

TECHNICAL ENVIRONMENTAL SYSTEMS

OPEN STUDIO – BUILDING SIMULATION PROJECT

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MASTER SCIENCE IN SUSTAINABLE ARCHITECTURE AND LANDSCAPE DESIGN

OPEN STUDIO – BUILDING SIMULATION PROJECT

Introduction

There is a great amount of things an architect has to take into consideration during the process of design. Lighting, heating and cooling, and even materials are all part of this process that can greatly affect the performance of a building. During this assignment, we shall analyze the energy consumption and performance in correlation with its condition system (heating and/or cooling), interior features and interior lighting. Our methodology of performing this analysis will include the use of Sketchup, OpenStudio and EnergyPlus.

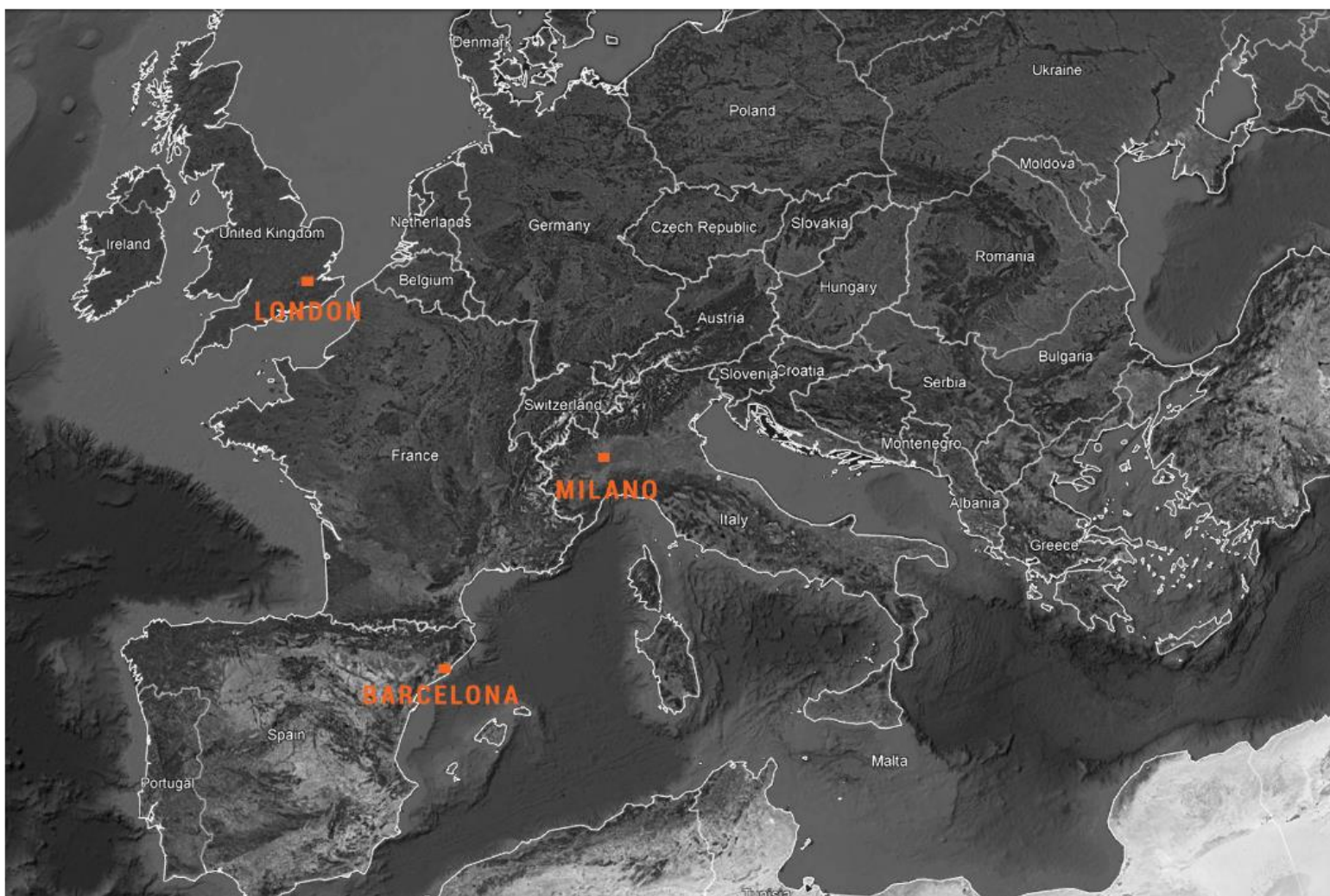
Process

We started off by designing a simple building that contained a lobby, two closed offices, a corridor and a storage room. Using OpenStudio, we determined 5 thermal zones and applied them to our building in these locations: Milano (Italy), Barcelona (Spain) and London (UK)

Later on, we determined the setting for the external walls, the roof and the windows. The wall components are one layer of stucco, 20 cm of concrete wall, a 25 cm wall insulation and a 1/2 inch gypsum panel. For the windows, a 05 mm glass is used. Lastly, the roof is conformed by a membrane of metal decking and roof insulation at 30 cm.

