Saving The Black Gold

Optimizing Energy Performance in A Typical Existing Residential Apartment Building In Jeddah, Saudi Arabia

The thesis will test and analyze how much energy can be saved by applying energy conservation measures arrived through passive analyses first, and then through energy simulation in a typical existing residential apartment building in Jeddah, Saudi Arabia. This simulation will model the results of one building in Jeddah, and then the results can be implemented in similar buildings throughout Jeddah.

++Thesis Statement

1-Understand the changeable passive strategies through the building performance analyses.

2-Idientify the passive strategies to minimize the energy consumption in lieu of more efficient active strategies.

3- Establish energy conservation measures that are realistically achievable.

++Goals

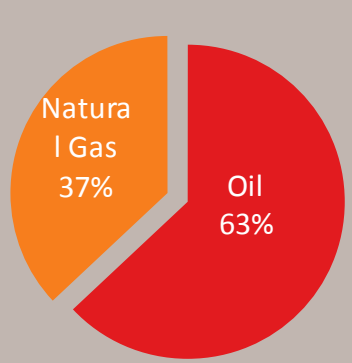
++Location

Around 40% of the Saudi Electrical Company's costumers In the western Province.

Jeddah is the largest city in the Western province and the 2nd Largest city in The Kingdom of Saudi Arabia.

++Explore > Generate > Consume

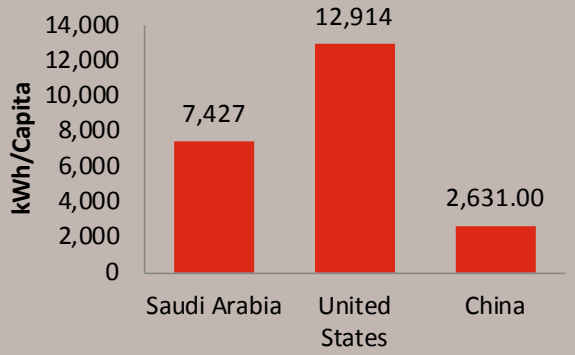
Fuel Type used in Electricity Production in 2011



The total generated amount of electricity in Saudi Arabia in 2011

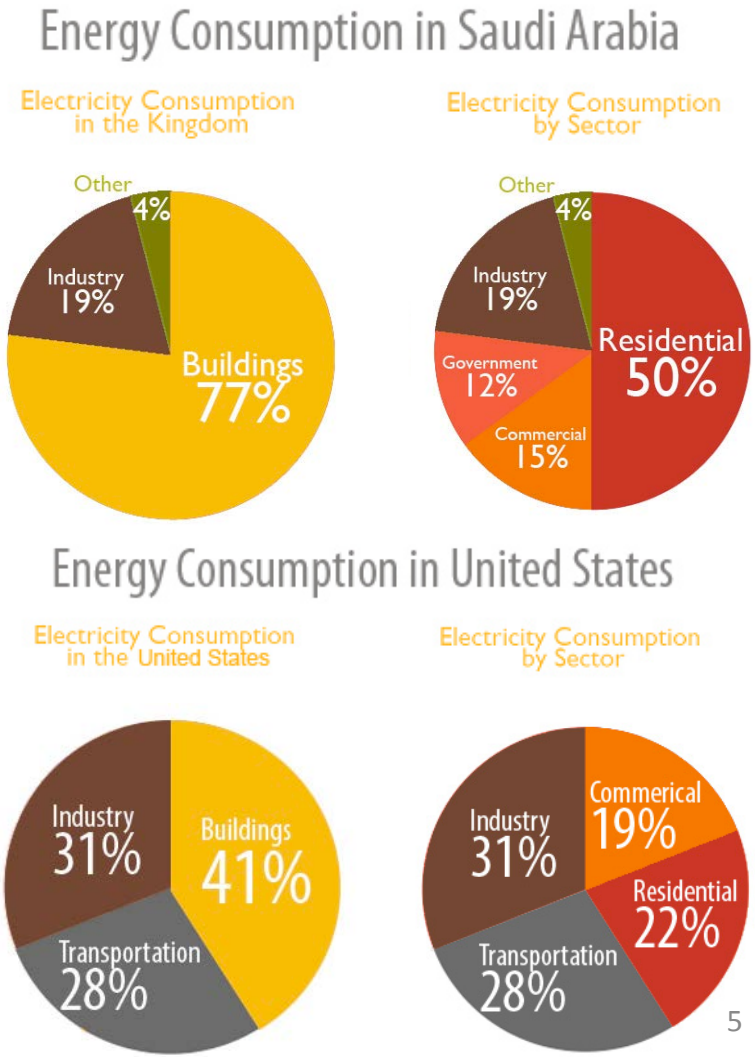
190,000 GWh

Electricity consumption/capita 2009



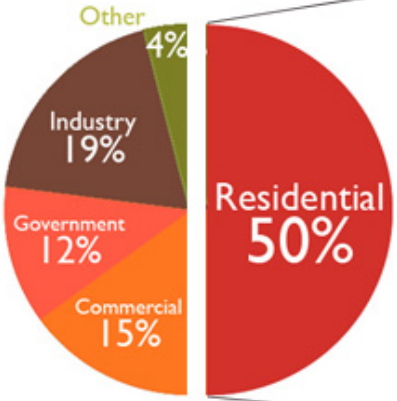
++Why Residential Buildings??

Residential buildings in Saudi Arabia consume 50% of the country's electricity

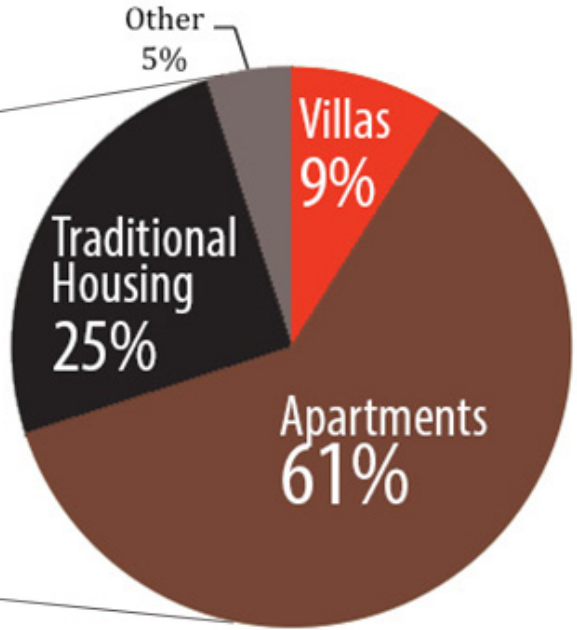


++Why Apartments??

Electricity Consumption by Sector



Housing Type Breakdown in Jeddah City



The Major Factor in Electricity Consumption

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The Climate

++Factors in Electricity Consumption

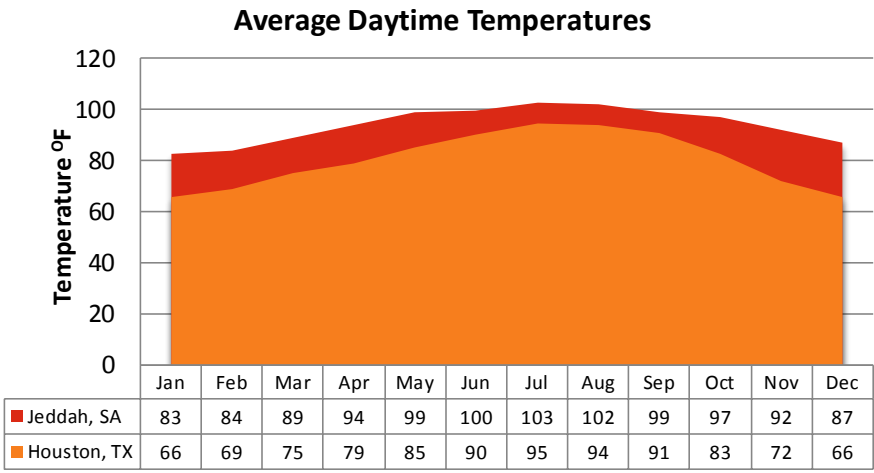
1-The Climate

	Jeddah Saudi Arabia	Houston, TX United States
Highest Temperature	125.6°F 52°C	109 °F 43 °C
Average Temperature	Jul 103 F	Jul 95 F
Precipitation	Zero In 2011, 1.1 in	50 in
Humidity	58%	77%

Summer in Saudi Arabia

8 Months

March until October



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jeddah, SA	83	84	89	94	99	100	103	102	99	97	92	87
Houston, TX	66	69	75	79	85	90	95	94	91	83	72	66

++Factors in Electricity Consumption

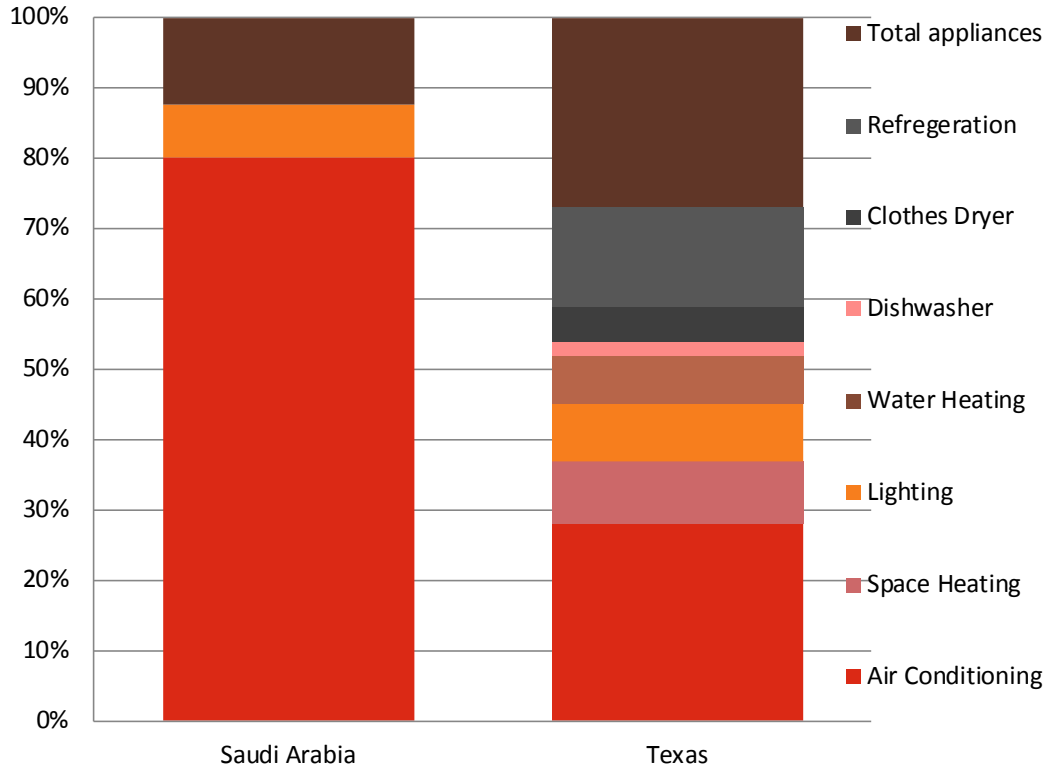
1-The Climate

80%

of the household electricity consumption is by **Air Conditioning**

The average A/C working hours in Saudi Arabia is between **16-17** hours and **24** hours in some cases.

