	23-Jul-11
Mall MEP	420	25-Jan-10	29-May-11
HVAC	319	04-Feb-10	10-Feb-11
A/C ducting	139	04-Feb-10	15-Jul-10
Fire fighting	294	06-Mar-10	10-Feb-11
A/C FCU	60	11-Mar-10	19-May-10
Mall Electrical	296	04-Feb-10	15-Jan-11
DB enclosure	44	04-Feb-10	27-Mar-10
fire alarm	246	04-Apr-10	15-Jan-11
cables	201	21-Apr-10	11-Dec-10
Mall Interior Finishes	456	06-Mar-10	18-Aug-11
Mall Conveying system	126	15-Jul-10*	08-Dec-10
Mall external wall finishes	90	12-Dec-10*	26-Mar-11
Facade cleaning system	140	10-Feb-11*	23-Jul-11
Podiun deck swimming pool	117	10-Mar-11*	24-Jul-11
Landscaping	85	24-May-11*	30-Aug-11
Final local authority approval	30	03-Feb-11*	09-Mar-11
Tower crane opening repair work	50	09-Jun-11*	06-Aug-11
Cleaning, testing and handing ov	40	24-Sep-11*	08-Nov-11
Final Completion	0		08-Nov-11

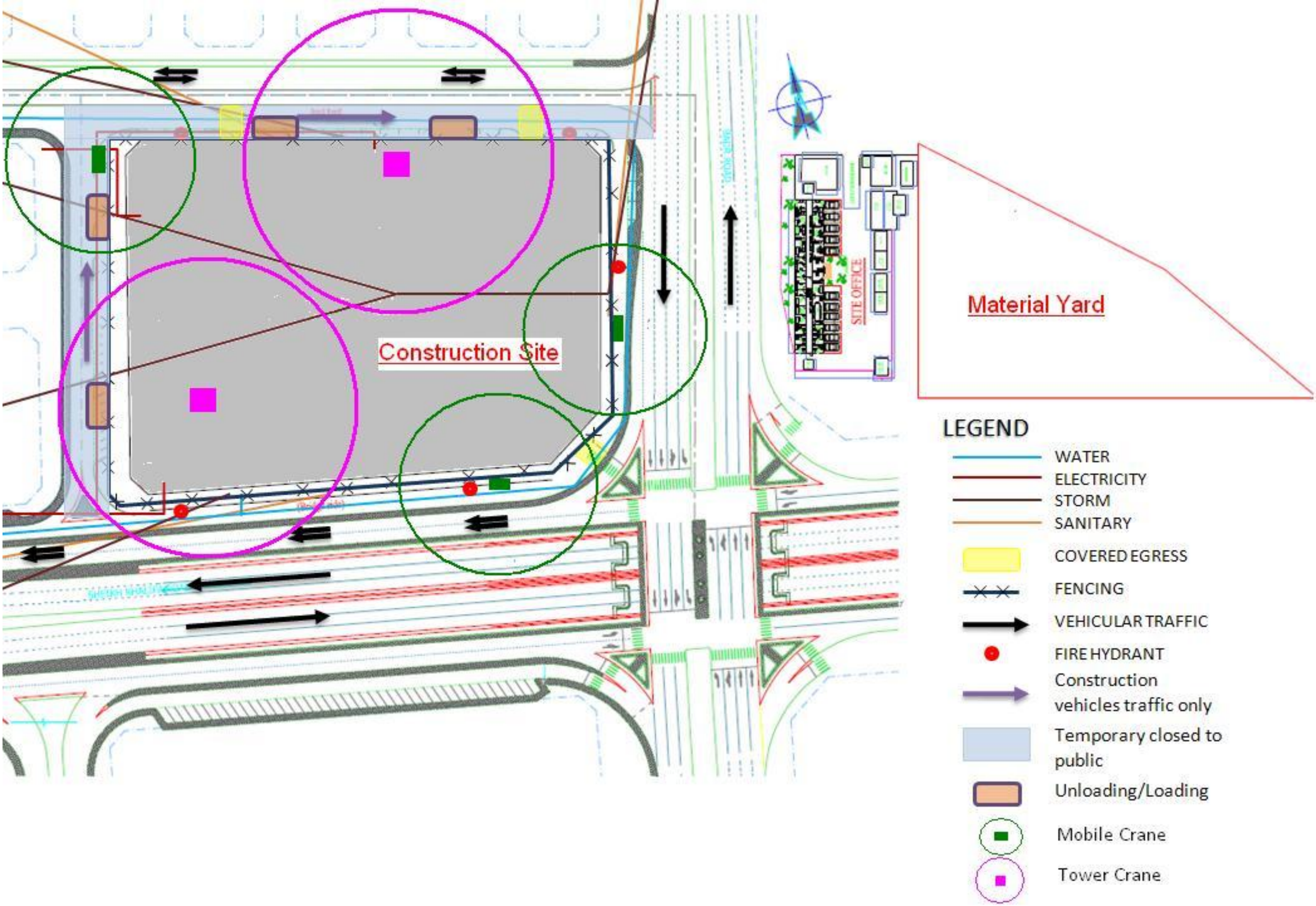


Actual Work | Critical Remaining Work | Sum...
Remaining Work | Milestone

TASK filter: 2 Week Lookahead.

Appendix B

Superstructure Phase Site Plan



0 75 ft 150 ft 300 ft
Scale

Murur Mixed-use Complex
Superstructure Phase Site Plan

Hamad Alrahmani
Construction Management

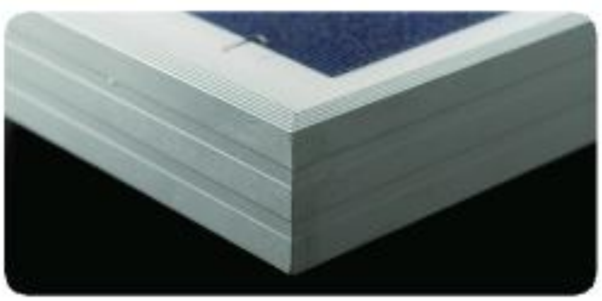
Appendix C

Yingli Solar Panels Data Sheet

YINGLI SOLAR

Power Your Life

YL235P-29b SERIES



* In compliance with our Warranty Terms and Conditions

OUR COMPANY

Yingli Solar is a vertically integrated manufacturer of solar photovoltaic modules. Under one roof we manufacture our ingots, wafers, cells and modules. This ensures that we can tightly control our material and production quality, offering our customers leading product durability and sustainable performance backed by our 25 year limited power warranty*.

PERFORMANCE

