POLITECNICO DI MILANO

BUILDING ENERGY PERFORMANCE

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Introduction

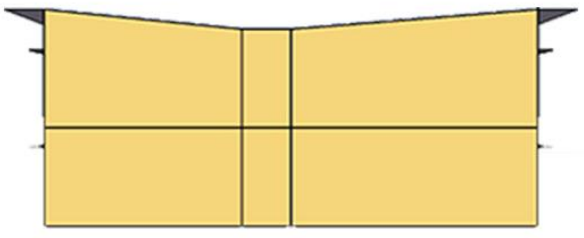
About Project

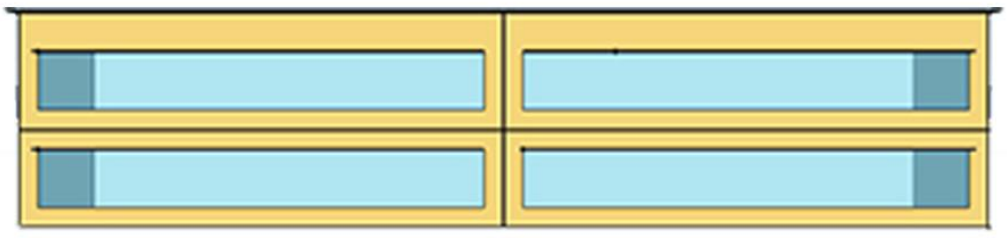
OBJECTIVE

Our objective for this assignment were to analyse a building in terms of it's energy performance in three different environmental conditions i.e. three different cities.

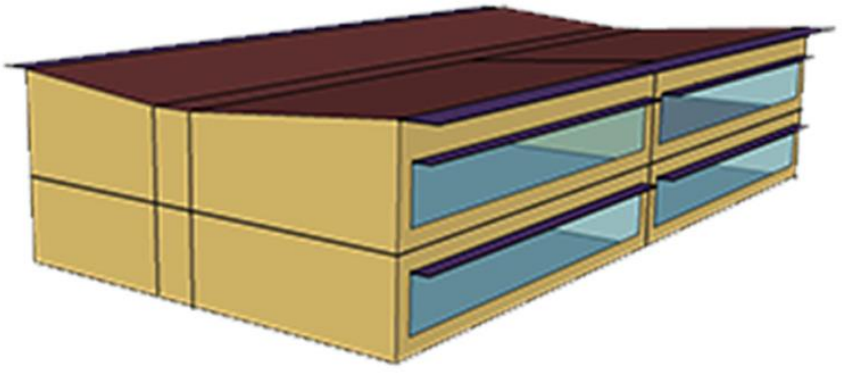
The requirements for this assignment were;
1) To calculate the annual energy consumption of a building with the same material in three different locations. (New Delhi, Dublin, Rome)
2) To calculate the annual energy consumption of the same building in one location with three different materials (Solid concrete with steel frame, wooden frame & metal)

THE BUILDING





Two story building which we have chosen in order to investigate the energy consumption of a building with varying enevironmental conditions and materials.
The proposed building is a commercial office building.
On both floors there are large open work spaces.



Experiment Procedure

1. Designing a building using SketchUp 3D and Open Studio software.
2. Calculating the yearly heating and cooling consumption of the building for a base case using open Studio and Energy Plus software.
3. Analysing the results to investigate the effect of change in the location and wall characteristics on the building's yearly energy consumption.
4. Accordingly, the simulation should be performed for three different cities and three different walls, and the corresponding obtained yearly consumptions should be compared with the ones of the base case.

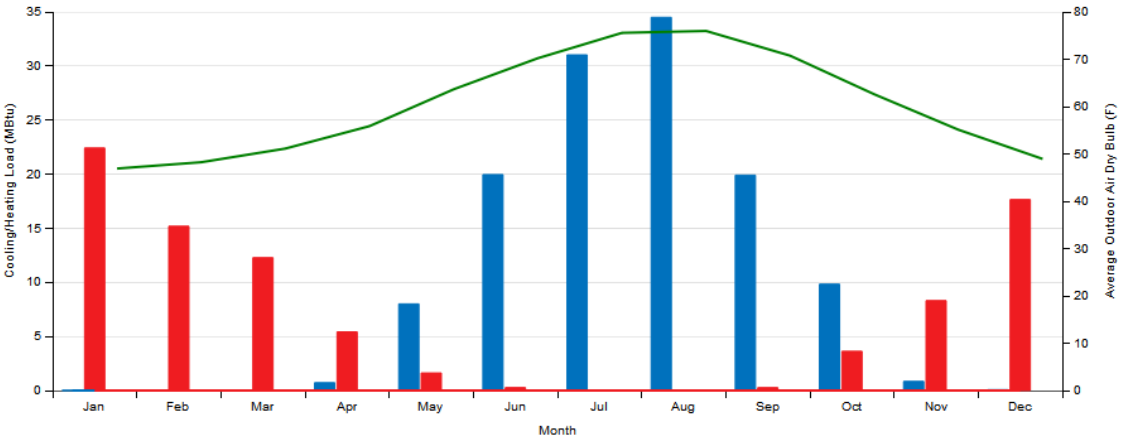
UNIT CONVERSION

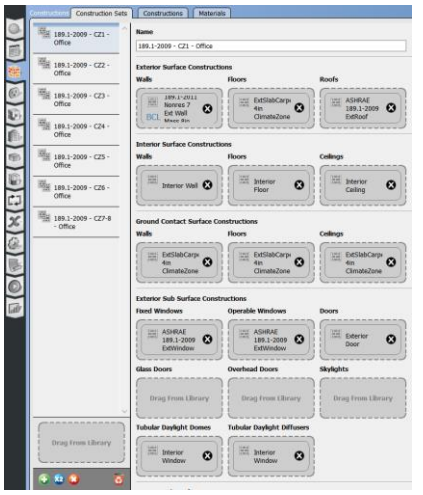
TYPE	BRITISH UNIT	INTERNATIONAL UNIT
ELEVATION	1 ft	0.3048 m
AREA	1 ft^2	0.092903 m^2
ENERGY	1 Btu	1055.056 J
ENERGY	1 mBtu	1055.056 J*10^6
ENERGY	1 kBtu	1055.056 J*10^3