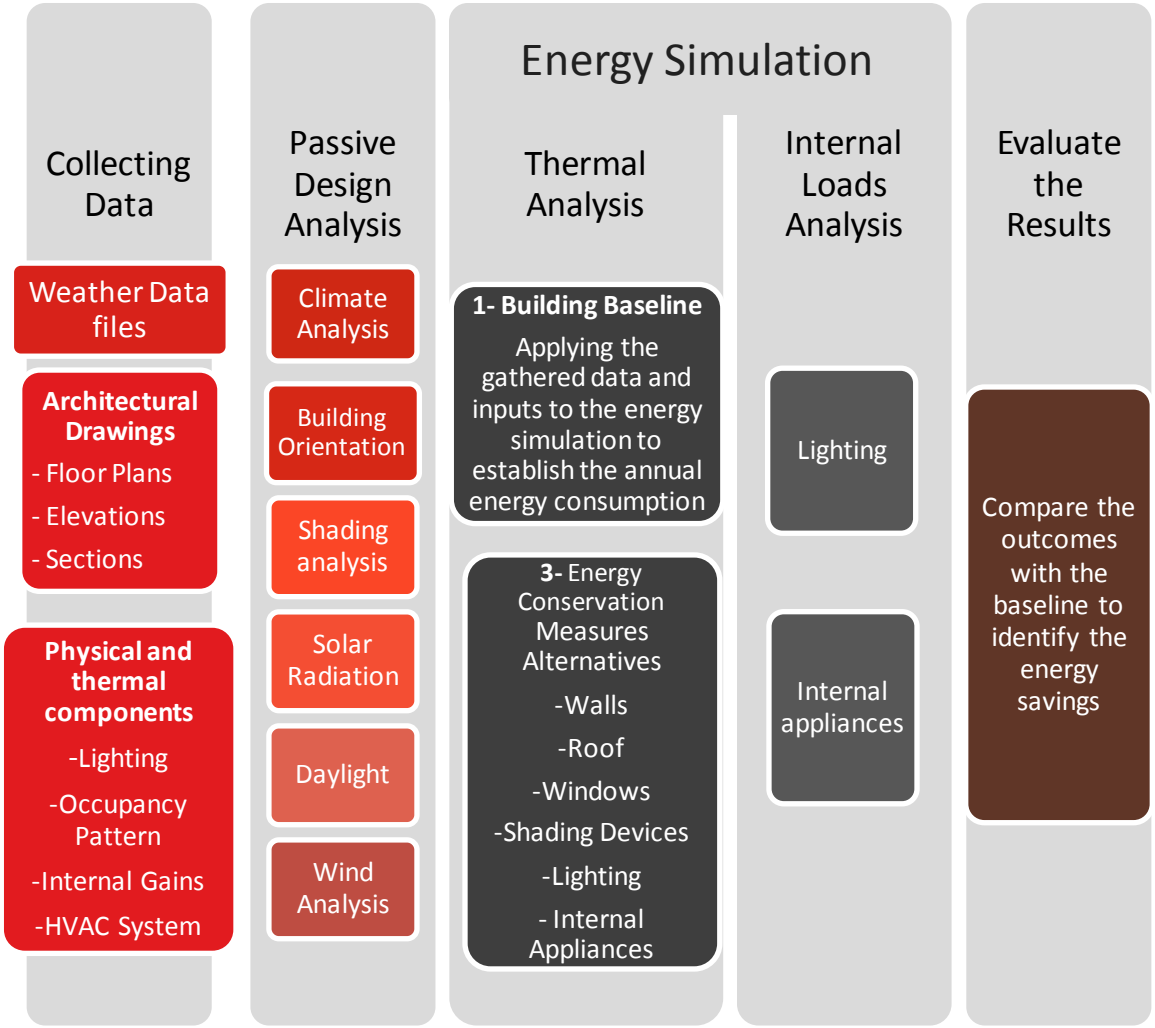
While cooling and heating in Texas is **9** hours



Household End-Use Comparison between Saudi Arabia and Texas

Methodology^{++}

++Methodology

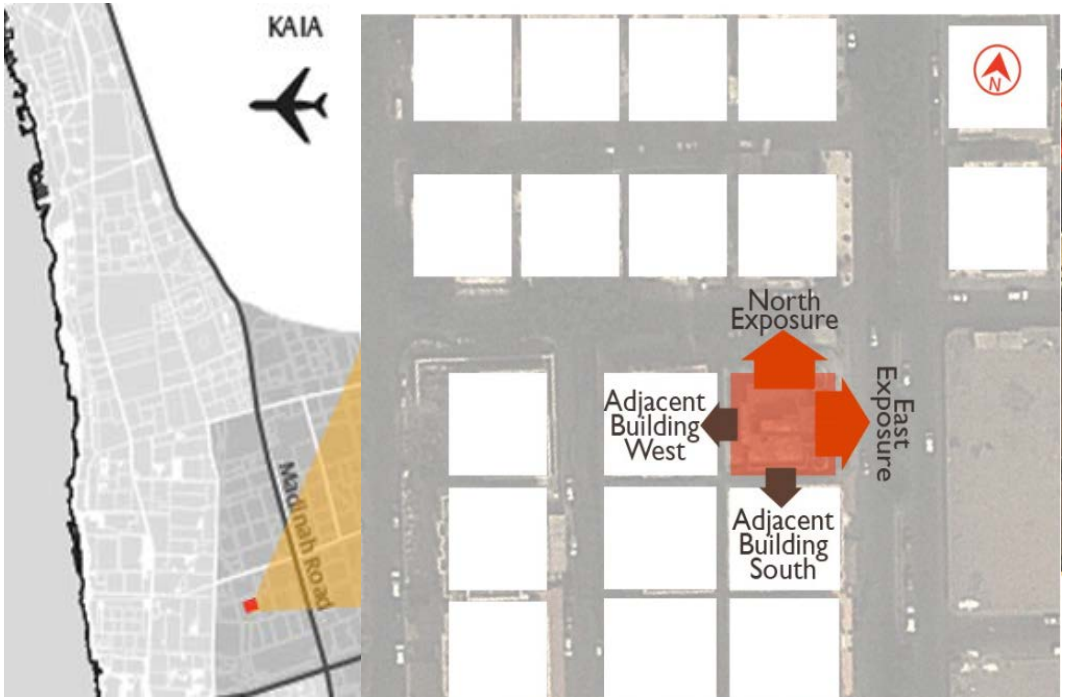


The Studied Building++

++The Studied building

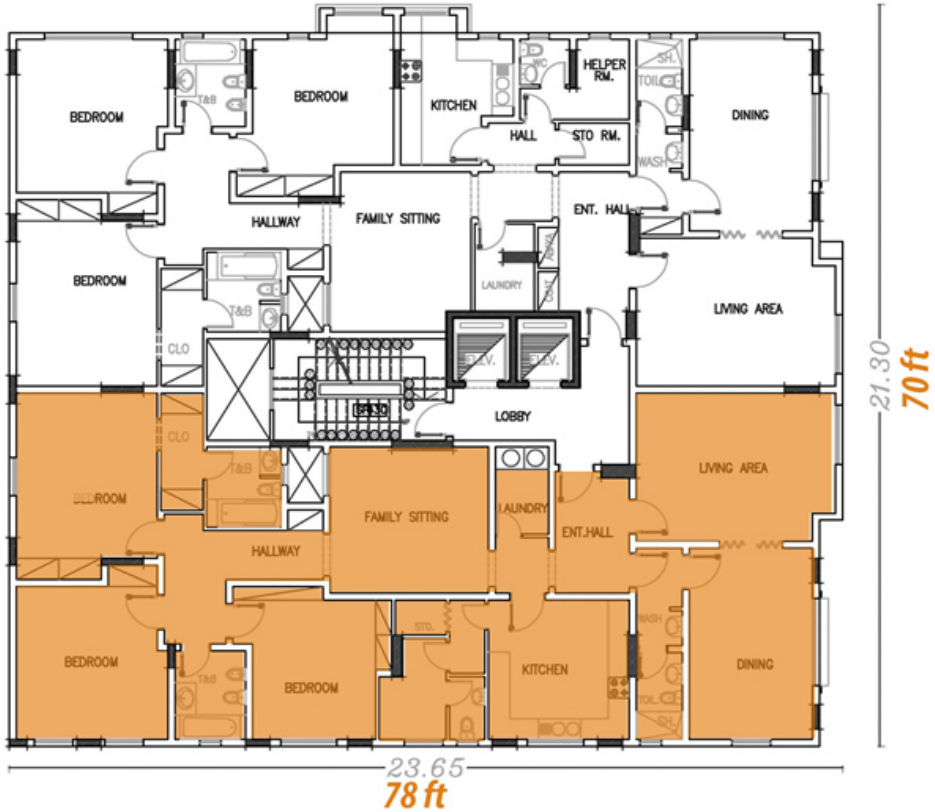
1-Building Description

Type	Description
Number of Floors	6 floors 1st-4th Floors: 8 apartments (two apartment/floor) 5th-6th Floors: 1 penthouse
Number of Units	Apartment: 8 Penthouse: 1
Unit Area	Apartment: 240 m^2 (2580 sf) Penthouse: 550 m^2 (5,920sf)