» High efficiency, polycrystalline solar cells with high transmission and textured glass deliver a module series efficiency of up to 14.4%, minimizing installation costs and maximizing the kWh output of your system per unit area.

» Power tolerance of +/-3%, minimizing PV system mismatch losses.

QUALITY & RELIABILITY

» Robust, corrosion resistant aluminium frame independently tested to withstand wind loads of 50 psf ensuring a stable mechanical life for your modules.

» Take confidence in our modules with a 5 year limited product warranty and a 25 year limited power warranty*.

» Modules protected by box during transportation and with 20 modules in a box on-site waste is minimized.

» Modules independently tested to ensure compliance with certification and regulatory standards.

» Manufacturing facility certified to ISO9001 Quality Management System standards.

WARRANTIES

5-year limited product warranty*
Limited power warranty*: 10 years at 90% of the minimal rated power output, 25 years at 80% of the minimal rated power output

QUALIFICATIONS & CERTIFICATES

IEC61215, IEC61730, UL1703, Class C Fire Rating, ISO9001

YL235P-29b SERIES

ELECTRICAL PARAMETERS

Electrical parameters at STC (1000 W/m², 25°C, AM 1.5G according to EN 60904-3)						
Module type		YL235P-29b	YL230P-29b	YL225P-29b	YL220P-29b	YL215P-29b
Power output, P_{max}	[W]	235.0	230.0	225.0	220.0	215.0
Power output tolerances	[%]	+/- 3	+/- 3	+/- 3	+/- 3	+/- 3
Module efficiency	[%]	14.4	14.1	13.8	13.5	13.2
Voltage at Pmax, V_{mpp}	[V]	29.5	29.5	29.5	29.0	29.0
Current at Pmax, I_{mpp}	[A]	7.97	7.80	7.63	7.59	7.41
Open-circuit voltage V_{oc}	[V]	37.0	37.0	36.5	36.5	36.0
Short-circuit current I_{sc}	[A]	8.54	8.40	8.28	8.15	8.10
Max. system voltage	[V]	UL: 600 V DC ; IEC: 1,000 V DC				
Max. series fuse rating	[A]	15				