Experiment 01

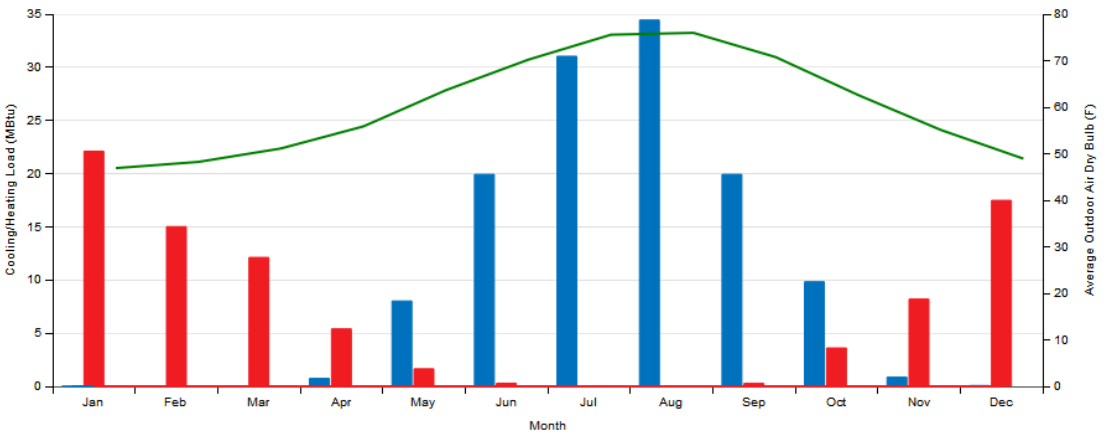
Three Different Exterior Materials

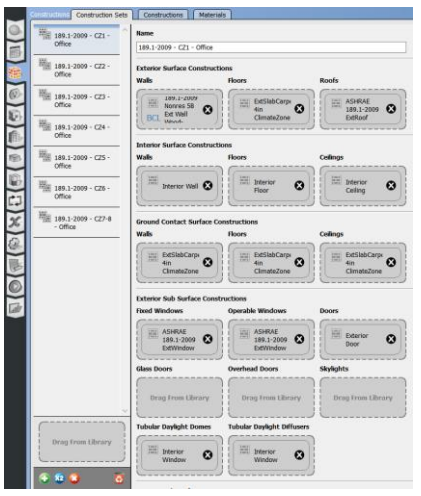
MATERIAL 01: 8 inch Solid Concrete with Steel frame.