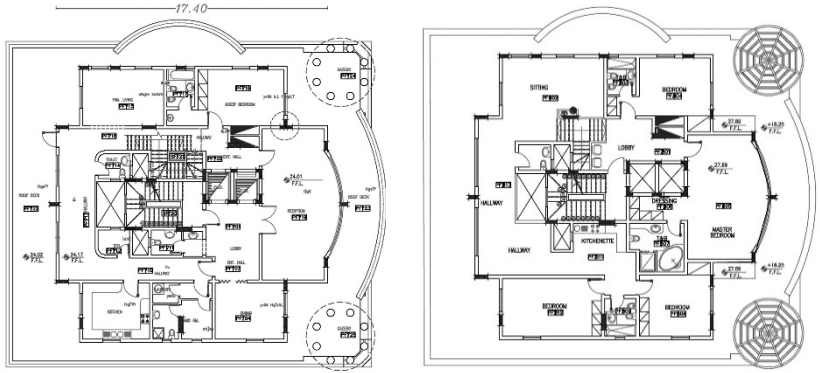


++The Studied building

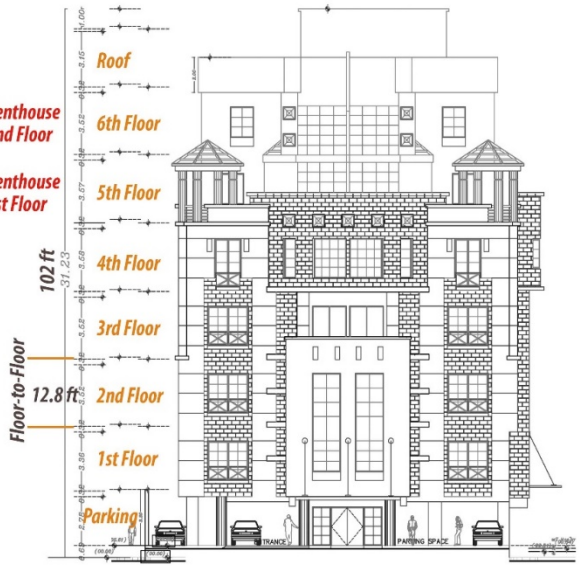
2-Architectural Drawings



1st -4th Typical Floor Plan



Penthouse 1st Floor

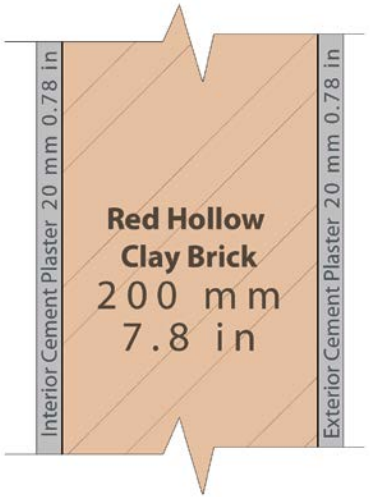


East Elevation

++The Studied building

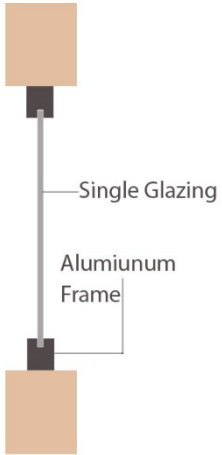
3-Building Construction Assembly

Wall Assembly



Roof Assembly

Windows Assembly

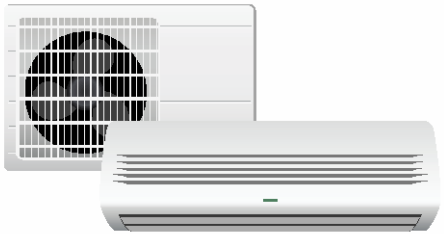


++The Studied building

4- HVAC System

HVAC

System



Single Room Cooling System

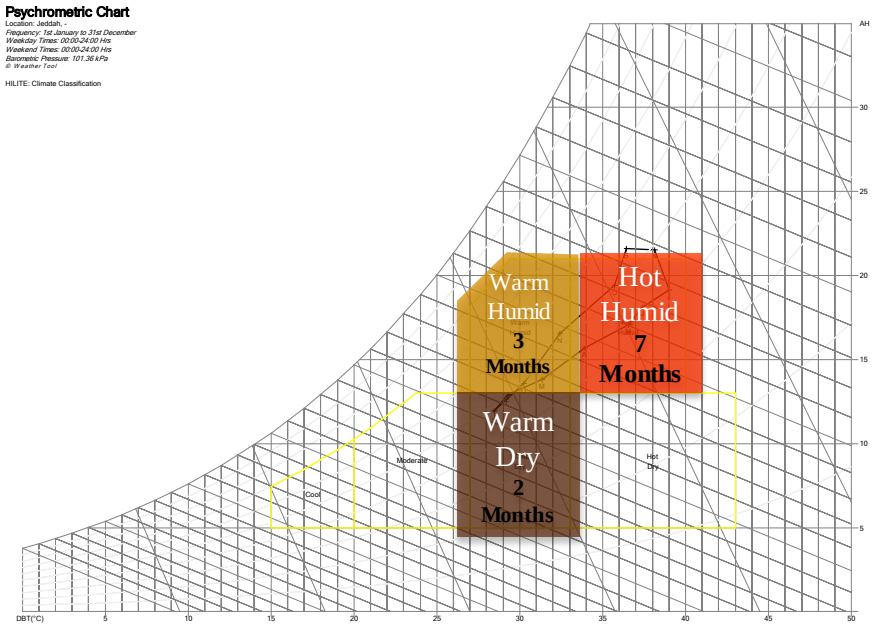
Electrical Heat Pump

Passive Design Analysis++

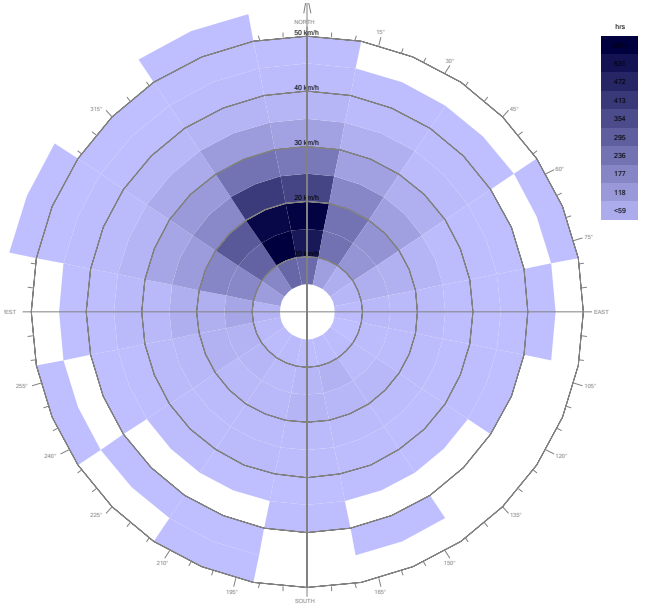
++Climate Analysis

1-Climate Classification

2-Wind Analysis



Wind Analysis



Passive Design Analysis ++

[Best Orientation]

++Best Orientation

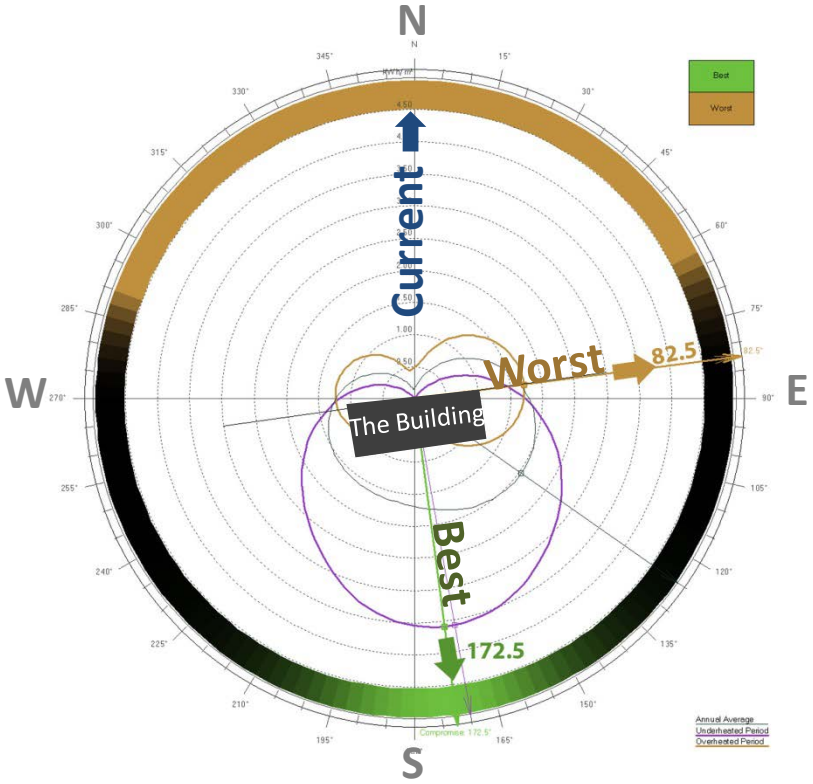
Best & Worst

Annual solar radiation collection of

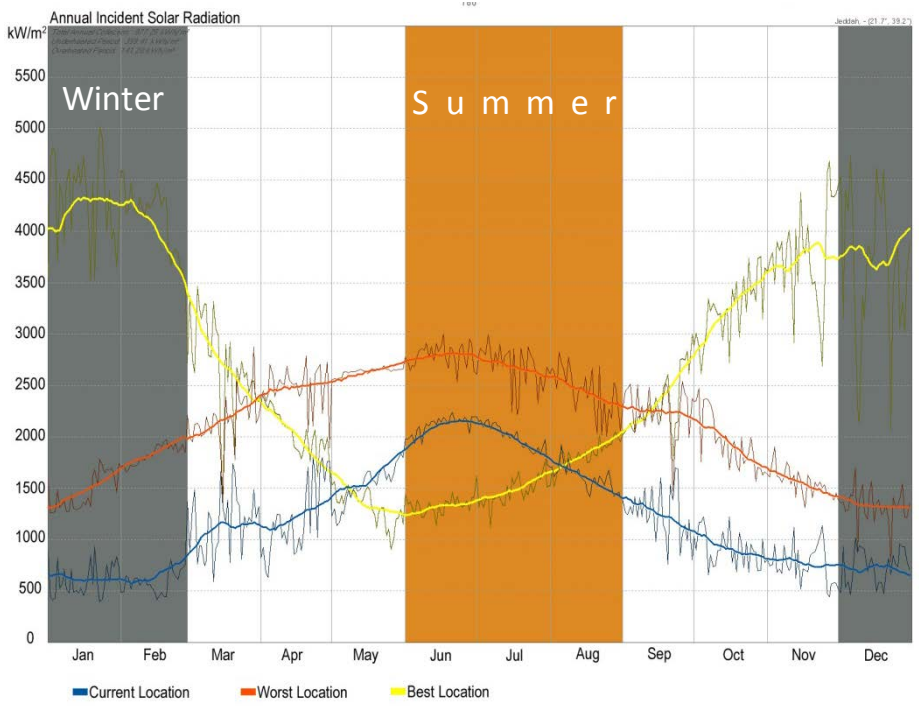
Suggested Best Orientation: 978.75 kWh/m²