THERMAL PARAMETERS

NOCT (Nominal Operating Cell Temperature)	[°C]	46 +/- 2
Temperature coefficient of the short-circuit current I_{sc}	[% / °C]	+ 0.06 +/- 0.01
Temperature coefficient of the open-circuit voltage V_{oc}	[% / °C]	- 0.37 +/-0.02
Temperature coefficient of the MPP power P_{mpp}	[% / °C]	- 0.45 +/- 0.05
Temperature coefficient of the MPP voltage V_{mpp}	[% / °C]	-0.49 +/- 0.02
Temperature coefficient of the MPP current I_{mpp}	[% / °C]	-0.05 +/- 0.01

MECHANICAL PARAMETERS

Dimensions (length / width / thickness [in])	65.0 / 39.0 / 2.0
Weight [lbs]	43.7
Junction box (protection degree / number of diodes)	IP65 / 6
Junction box dimensions (length / width / thickness [in])	6.0 / 4.8 / 1.0
Positive USE-2 cable (length [in] / AWG)	47.2 / 12
Negative USE-2 cable (length [in] / AWG)	47.2 / 12
Plug connector (type / protection degree)	MC4 Locking Connector (UV Resistant) / IP65
Front cover (material / thickness [mm])	Tempered glass / 3.2mm
Cell type (quantity / technology / length / width [in])	60 / Polycrystalline / 6.14 x 6.14
Frame (material / color)	Robust anodized aluminum alloy / Silver

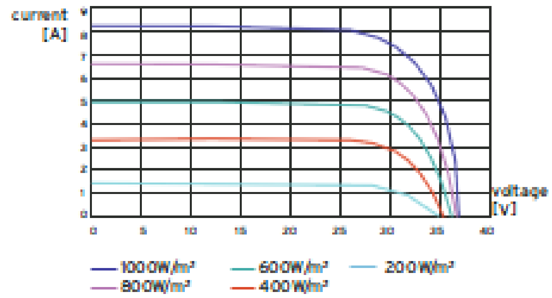
OPERATING CONDITIONS

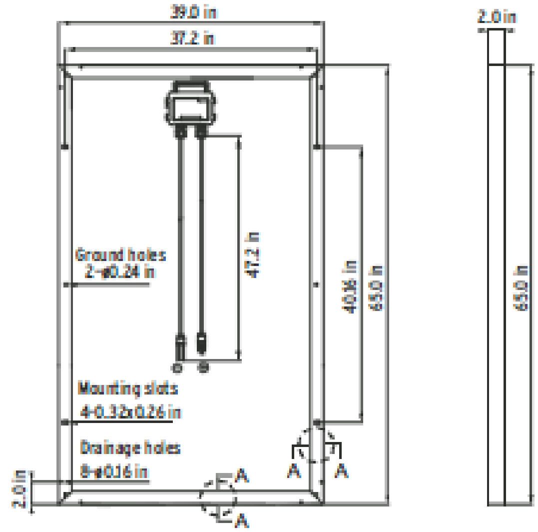
Operating temperature [°C]	-40 to +90
Max. wind load [psf]	50
Max. snow load [psf]	113

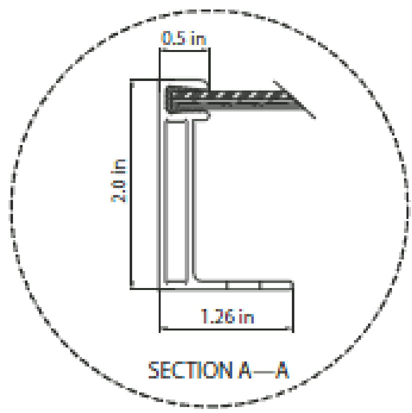
PACKAGING

Number of modules per pallet box	20
Box size (length / width / depth [in])	70 / 44 / 40
Box weight [lbs]	917

I-V CURVES







Solar modules are electrical generating equipment, and should only be handled or installed by professionals. Read the instruction manual in its entirety before handling, installing, and operating Yingli modules.

Yingli Green Energy Americas, Inc.
us-info@yinglisolar.com
Tel: +1 (888) 686-8820

Specifications included in this datasheet are representative values and serve only for comparisons of different module types. Specifications are subject to change without notice.