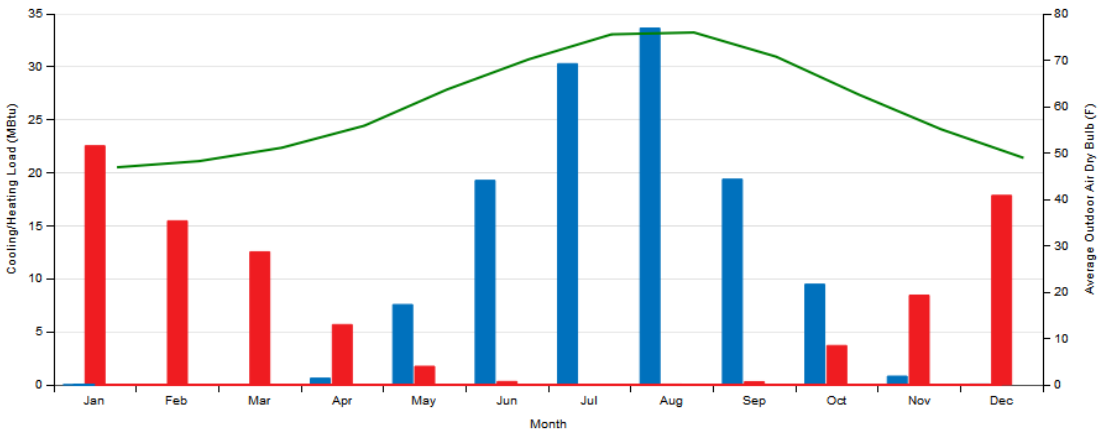


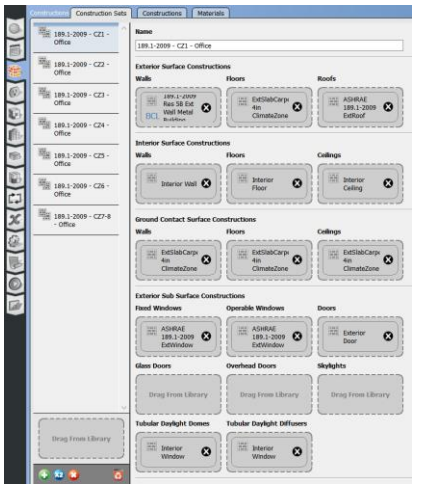
MATERIAL 02: Wooden Framed





MATERIAL 02: Metal

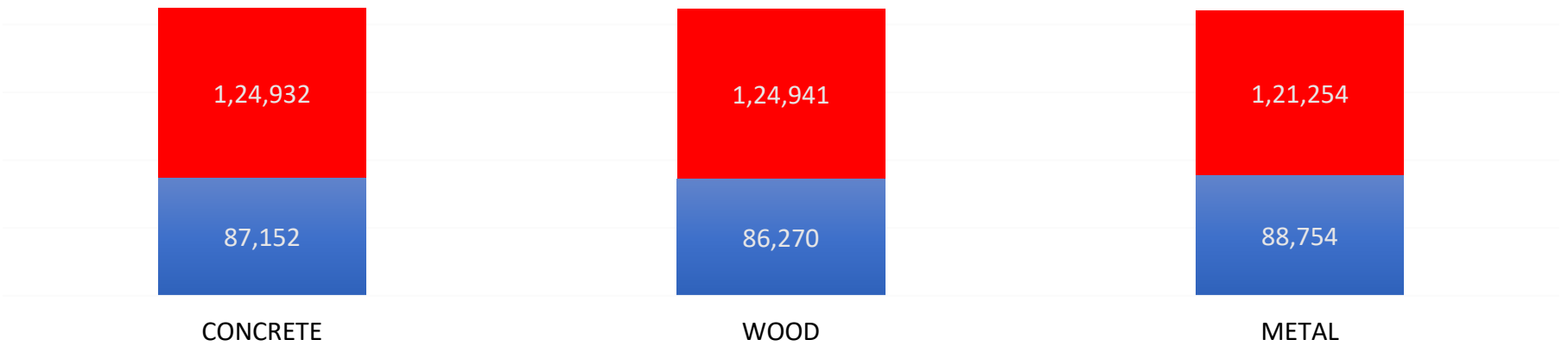


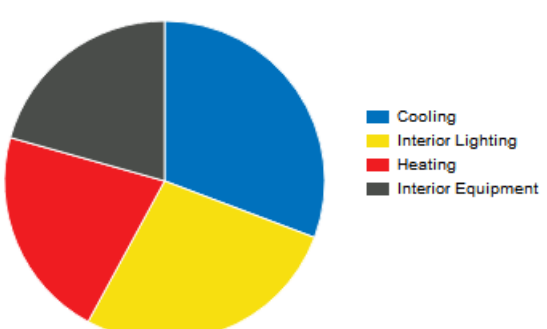


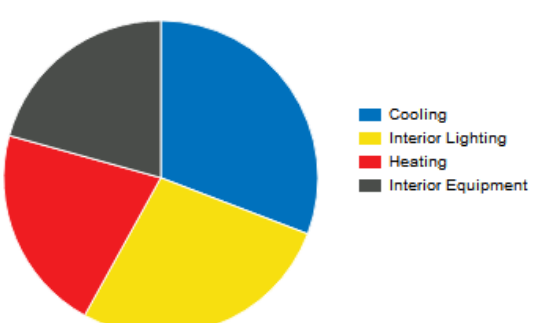
As can be seen from the data, the daily temperature of the building is nearly the same in the three cases. However the insulation and heat dissipation is different between these three kinds of materials. Concrete does have great insulation but has the worst heat dissipation in these three materials. As for metal, it has a opposite situation with concrete. It's heat dissipation is good but insulation is not so well. So that concrete consume the most energy when cooling but consume the minimal energy when heating.

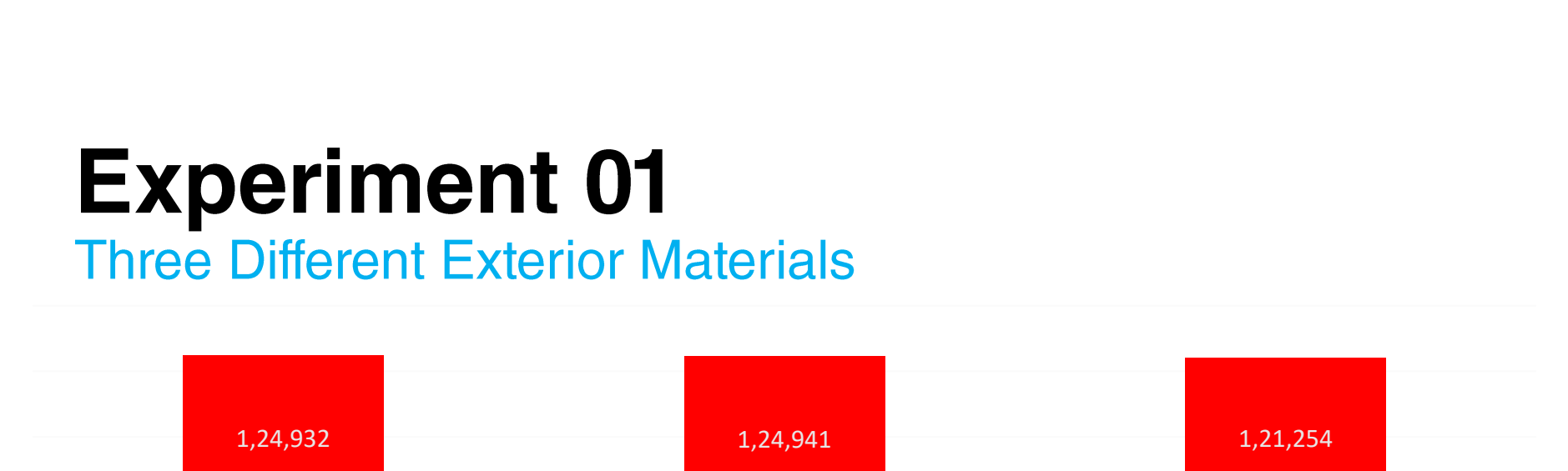
Experiment 01

Three Different Exterior Materials









CONCRETE **WOOD** **METAL**

The data from these pie charts and bar graphs shows that the energy output of three buildings with three kinds of exterior walls in the same city of Rome.
As the weather is a constant value in this scenario we can see the consumption of energy is almost the same with slight differences. For heating, metal consumes the most energy and concrete consumes the least. However for cooling, it is vice-versa. Interior lighting and equipment values are nearly the same in this case.
Analysing the pattern of Heating and Cooling power consumption, July and August are the months with highest consumption of power for cooling and January and December are the months with highest consumption of power for heating.

Experiment 01

Three Different Exterior Materials

Site and Source Energy

	Total Energy (kBtu)	Energy Per Total Building Area (kBtu/ft^2)	Energy Per Conditioned Building Area (kBtu/ft^2)
Total Site Energy	406357.6	40.6	40.6
Net Site Energy	406357.6	40.6	40.6
Total Source Energy	1062057.5	106.2	106.2
Net Source Energy	1062057.5	106.2	106.2

Site and Source Energy

	Total Energy (kBtu)	Energy Per Total Building Area (kBtu/ft^2)	Energy Per Conditioned Building Area (kBtu/ft^2)
Total Site Energy	405485.6	40.5	40.5
Net Site Energy	405485.6	40.5	40.5
Total Source Energy	1058872.9	105.9	105.9
Net Source Energy	1058872.9	105.9	105.9

Site and Source Energy

	Total Energy (kBtu)	Energy Per Total Building Area (kBtu/ft^2)	Energy Per Conditioned Building Area (kBtu/ft^2)
Total Site Energy	404272.4	40.4	40.4
Net Site Energy	404272.4	40.4	40.4
Total Source Energy	1063953.2	106.4	106.4
Net Source Energy	1063953.2	106.4	106.4

From the table we infer that the net site and source energy values in these three cases are nearly same.