Suggested Worst Orientation: 790.5 kWh/m²

Studied building Orientation: 442.8 kWh/m²



Best and Worst Orientation



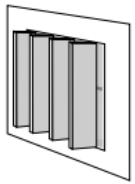
Annual Incident Solar Radiation Comparison

Passive Design Analysis++

[Shading & Solar Radiation Analysis]

++ Solar Radiation Analysis

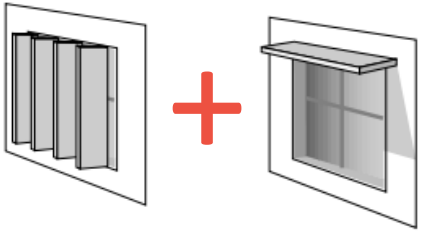
Shading Strategies

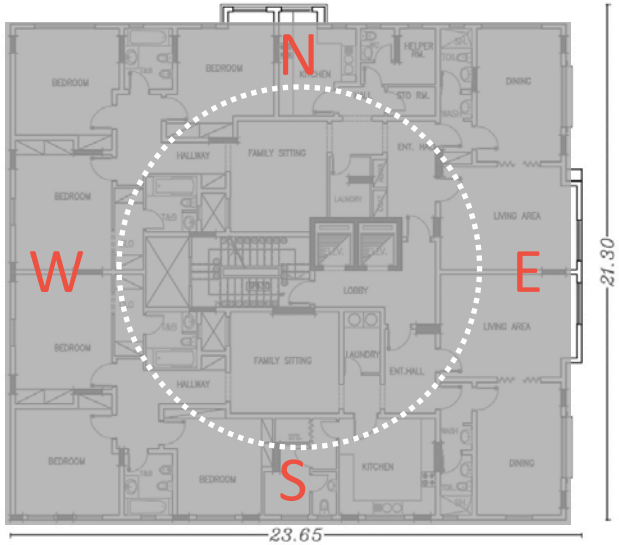


Vertical fins: useful on north to block early morning and late afternoon low sun.

Vertical fins: best on East.

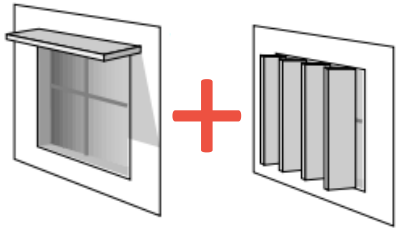
Overhang useful on the east and west.



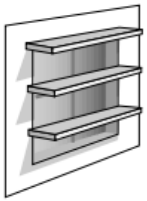


Overhang useful on the east and west.

Vertical fins: best on west.



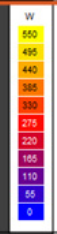
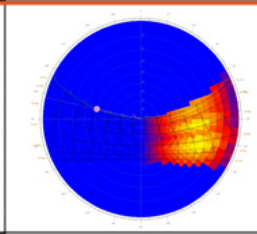
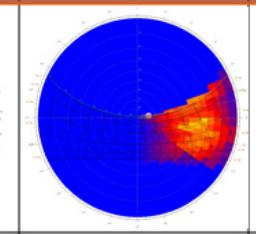
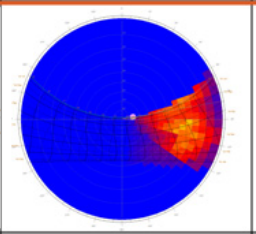
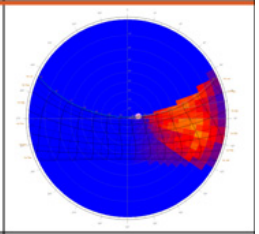
Horizontal Louvers: best on south



++ Solar Radiation Analysis

Shading and Incident solar radiation Analysis

This analysis was applied for each façade on the 4th floors to identify what type of shading devices were suitable for the building.

East Facade	Baseline		Strategy 1	Strategy 2	Strategy 3
Windows Shading analysis 4th Floor	Windows Baseline 		30° tilted Vertical Fins 300mm (11.8in) 	30° tilted Vertical Fins + One Horizontal Louver 300mm (11.8in) 	30° tilted Vertical Fins 300mm (11.8in) + One Horizontal Louver 500mm (19.7in) 
Stereographic Diagram 					
Annual Average Shade	52%		67%	71%	73%
Brightest day 16thFebruary	7:00am-12:00pm	58%	80%	81%	81%
	13:00am-17:00pm	100%	100%	100%	100%
Hottest day 19th June	6:00am-12:00pm	0%	9%	24%	30%
	13:00am-18:00pm	100%	100%	100%	100%
Total Annual Incident Solar Radiation	568 kWh/m2		411 kWh/m2	376 kWh/m2	349 kWh/m2
Total Solar Transmitted	402 kWh/m2		291 kWh/m2	266 kWh/m2	247 kWh/m2

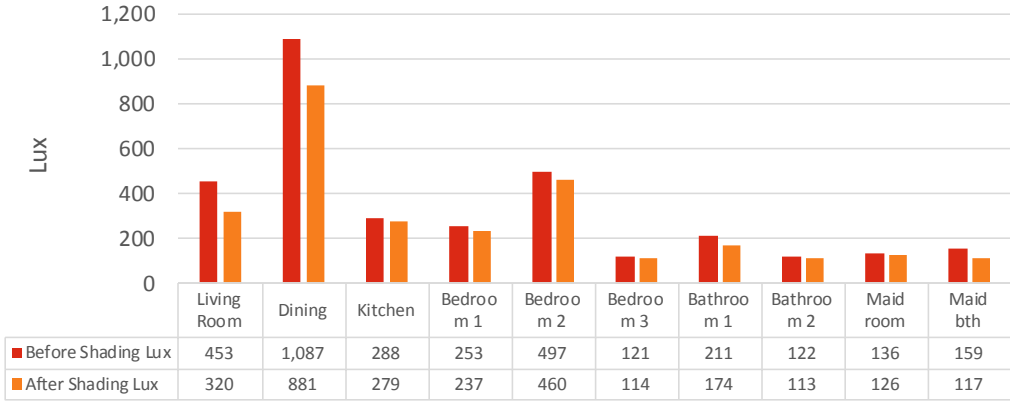
Passive Design Analysis ++

[Daylight Analysis]

++ Daylight Analysis

The 1st and the 4th floors were analyzed to identify if the internal spaces are receiving enough daylight, and the effect of the shading devices on these floors.

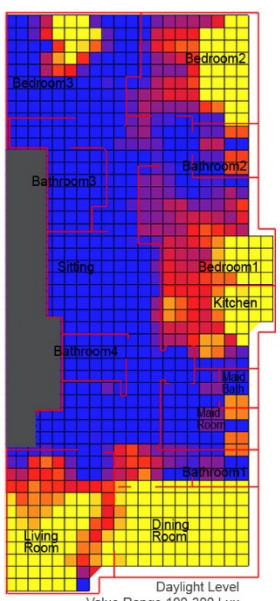
All the internal spaces that have access to daylight receive a sufficient amount. The amount of daylight either falls within the recommended illumination level (100-200 lux) (10-20 fc) or under the useful daylight level (2000lux) (200fc)



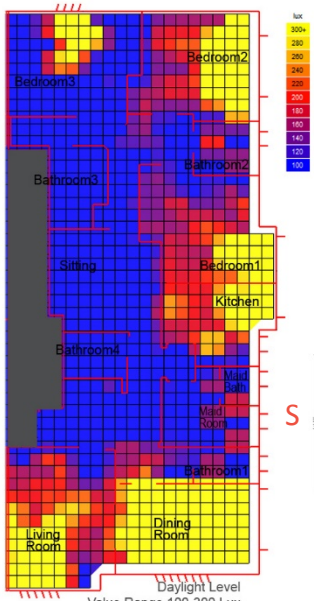
	Living Room	Dining	Kitchen	Bedroom 1	Bedroom 2	Bedroom 3	Bathroom 1	Bathroom 2	Maid room	Maid bth
Before Shading Lux	453	1,087	288	253	497	121	211	122	136	159
After Shading Lux	320	881	279	237	460	114	174	113	126	117

Activity	Recommended Illumination	
	lux	*foot-candles*
Parking lots / sidewalks at night	20 - 50	2 - 5
Warehouses, Homes, Lobbies, Restrooms, General office	100 - 200	10 - 20
Computer work, Laboratories, Reading & writing (good copies, high contrast), Simple inspection, Materials handling	500	50
Supermarkets, General mechanical / electronics work	750	75
Drafting / drawing work, Detailed mechanical / electronics work, Detailed inspection, Surgery	1,000	100
Detailed drafting / drawing, Precision mechanical / electronics work	1,500 - 2,000	150 - 200
Very lengthy and precise visual tasks with low contrast	2,000 - 10,000	200 - 1,000

Illuminating Engineering Society



Before Applying Shading Devices



After Applying Shading Devices

[Energy Simulation]