DS-YL235P-29b-SERIES-US-EN-201001-v01

YINGLI SOLAR
Power Your Life

Appendix D

Solectria PVI 3000 Inverter

Grid-Tied PV Inverters

PVI 3000 PVI 4000 PVI 5000 PVI 5300

a breakthrough in efficiency and quality

- top CEC efficiency
- DC disconnect
- string combiner
- quick-mount bracket
- lightweight
- 10 year warranty
- powerful LCD display
- latest UL1741/IEEE1547
- universal 240/208VAC
- positive ground option
- transformer isolation
- free PC software and RS232&485 parts
- detachable DC wiring box

Solectria introduces the PVI 3000/4000/5000/5300 inverter: exceptional quality and efficiency with more standard features.

Product Information

INVERTER SPECIFICATIONS

Input

	PVI 3000	PVI 4000	PVI 5000	PVI 5300
Continuous Power @240 VAC	3050W	4100W	5150W	5575W
@208 VAC	2840W	3580W	4520W	4840W
Recommended Max. PV @240 VAC	3600W	4900W	6200W	6700W
Array Power, STC Rating @208 VAC	3400W	4300W	5400W	5800W
MPPT Voltage Range	200V-550 VDC	200V-550 VDC	200V-550 VDC	200V-550 VDC
Maximum Input Voltage	600 VDC	600 VDC	600 VDC	600 VDC
Strike Voltage	235 VDC	235 VDC	235 VDC	235 VDC
Maximum Input Current	16 A	20 A	25 A	25 A
Maximum Short Circuit Current	24 A	24 A	30 A	30 A
Fused Inputs	3	4	4	4

Output

	PVI 3000	PVI 4000	PVI 5000	PVI 5300
Continuous Power @240 VAC	2900W	3900W	4900W	5300W
@208 VAC	2700W	3400W	4300W	4600W
Voltage Range @240 VAC	212-264 VAC	212-264 VAC	212-264 VAC	212-264 VAC
@208 VAC	184-228 VAC	184-228 VAC	184-228 VAC	184-228 VAC
Frequency	60Hz Range: 59.3-60.5Hz	60Hz Range: 59.3-60.5Hz	60Hz Range: 59.3-60.5Hz	60Hz Range: 59.3-60.5Hz
Continuous Current	13 A	16.3 A	20.7 A	22.1 A
Output Current Protection	15 A	20 A	25 A	25 A
Max. Backfeed Current	0 A	0 A	0 A	0 A
Power Factor	Utility, >99%	Utility, >99%	Utility, >99%	Utility, >99%
THD	<3%	<3%	<3%	<3%
Efficiency Peak @240 VAC	96.7	96.7	96.7	96.6
@208 VAC	96.4	96.5	96.4	96.3
CEC Efficiency @240 VAC	96	96	96	96
@208 VAC	95.5	95.5	96.0	95.5

General

	PVI 3000	PVI 4000	PVI 5000	PVI 5300
Enclosure	Rainproof, NEMA 3R			
Housing Material	Painted aluminum			
Ambient Temperature Range	-25ºC to +55ºC			
Cooling	Convection	Convection and fan assist		
Weight	47 lb (21.4 kg)	48 lb (21.8 kg)	58.5 lb (26.6 kg)	60 lb (27.4 kg)
Size (L x W x H)	29.75 in x 17.75 in x 6.75 in (741mm x 454mm x 175mm)		29.75 in x 17.75 in x 8.27 in (741mm x 454mm x 210mm)	
Wire Sizes	14 to 6 AWG input and output connections			
Standards	UL1741/IEEE1547, IEEE1547.1, ANSI62.41.2, FCC part 15 B			
Warranty	10 years standard			

INDUSTRY LEADING FEATURES

- *Highest efficiency tranformer isolated inverters in the industry, 96% CEC, full line!*
- *Fuly integrated with DC disconnect, 3 or 4 fuse combiner and detachable DC wiring box.*
- *Easy installation with low weight (47-60 lb) with quick-mount bracket feature, and universal 240/208 VAC operation.*
- *High reliability, 10 year warranty and certification to latest UL1741/IEEE1547.*
- *Free PC software and both RS232&485 communication ports.*

SOLECTRIA RENEWABLES

Lawrence, Massachusetts

USA

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E-mail: inverters@solren.com

www.solren.com

Appendix E

Nysan Aerofoil Louvers Data Sheet

Aerofoil (fin) louvers deflect thermal gain from incident sun, integrating light control into the building envelope. Well designed louver configurations can be as striking as they are effective, shading the façade against low or high sun angles while also making an aesthetic statement.