Site to Source Energy Conversion Factors

	Site=>Source Conversion Factor
Electricity	3.167
Natural Gas	1.084
District Cooling	1.056
District Heating	3.613

From the table of site to source conversion factors, it gives us the different proportion of 4 factors. Site to source conversion factor can help us to see each index clearly. The electricity and district heating are the highest, the electricity is 3.167, district heating is 3,613. While the natural gas and district cooling are not that high, natural gas is 1.084 and the district cooling is 1.056.

Experiment 02

Three Different Locations

1. Designing a building using SketchUp 3D and Open Studio software.
2. Calculating the yearly heating and cooling consumption of the building for a base case using open Studio and Energy Plus software.
3. The simulation was performed for three different cities and the results were obtained.
4. The results were analysed using comparison of graphs and data.
5. Conclusion was made based on the results.

The three cities chosen for this experiment were Rome, New Delhi and Dublin respectively.

Experiment 02

Rome

ROME CLIMATE TABLE // HISTORICAL WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	7.7	8.9	10.8	13.7	17.7	21.7	24.4	24.3	21.3	16.8	12.3	8.9
Min. Temperature (°C)	3.8	4.5	6.1	8.5	12.2	15.9	18.3	18.4	15.9	11.7	8	5
Max. Temperature (°C)	11.7	13.3	15.5	18.9	23.3	27.5	30.6	30.2	26.7	21.9	16.7	12.9
Avg. Temperature (°F)	45.9	48.0	51.4	56.7	63.9	71.1	75.9	75.7	70.3	62.2	54.1	48.0
Min. Temperature (°F)	38.8	40.1	43.0	47.3	54.0	60.6	64.9	65.1	60.6	53.1	46.4	41.0
Max. Temperature (°F)	53.1	55.9	59.9	66.0	73.9	81.5	87.1	86.4	80.1	71.4	62.1	55.2
Precipitation / Rainfall (mm)	79	70	70	62	46	35	17	33	73	103	114	96

There is a difference of 97 mm of precipitation between the driest and wettest months. The average temperatures vary during the year by 16.7 °C.

Building Summary

Information	Value	Units
Building Name	Building 1	building_name
Net Site Energy	406,358	kBtu
Total Building Area	10,000	ft^2
EUI (Based on Net Site Energy and Total Building Area)	40.64	kBtu/ft^2
OpenStudio Standards Building Type		

Weather Summary

	Value
Weather File	ROME - ITA IWEC Data WMO#=162420
Latitude	41.80
Longitude	12.23
Elevation	10 (ft)
Time Zone	1.00
North Axis Angle	0.00
ASHRAE Climate Zone	4A

Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
ROME ANN CLG .4% CONDNS DB=>MWB	87.8	17.1	73.04	Wetbulb [F]	11.18	170.0
ROME ANN CLG .4% CONDNS DP=>MDB	81.68	17.1	77.18	Dewpoint [F]	11.18	170.0
ROME ANN CLG .4% CONDNS ENTH=>MDB	83.66	17.1	34.35	Enthalpy [Btu/lb]	11.18	170.0
ROME ANN CLG .4% CONDNS WB=>MDB	83.3	17.1	78.62	Wetbulb [F]	11.18	170.0
ROME ANN HTG 99.6% CONDNS DB	30.56	0.0	30.56	Wetbulb [F]	7.38	70.0
ROME ANN HTG WIND 99.6% CONDNS WS=>MCDB	50.9	0.0	50.9	Wetbulb [F]	30.87	70.0
ROME ANN HUM_N 99.6% CONDNS DP=>MCDB	38.48	0.0	17.6	Dewpoint [F]	7.38	70.0

Experiment 02

New Delhi

NEW DELHI CLIMATE TABLE // HISTORICAL WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	14.2	16.9	22.7	28.6	33.5	34.3	31.1	29.8	29.2	25.8	20.1	15.6
Min. Temperature (°C)	7.3	10.1	15.1	20.9	26.4	28.6	27.1	26	24.5	18.6	11.7	7.9
Max. Temperature (°C)	21.2	23.8	30.3	36.3	40.6	40	35.2	33.6	34	33	28.6	23.4
Avg. Temperature (°F)	57.6	62.4	72.9	83.5	92.3	93.7	88.0	85.6	84.6	78.4	68.2	60.1
Min. Temperature (°F)	45.1	50.2	59.2	69.6	79.5	83.5	80.8	78.8	76.1	65.5	53.1	46.2
Max. Temperature (°F)	70.2	74.8	86.5	97.3	105.1	104.0	95.4	92.5	93.2	91.4	83.5	74.1
Precipitation / Rainfall (mm)	15	10	14	3	11	42	205	246	112	26	3	6

The precipitation varies 243 mm between the driest month and the wettest month. The average temperatures vary during the year by 20.1 °C.

Building Summary

Information	Value	Units
Building Name	Building 1	building_name
Net Site Energy	662,012	kBtu
Total Building Area	10,000	ft^2
EUI (Based on Net Site Energy and Total Building Area)	66.20	kBtu/ft^2
OpenStudio Standards Building Type		

Weather Summary

	Value
Weather File	New Delhi Delhi IND ISHRAE WMO#=421820
Latitude	28.58
Longitude	77.20
Elevation	709 (ft)
Time Zone	5.50
North Axis Angle	0.00
ASHRAE Climate Zone	1A

Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
NEW DELHI ANN CLG .4% CONDNS DB=>MWB	107.6	17.46	71.96	Wetbulb [F]	7.16	320.0
NEW DELHI ANN CLG .4% CONDNS DP=>MDB	87.44	17.46	81.14	Dewpoint [F]	7.16	320.0
NEW DELHI ANN CLG .4% CONDNS ENTH=>MDB	93.02	17.46	40.54	Enthalpy [Btu/lb]	7.16	320.0
NEW DELHI ANN CLG .4% CONDNS WB=>MDB	92.48	17.46	83.3	Wetbulb [F]	7.16	320.0
NEW DELHI ANN HTG 99.6% CONDNS DB	43.34	0.0	43.34	Wetbulb [F]	1.12	270.0
NEW DELHI ANN HTG WIND 99.6% CONDNS WS=>MCDB	67.28	0.0	67.28	Wetbulb [F]	15.66	270.0
NEW DELHI ANN HUM_N 99.6% CONDNS DP=>MCDB	72.5	0.0	29.48	Dewpoint [F]	1.12	270.0

Experiment 02

Dublin

DUBLIN CLIMATE TABLE // HISTORICAL WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	5.2	5.1	6.4	8.2	10.7	13.5	15.3	15.1	13.4	10.8	7.2	5.9
Min. Temperature (°C)	2.5	2.4	3.1	4.4	6.7	9.4	11.3	11.1	9.6	7.5	4.3	3.2
Max. Temperature (°C)	7.9	7.9	9.8	12	14.8	17.7	19.4	19.2	17.2	14.2	10.2	8.7
Avg. Temperature (°F)	41.4	41.2	43.5	46.8	51.3	56.3	59.5	59.2	56.1	51.4	45.0	42.6
Min. Temperature (°F)	36.5	36.3	37.6	39.9	44.1	48.9	52.3	52.0	49.3	45.5	39.7	37.8
Max. Temperature (°F)	46.2	46.2	49.6	53.6	58.6	63.9	66.9	66.6	63.0	57.6	50.4	47.7
Precipitation / Rainfall (mm)	70	52	53	50	60	55	53	71	75	76	72	80

There is a difference of 30 mm of precipitation between the driest and wettest months. During the year, the average temperatures vary by 10.2 °C.

Building Summary

Information	Value	Units
Building Name	Building 1	building_name
Net Site Energy	431,541	kBtu
Total Building Area	10,000	ft^2
EUI (Based on Net Site Energy and Total Building Area)	43.15	kBtu/ft^2
OpenStudio Standards Building Type		

Weather Summary

	Value
Weather File	DUBLIN - IRL IWEC Data WMO#=039690
Latitude	53.43
Longitude	-6.3
Elevation	279 (ft)
Time Zone	0.00
North Axis Angle	0.00
ASHRAE Climate Zone	5A

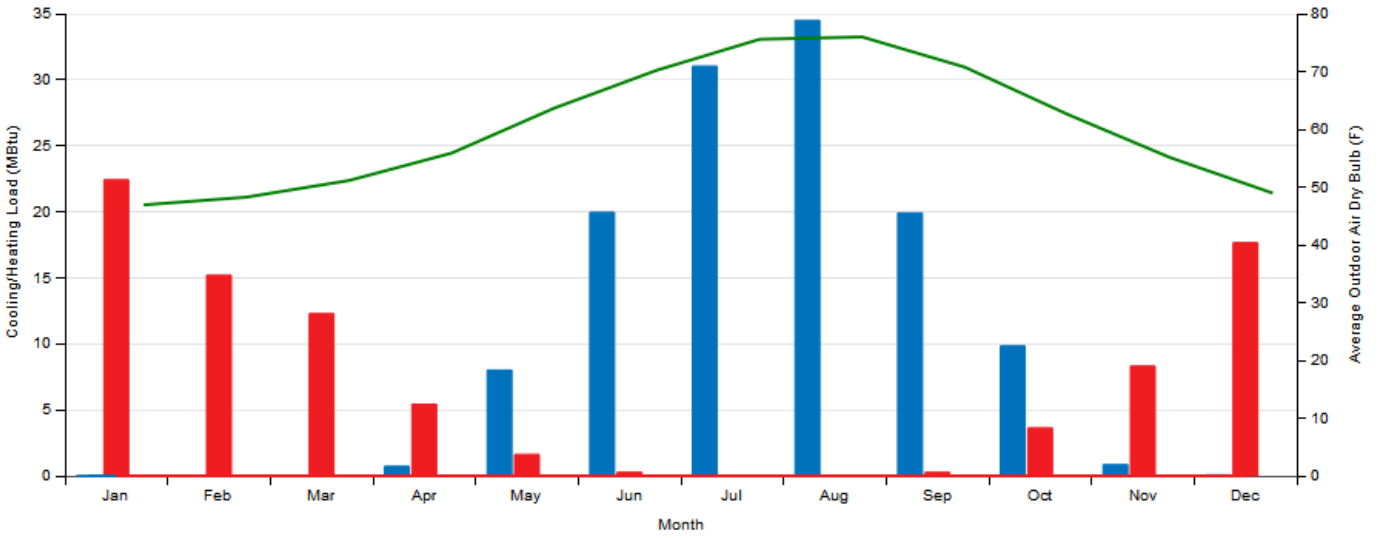
Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
DUBLIN ANN CLG .4% CONDNS DB=>MWB	71.78	12.96	62.78	Wetbulb [F]	10.74	130.0
DUBLIN ANN CLG .4% CONDNS DP=>MDB	66.92	12.96	62.24	Dewpoint [F]	10.74	130.0
DUBLIN ANN CLG .4% CONDNS ENTH=>MDB	69.44	12.96	21.93	Enthalpy [Btu/lb]	10.74	130.0
DUBLIN ANN CLG .4% CONDNS WB=>MDB	69.44	12.96	64.4	Wetbulb [F]	10.74	130.0
DUBLIN ANN HTG 99.6% CONDNS DB	28.58	0.0	28.58	Wetbulb [F]	8.05	260.0
DUBLIN ANN HTG WIND 99.6% CONDNS WS=>MCDB	46.94	0.0	46.94	Wetbulb [F]	37.8	260.0
DUBLIN ANN HUM_N 99.6% CONDNS DP=>MCDB	33.08	0.0	23.36	Dewpoint [F]	8.05	260.0