Thermal Analysis

Cooling Loads

Autodesk Ecotect

Internal Loads Analysis

Lighting Loads
Electrical Appliances

Open Studio
Energy Plus

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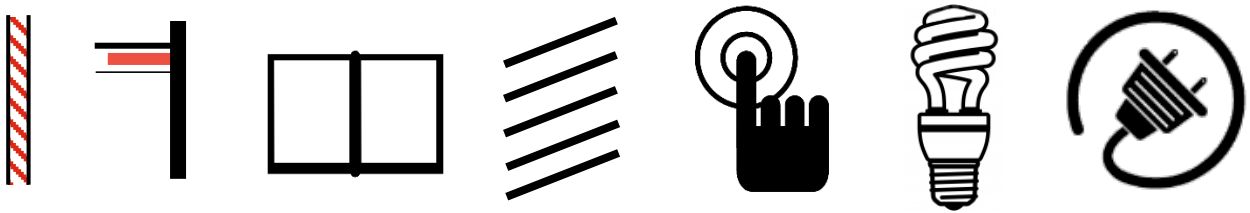
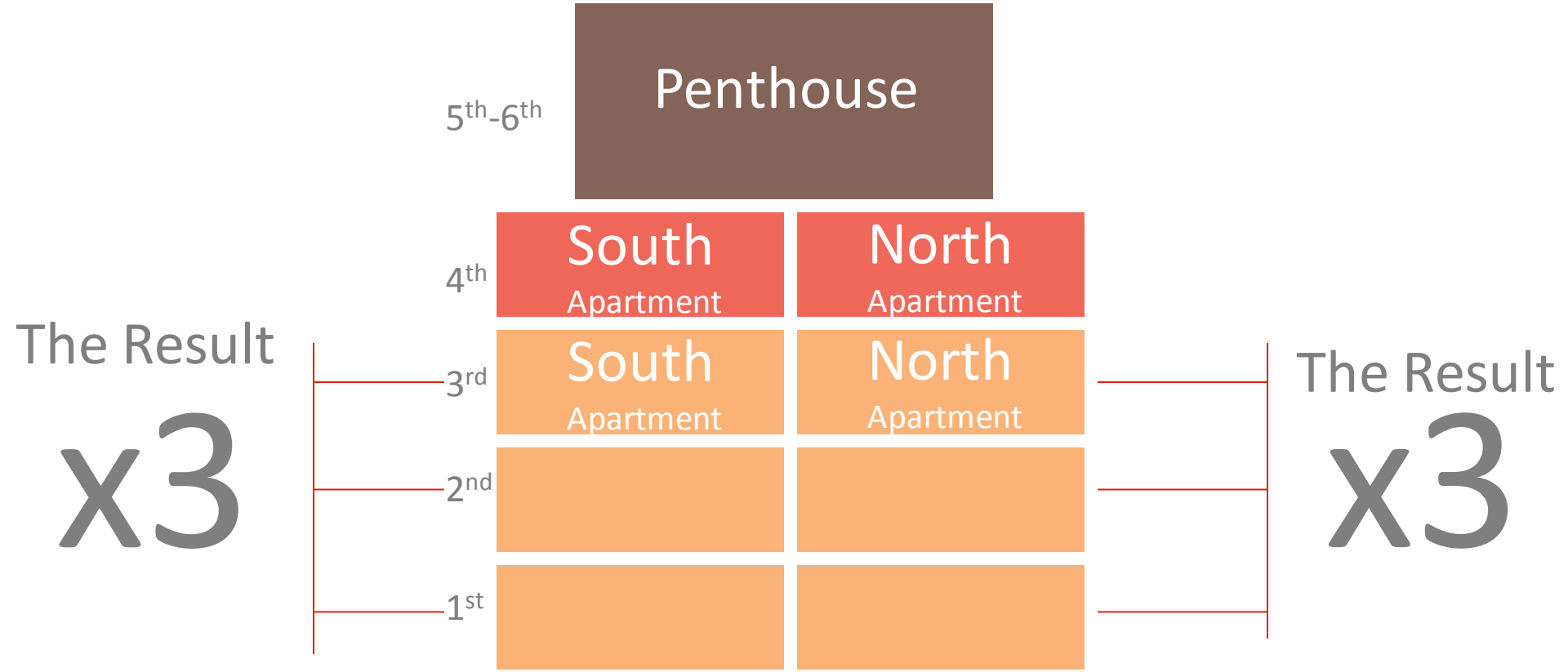
[Thermal Analysis]

Building Baseline
Energy Conservation Measures

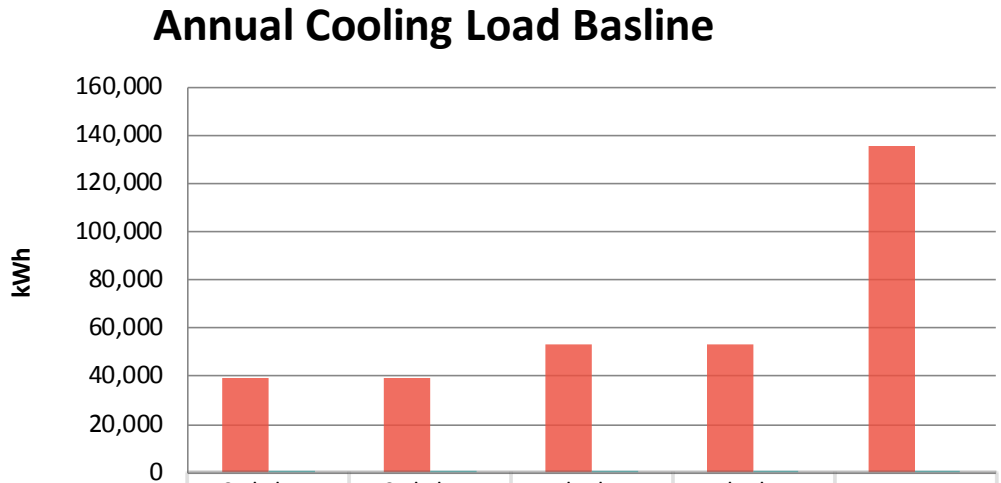


++Calculation Process



++Thermal Analysis

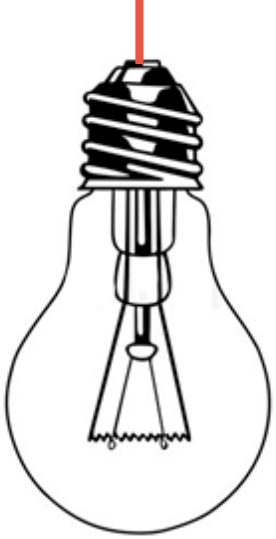
Building Baseline



	North Apt. 1st-3rd Floors	South Apt. 1st-3rd Floors	4th Floor North Apt.	4th Floor South Apt.	Penthouse
kWh	117,219	118,221	53,242	53,502	135,563
Total Building Cooling Load - kWh	477,747				

++Thermal Analysis

Heat Gains

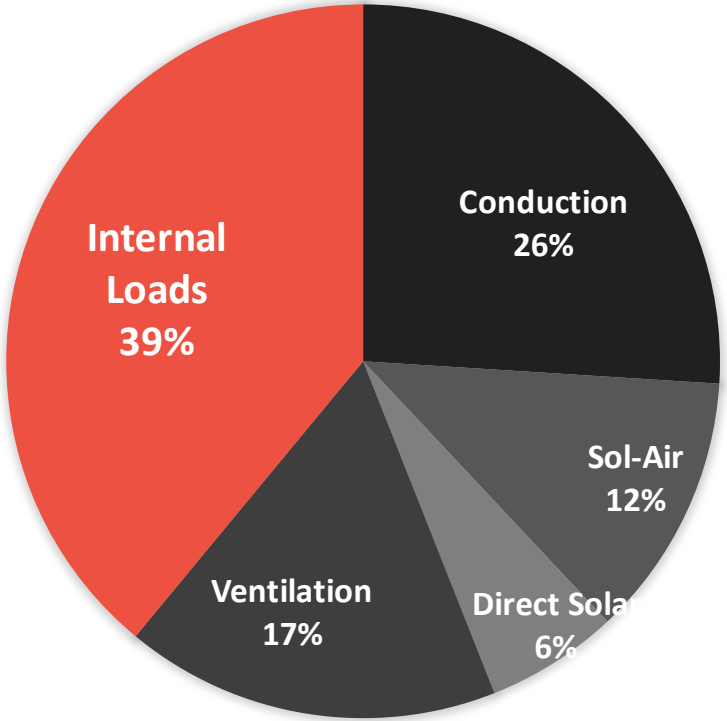


The major source of heat

Internal Loads

39%

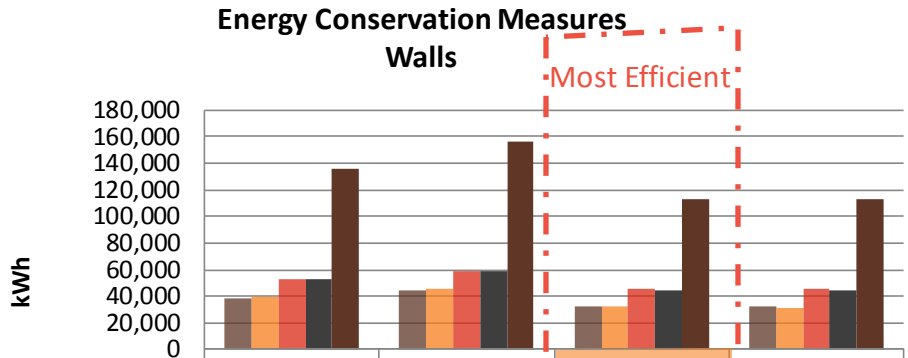
Annual Heat Gains Breakdown



++Thermal Analysis

Energy Conservation Measures

Walls



	(Baseline) Red Clay Brick	(Alt 1) Concrete Block	(Alt 2) Red Clay Brick with 50mm Extruded Polystyrene	(Alt 3) Red Clay Brick with 75mm Extruded Polystyrene
3rd Floor North Apt	39,073	44,332	32,692	32,497
3rd Floor South Apt	39,407	45,625	31,977	31,754
4th Floor North Apt	53,242	58,695	46,115	45,946
4th Floor South Apt	53,502	59,219	44,629	44,423
Penthouse	135,563	156,610	113,382	112,854