As with any system, design considerations such as louver size and composition affect performance:

- Single piece extruded Nysan aerofoil louvers from 4" (100mm) to 24" (600mm) tip to tip
- Extruded louvers are more durable, while fabricated designs can include perforation to modify their performance
- Louver shapes, composition, and finish also can be used to create specific daylighting effects as well as establishing a different aesthetic

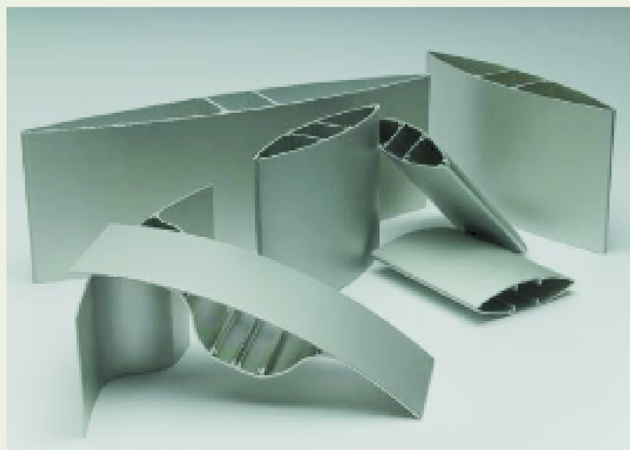
Sun-louver systems incorporate three basic elements:

- Louvers to provide shading incorporating fin and end caps
- For operable louvers, an operating strip that adjusts louver orientation
- Brackets and frame that fix the system to the facade

Aerofoil Features:

- Fabricated Nysan louvers can be created at nearly any size
- Aerofoil composition is typically metal *(aluminum or steel)*, but many other options exist, including glass and wood *(see custom, page 13)*
- Nysan metal louvers typically have an anodized aluminum finish to ensure long product life and minimal maintenance. Other finishes include polyester powder coating and fluoropolymer painting. All resist damage due to sun or weather

Left:
Project: Biodesign Institute at ASU, Phase 1, Tempe, AZ
Architect: Gould Evans and Lord, Aeck & Sargent Architecture
Dealer: HCI Resources
Product: Internal 5" Motorized Aerofoil Louvers



EXTRUDED SUN LOUVER:

Extruded sun louvers are single piece extrusions available in a wide range of shapes and profiles. The advantage to single piece extrusion is they are less susceptible to environmental damage caused by freeze/thaw cycles and maintain consistency and shape over large spans and show substantially less staining and streaking after years of exposure.

FABRICATED SUN LOUVER:

Fabricated sun louvers include any louver which is made up from a series of sections or pieces. Advantages of a fabricated louver are the ability to include perforations, different materials (glass, timber) and large or irregular shapes.

The façade orientation in relation to the sun also determines the optimal configuration:

- Louvers are typically specified horizontally for south-facing elevations and can be positioned to provide optimal shading at a particular sun angle
- On eastern and western elevations, by contrast, louvers are configured vertically to provide shading at lower sun angles

Nysan Aerofoil System Features

- Optional Nysan SolarWare™ software models the progression of sun angles to ensure optimal configuration and performance of the louver system
- Louvers can project horizontally out above the glazing when mounted in a panel (brise soleil) configuration (see next page)
- Nysan louver and mounting systems are engineered to withstand loads from wind and snow/ice, and can be designed for easy removal when necessary

BUILDING ORIENTATION:

Building Orientation refers to the physical facades of the building in orientation to proper compass points (N, E, S, W).

SUN ANGLE:

The position of the sun is determined from two angles – the altitude angle and the azimuth angle. The altitude angle indicates the height of the sun in the sky; the azimuth angle indicates how far the sun is from due north/south.

Appendix F

Average Monthly Window Solar Heat Gain

Monthly heat gain obtained from the windows heat gain tool from www.susdesign.com

Monthly Heat Gain	
Units	BTU / FT^2 / month
January	26,449
February	20,639
March	16,062
April	8,977
May	7,314
June	7,033
July	6,784
August	8,786
September	16,205
October	24,287
November	26,740
December	26,870
Latitude	25
Surface	Default
Ground Reflectance	0.2
Window Orientation	10° East of South
Window	Double Glazed
Window SHGC	0.65
Units	BTU / FT^2 / month