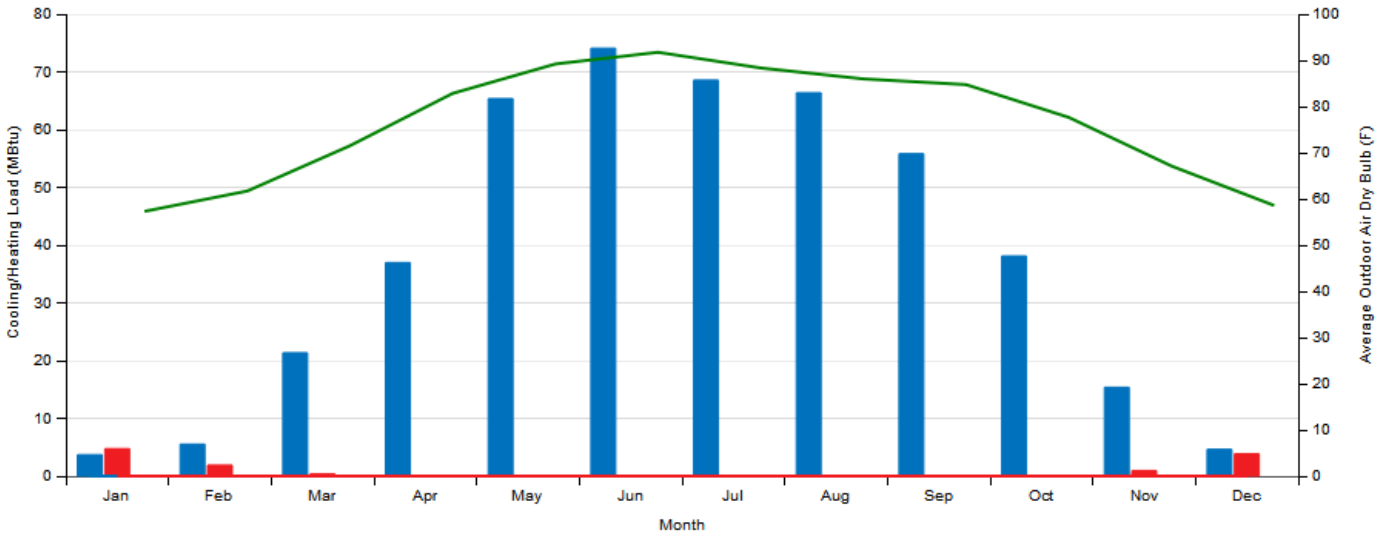
Experiment 02

Results

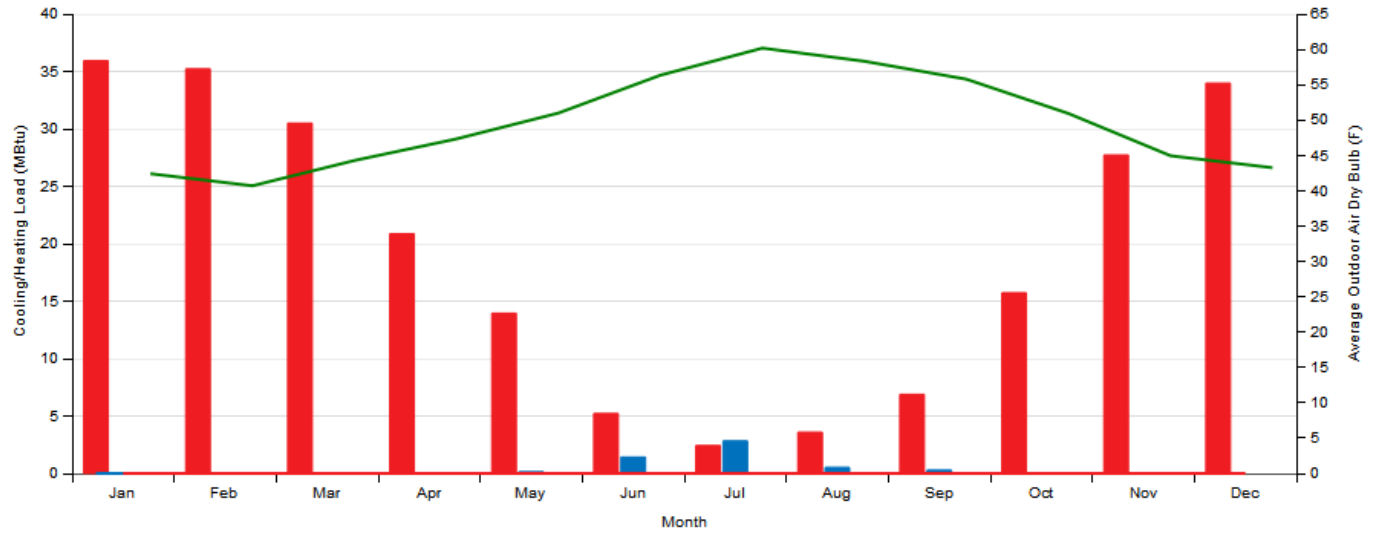
Monthly Power Load Profile



Rome



New Delhi



Dublin

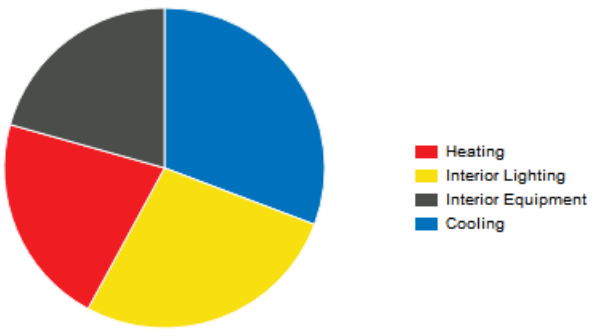
From the results of experiment 2 we can see that the monthly power load changes significantly between the three cities. The highest cooling consumption in the building when located in Rome occurs in August, when in New Delhi it occurs in June and July In Dublin.
The highest heating consumption occurs in January in Rome, January in New Delhi and also January in Dublin.