Most Efficient Wall Measure

(Alt 2) Insulated Red Clay Brick Wall with 50mm Extruded Polystyrene-Type 1

Total Savings

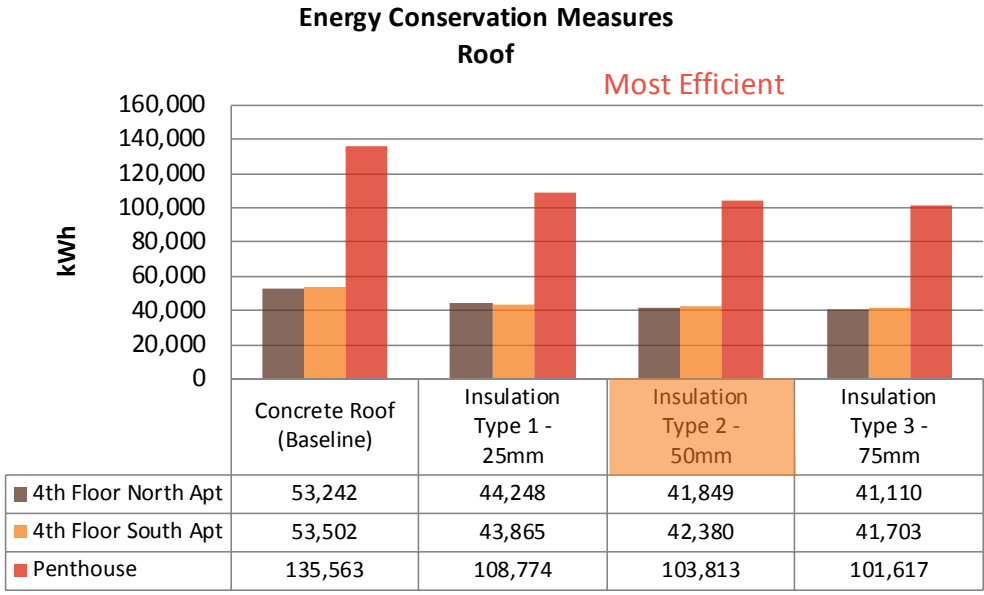
17%

Insulated Red Clay Brick Wall – Type 1				
Units	Before ECM Baseline kWh	Alt 2 kWh	Savings %	Energy Reduction kWh
Total Building Cooling Load - kWh	477,747	398,133	**17%**	**79,614**

++Thermal Analysis

Energy Conservation Measures

Roof



	Concrete Roof (Baseline)	Insulation Type 1 - 25mm	Insulation Type 2 - 50mm	Insulation Type 3 - 75mm
4th Floor North Apt	53,242	44,248	41,849	41,110
4th Floor South Apt	53,502	43,865	42,380	41,703
Penthouse	135,563	108,774	103,813	101,617

Most Efficient Roof Measure

Concrete roof with a 50mm Extruded Polystyrene - Type 2

Total Savings

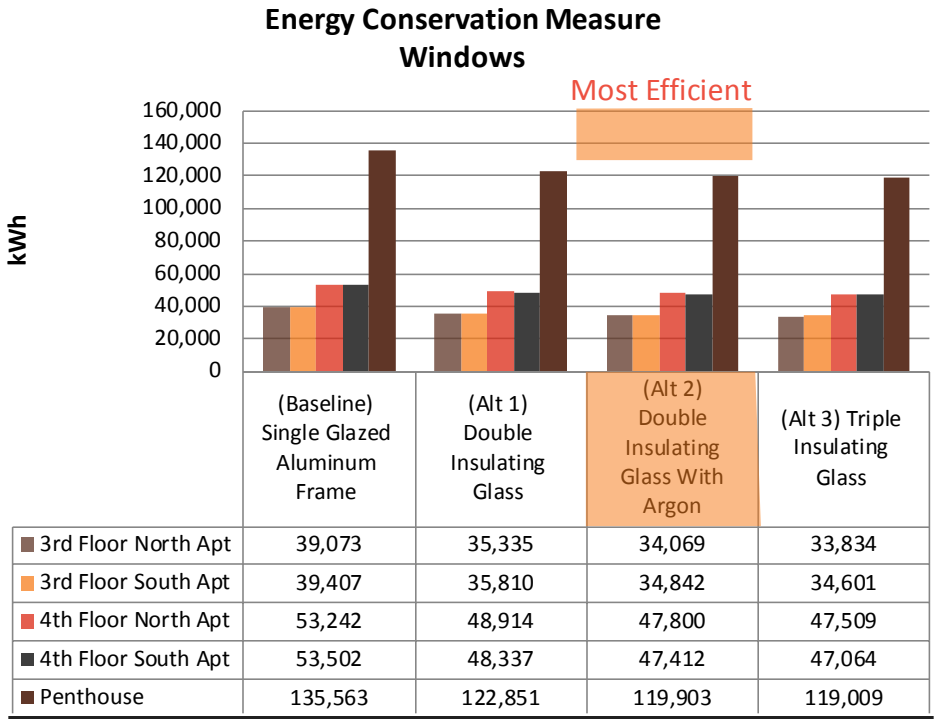
11%

Units	Baseline kWh	Insulation Type 2 50 mm kWh	Savings %	Energy Reduction kWh
Total Building Cooling Load	477,747	423,482	11%	54,265

++Thermal Analysis

Energy Conservation Measures

Windows



Most Efficient Windows Measure

(Alt 2) Double Insulating Glass With Aragon

Total Savings

12%

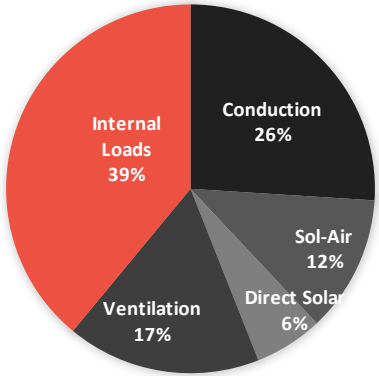
Alternative Two Savings Double Insulating Glass With Argon (25mm)				
Units	Baseline kWh	Alt 3 kWh	Savings %	Energy Reduction kWh
Total Building Cooling Load - kWh	477,747	421,848	12%	55,899

++Thermal Analysis

Energy Conservation Measures

Shading Devices

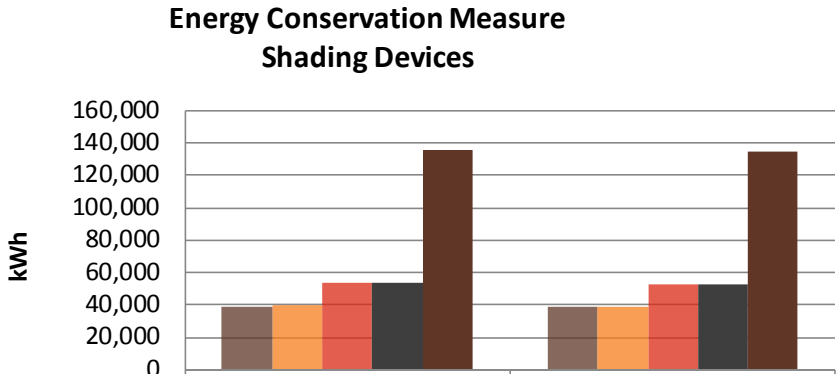
Annual Heat Gains Breakdown



With shading Devices

Total Savings

0.9%



	Baseline	With Shading Devices
3rd Floor North Apt	39,073	38,838
3rd Floor South Apt	39,407	39,167
4th Floor North Apt	53,242	52,874
4th Floor South Apt	53,502	52,365
Penthouse	135,563	134,334

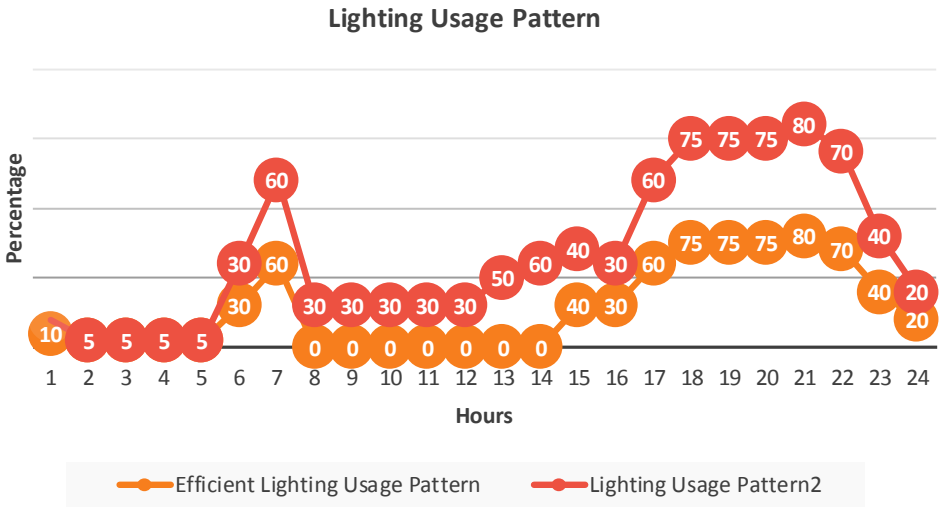
Shading Devices

Units	Baseline kWh	With Shading Devices kWh	Savings %	Energy Reduction kWh
Total Building Cooling Load - kWh	477,747	473,588	0.9%	4,159

++Thermal Analysis

Energy Conservation Measures

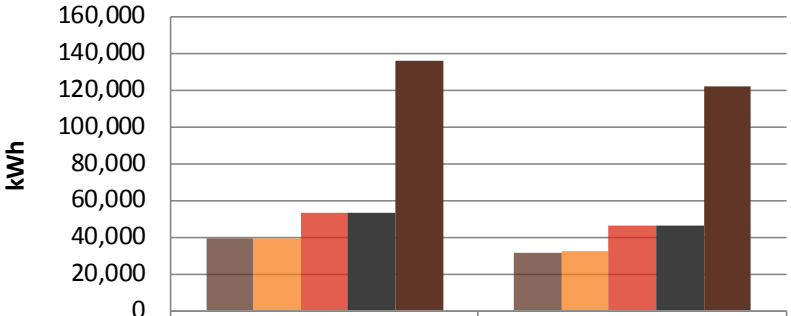
Lighting Usage Pattern



Total Savings

15%

Energy Conservation Measures
Lighting Usage Pattern



	Baseline	Efficient Lighting Schedule
3rd Floor North Apt	39,073	31,802
3rd Floor South Apt	39,407	32,180
4th Floor North Apt	53,242	46,310
4th Floor South Apt	53,502	45,986
Penthouse	135,563	122,455