Experiment 02

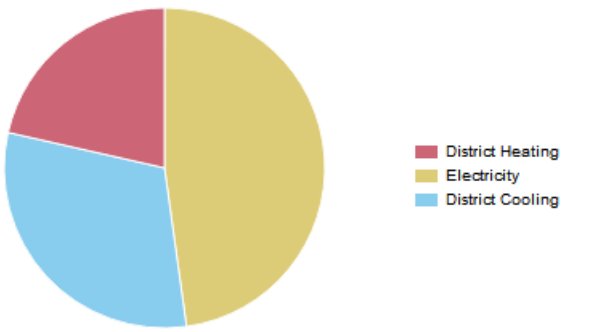
Results

Resource Usage

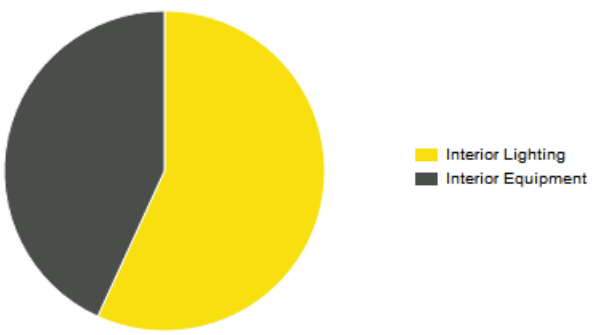
Rome



Energy Use - view table

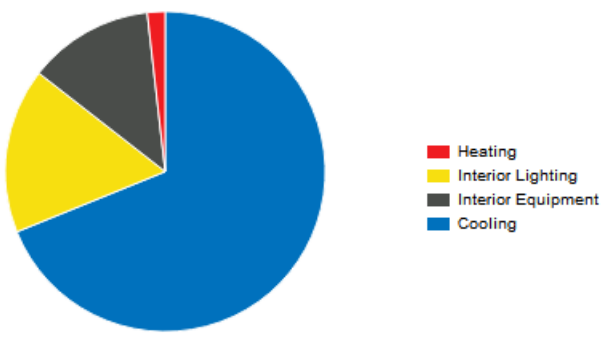


EUI - Electricity - view table

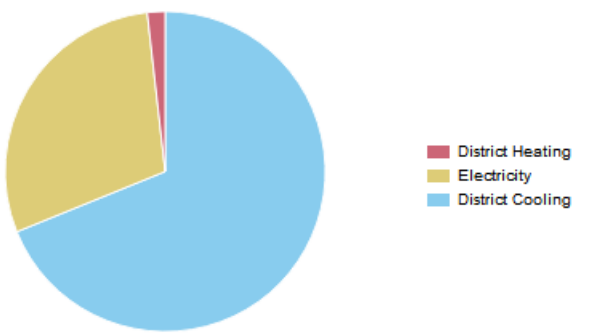


EUI - Gas - view table

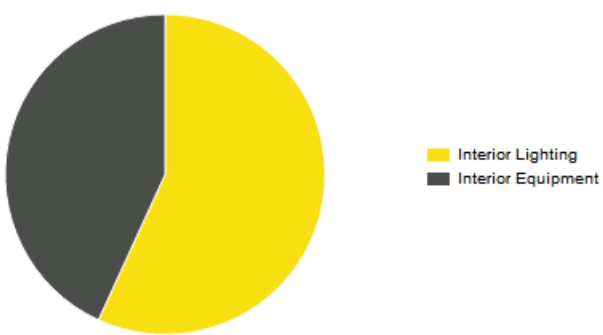
New Delhi



Energy Use - view table

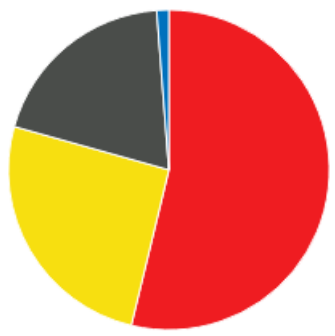


EUI - Electricity - view table

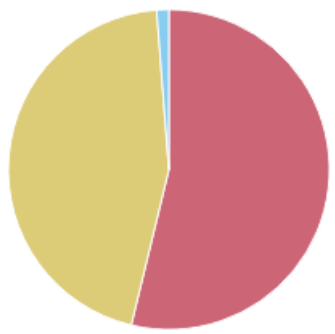


EUI - Gas - view table

Dublin



Energy Use - view table



EUI - Electricity - view table

EUI - Gas - view table

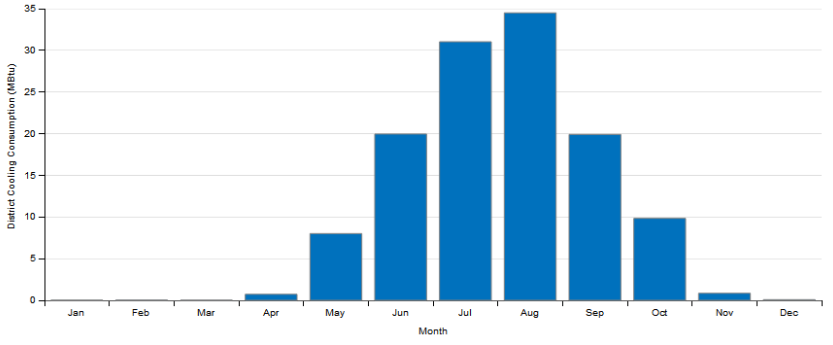
The results of the resource use in the three cities show that in Rome the highest energy use is cooling, due to the long hot summers, followed second by interior lighting and last by cooling. In New Delhi the highest energy use is cooling due to the high average temperature here, followed secondly by interior equipment and only a very small proportion of energy is used for heating due to the hot climate. In Dublin the majority of the energy use is dedicated to heating and a very small proportion is dedicated to cooling.

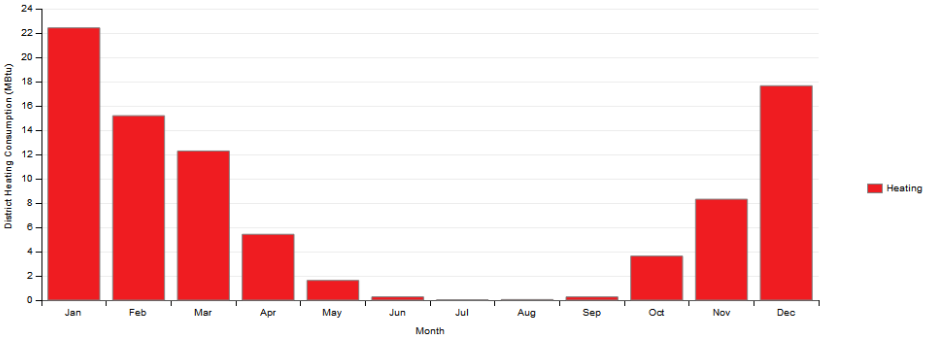
Experiment 02

Results

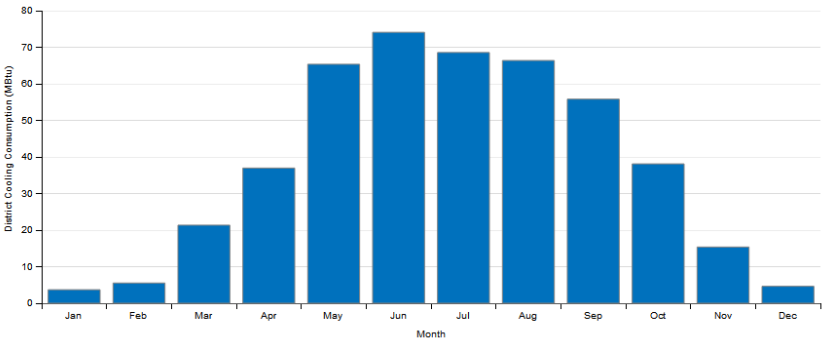
Monthly Heating and Cooling

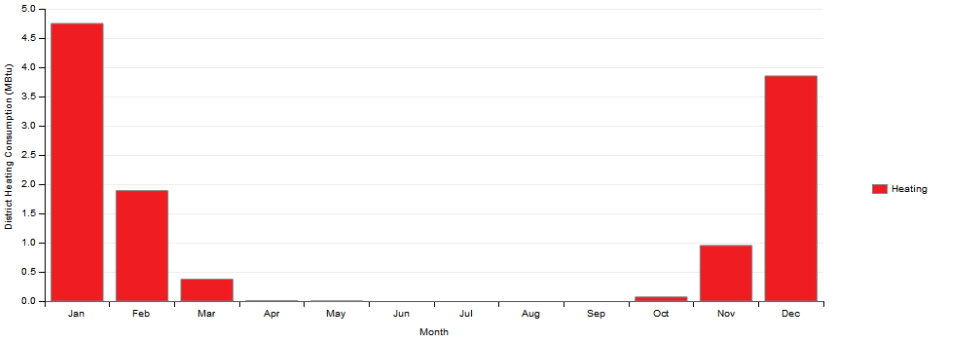
Rome



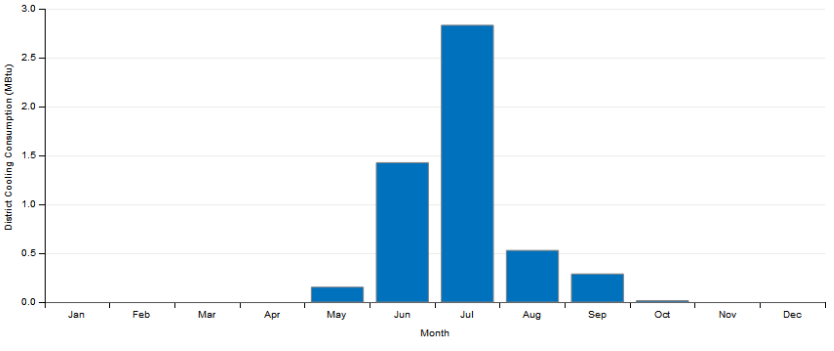


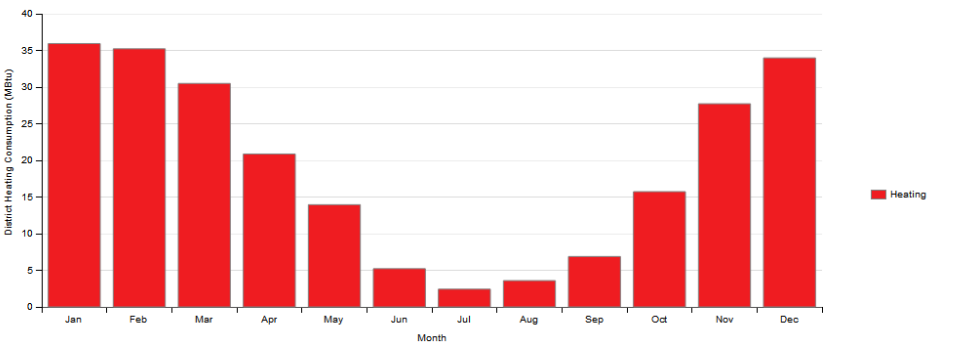
New Delhi





Dublin





Experiment

Conclusion

1. Experiment 01; taking our chosen building and calculating the yearly heating and cooling consumption in three different scenarios of different exterior material. The three materials being solid concrete with steel frame, wooden frame and metal. From our results we concluded that the daily temperature of the building in each case was almost identical however the insulation and heat dissipation is different between these three kinds of materials. Concrete does have great insulation but has the worst heat dissipation in these three materials. For metal the heat dissipation is good but insulation is poor. We concluded that concrete consumes the most energy when cooling but consume the minimal energy when heating. For all three materials we concluded that July and August are the months with highest consumption of power for cooling and January and December are the months with highest consumption of power for heating.

2. Experiment 02; Calculating the yearly heating and cooling consumption of the building for three different cities: Rome, New Delhi and Dublin. The highest cooling consumption in the building when located in Rome occurs in August, when in New Delhi it occurs in June and January In Dublin. The highest heating consumption occurs in January in Rome, January in New Delhi and July in Dublin. The highest consumption of energy in Rome is dedicated to cooling followed by interior lighting. It can be concluded that the hot summers mean that cooling is needed. In New Delhi the majority of energy use is directly related to cooling, this is due to the hot climatic conditions of New Delhi and the high average temperatures. Dublin is contrary to New Delhi where the majority of Energy use is dedicated to heating and only a small proportion to cooling. This is due to Dublin’s low average temperatures.