Lighting Schedule

Units	Baseline kWh	Efficient Lighting Schedule kWh	Savings %	Energy Reduction kWh
Total Building Cooling Load -kWh	477,747	406,697	15%	71,050

++Thermal Analysis

Energy Conservation Measures

Efficient Lighting Fixtures

Baseline

100 Fixtures X 35Watt Halogen Spotlight

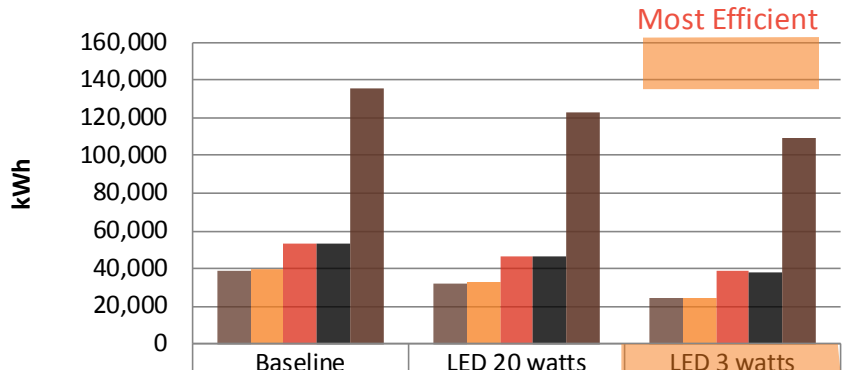
Most Efficient Lighting Fixtures

LED 3 Watts

Total Savings

30%

Energy Conservation Measure
Efficient Lighting Fixtures



	Baseline	LED 20 watts	LED 3 watts
3rd Floor North Apt	39,073	32,124	24,447
3rd Floor South Apt	39,407	32,549	24,452
4th Floor North Apt	53,242	46,492	38,644
4th Floor South Apt	53,502	46,142	38246
Penthouse	135,563	123,258	109522

Efficient Lighting Fixtures Impact

Units	Baseline kWh	Efficient Lighting Schedule kWh	Savings %	Energy Reduction kWh
Total Building Cooling Load -kWh	477,747	333,109	30%	144,635

++Thermal Analysis

Energy Conservation Measures

Internal Appliances

Electrical Appliances Loads	Apartments	Penthouse
baseline	5.7 W/m^2	5.7 W/m^2
Efficient Electrical Appliances 1	3.875008 W/m^2	3.875008 W/m^2

1. ASHRAE_189.1-2009 Climate Zone 1-3 Mid-rise Apartment - Electric Equipment standard (Openstudio Database)

No Cooling Load

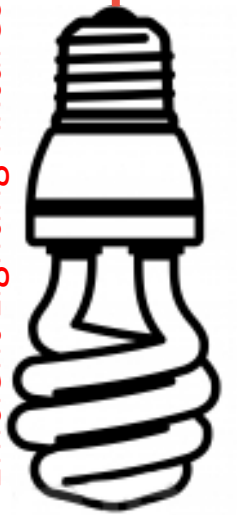
Reduction

By applying efficient Appliances

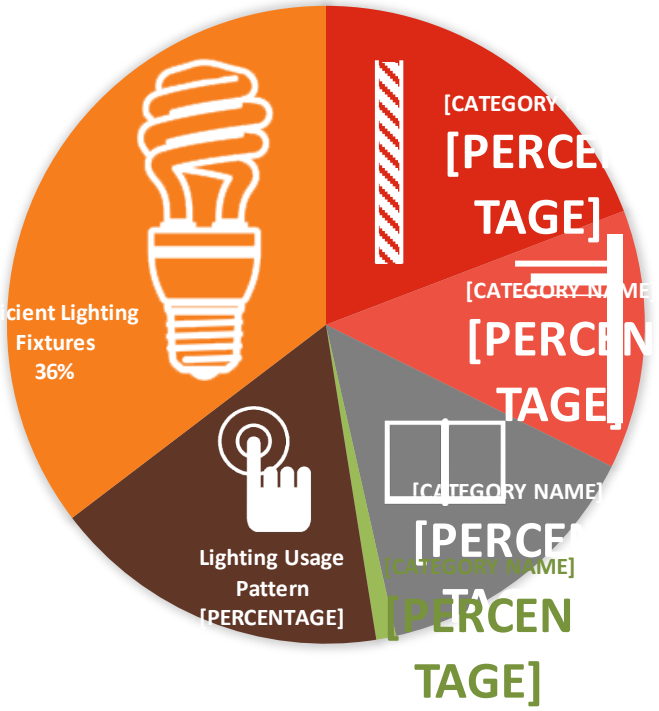
++Thermal Analysis

Energy Conservation Measures Summary

The Most Saving is from Efficient Lighting Fixtures



36%



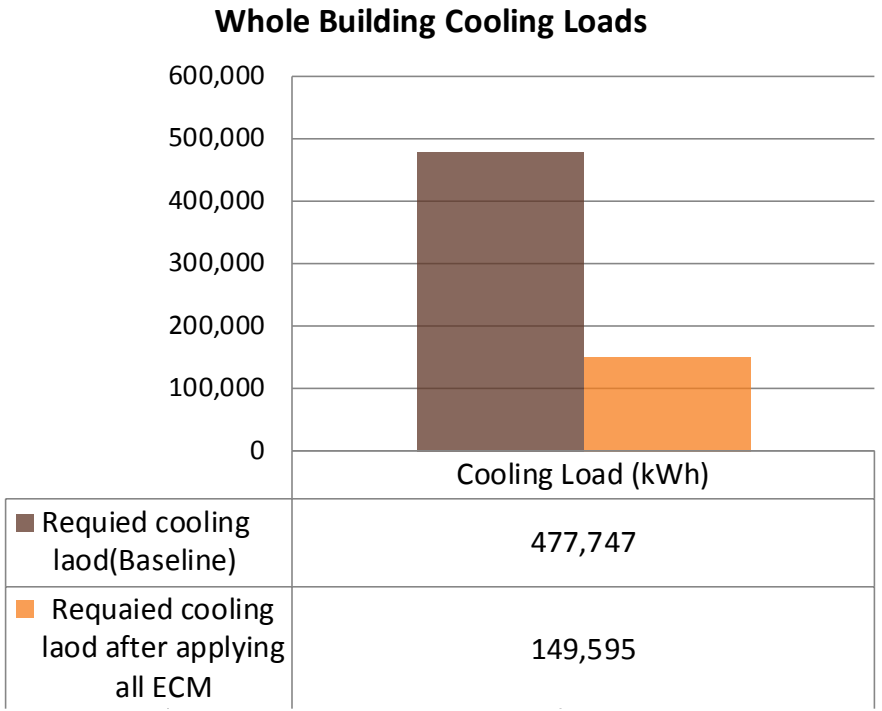
Total Savings

86%

++Thermal Analysis

Whole Building Cooling Loads

After applying all the ECMs together in the simulation model, results showed less reduction in cooling load savings. This happens because the selected ECMs have an effect on each other's performance. For example, using efficient lighting fixtures reduces the saving from applying efficient usage pattern.



	Annual required Cooling load	Cooling Load kWh/m²
Baseline	477,747	193
The Building with all EMC	149,595	61
Annual Savings	69%	

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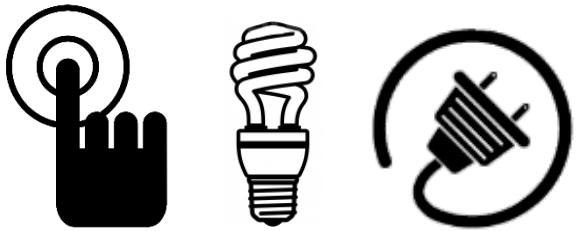
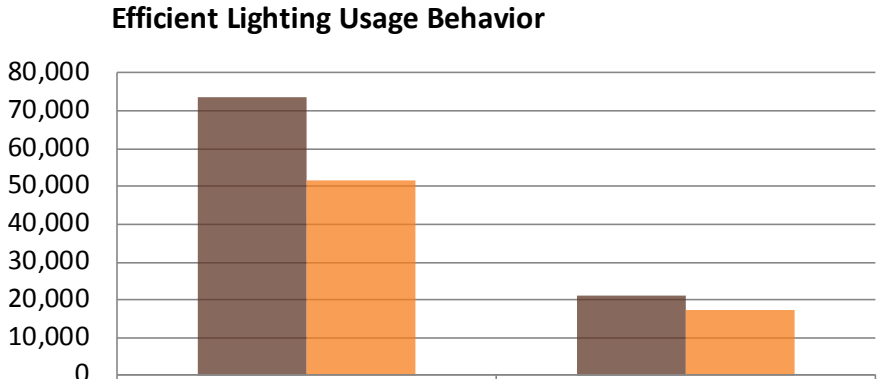
[Internal Loads]



++Internal Loads

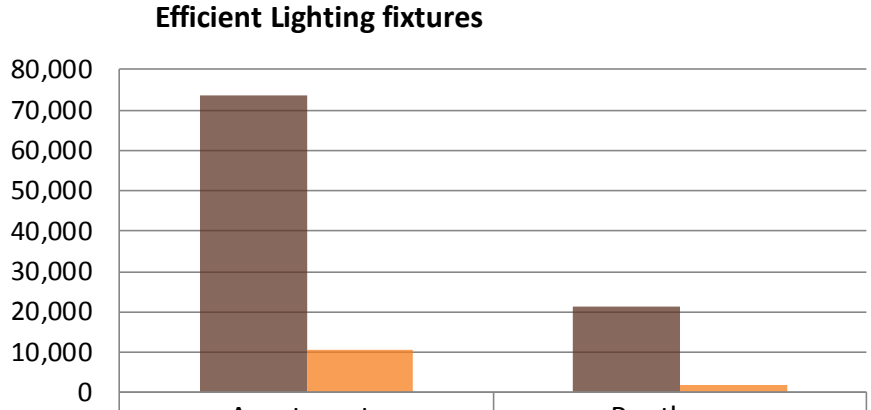
Lighting Usage Pattern



	Apartments	Penthouse
Baseline - kWh	73,530	21,150
After Schedule - kWh	51,560	17,400
Savings	**30%**	**18%**
Energy Reduction	21,970	3,750

++Internal Loads

Efficient Lighting Fixture



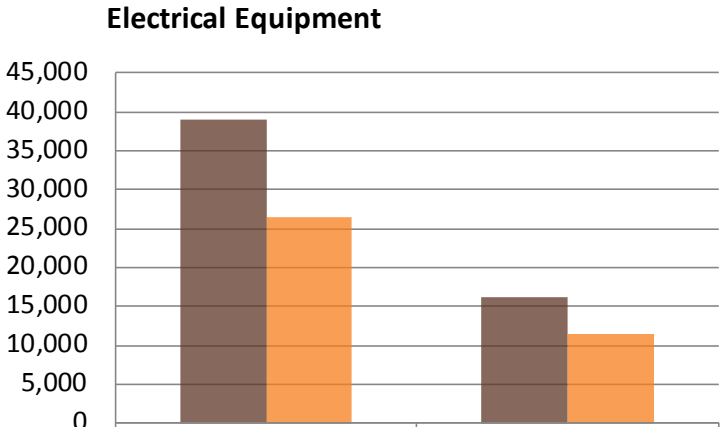
	Apartments	Penthouse
Baseline - kWh	73,530	21,150
With Efficient Lighting fixtures - kWh	10,601	1,826
Savings	**86%**	**91%**
Energy Reduction	62,929 kWh	19,324 kWh

++Internal Loads

Internal Appliances

Electrical Appliances Loads	Apartments	Penthouse
baseline	5.7 W/m^2	5.7 W/m^2
Efficient Electrical Appliances 1	3.875008 W/m^2	3.875008 W/m^2

1. ASHRAE_189.1-2009 Climate Zone 1-3 Mid-rise Apartment - Electric Equipment standard (Openstudio Database)



	Apartments	Penthouse
Baseline - kWh	39,070	16,180
With Efficient Electrical Equipment - kWh	26,500	11,400

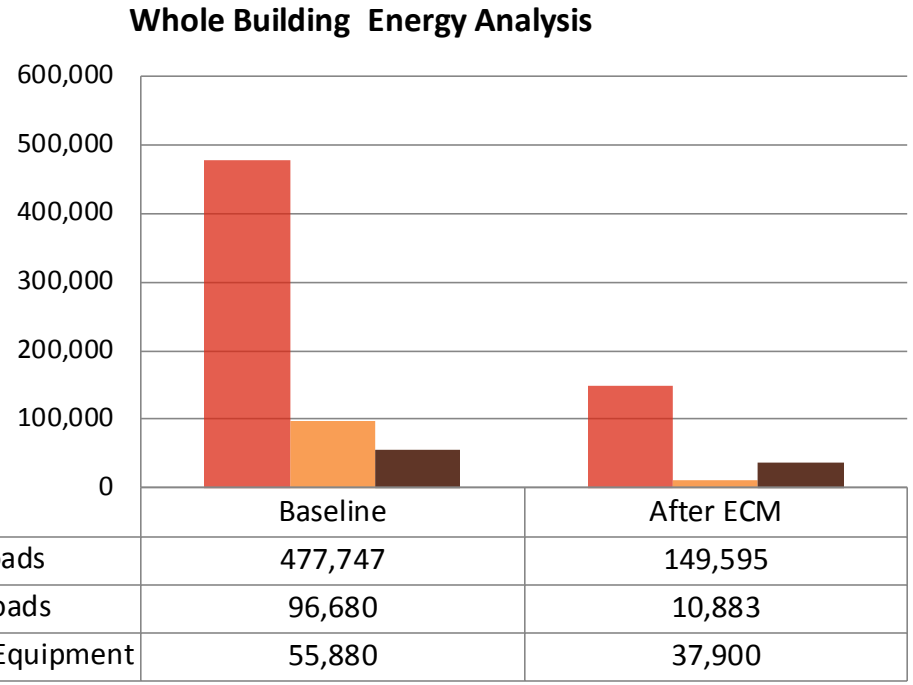
Savings	32%	30%
Total Building With Efficient Electrical Equipment - kWh	37,900	

++Energy Simulation

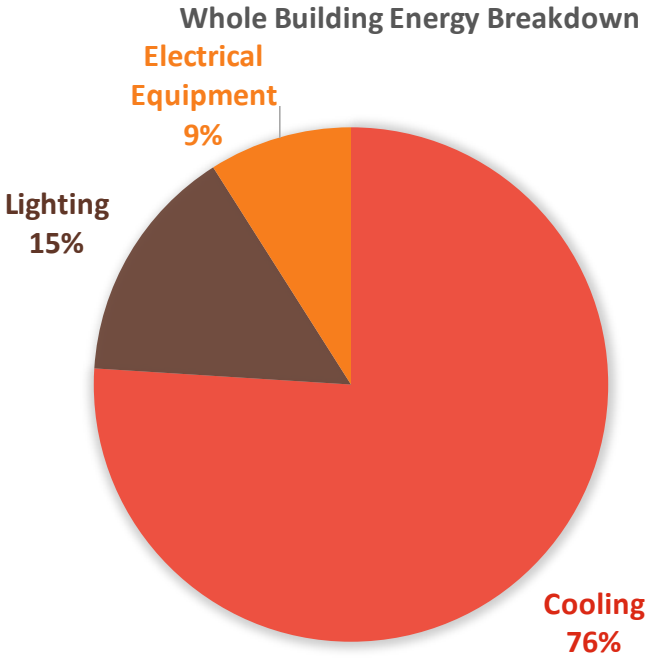
Whole Building Energy Analysis

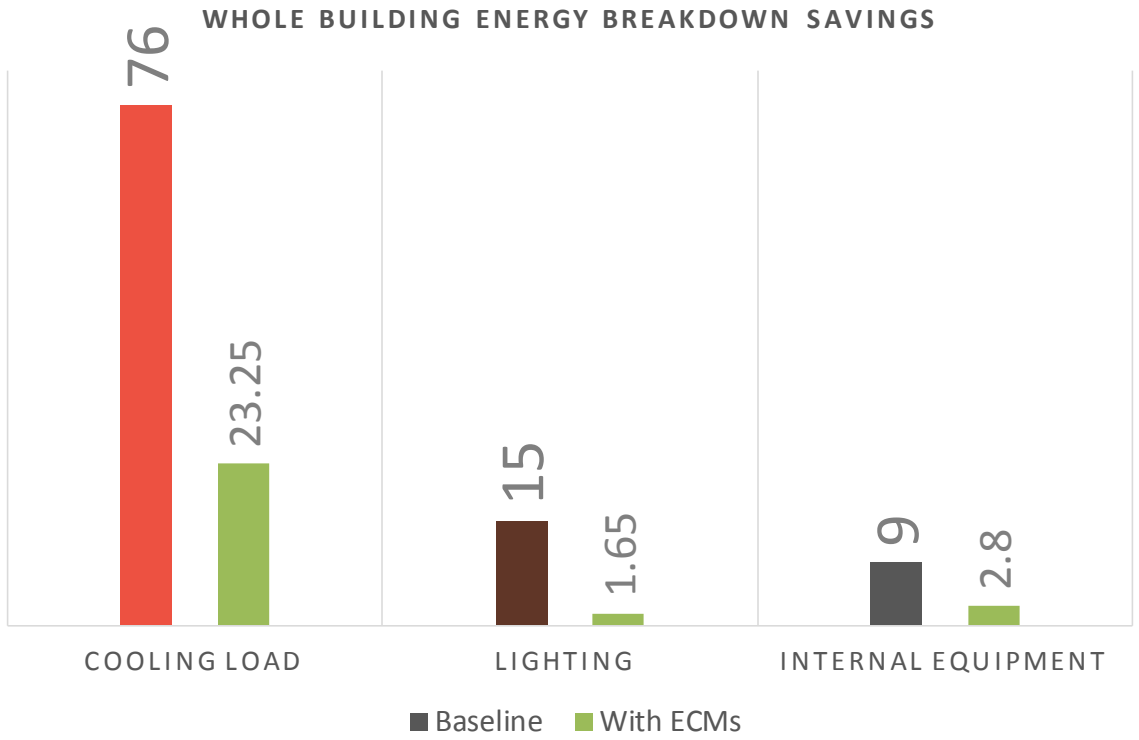
Total Building Energy Saving

68%



	Baseline	With ECM	Savings
Cooling	477,747	149,595	69%
Lighting	96,680	10,883	89%
Electrical Appliances	55,880	37,900	32%
Total	630,307	198,378	**68%**


Whole Building Energy Breakdown
Electrical Equipment 9%
Lighting 15%
Cooling 76%

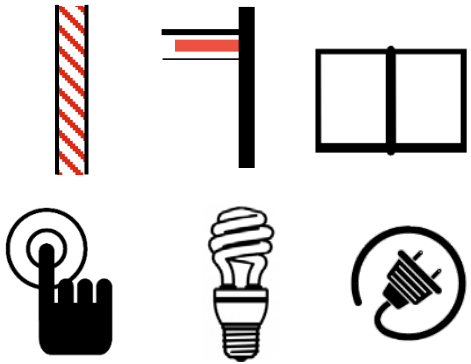

WHOLE BUILDING ENERGY BREAKDOWN SAVINGS
76
23.25
15
1.65
9
2.8
COOLING LOAD
LIGHTING
INTERNAL EQUIPMENT
Baseline
With ECMs

++Energy Simulation

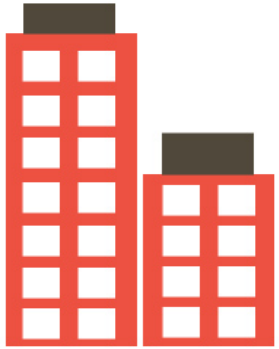
Whole Building Energy Analysis

	The Average three bedroom apartment In Jeddah City Consume	Four bedrooms penthouse Consume
Baseline	53,300 kWh	174,000 kWh
With ECM	**18,000 kWh** **66% Reduction**	**50,800 kWh** **71% Reduction**

Energy Conservation Measures



Residential Buildings



Energy Reduction

68%

شكراً

Thank You