Results

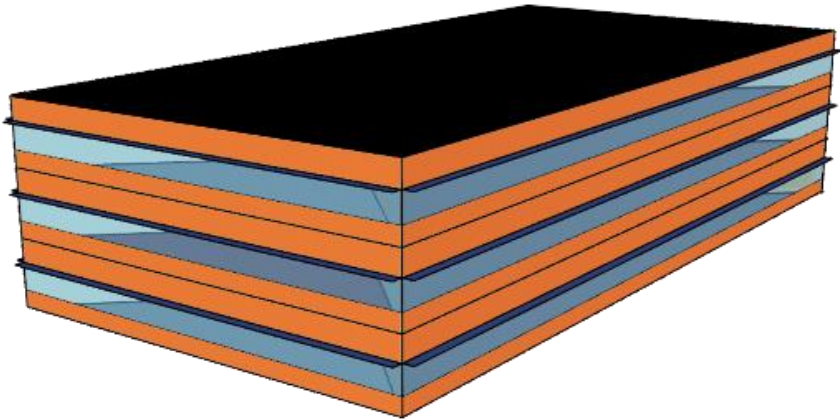
We shall be comparing the wall, stucco, concrete, wall insulation and the gypsum panel in each of the cities listed above. Last, we will take the city of London as a case study and change one wall component to see how it reacts in order to improve energy performance of our building.



OPEN STUDIO – BUILDING SIMULATION PROJECT

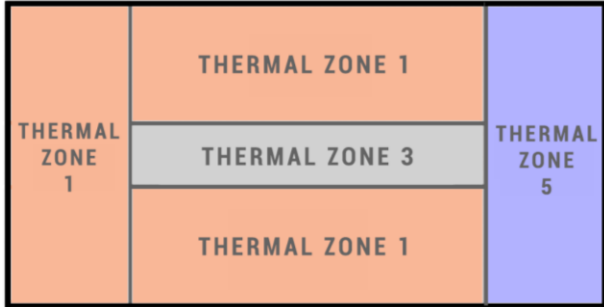
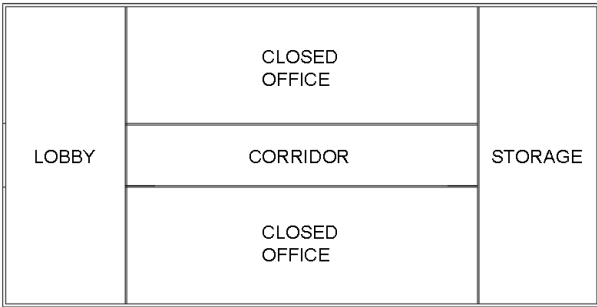
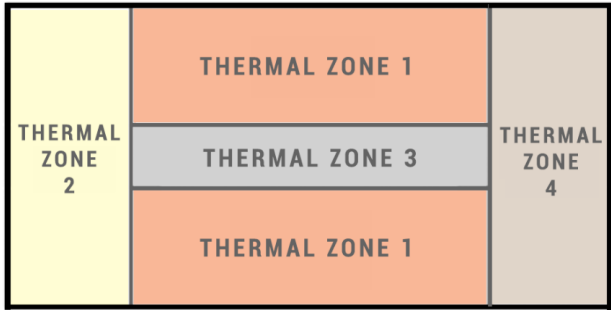
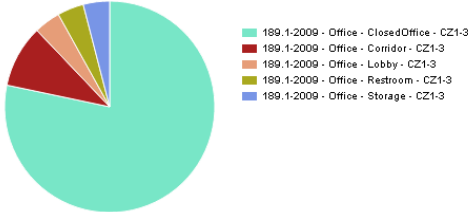
Building Summary

Data	Value
Building Name	Building_1
Total Site Energy	1,128,073 kBtu
Total Building Area	25,833 ft^2
Total Site EUI	43.67 kBtu/ft^2
OpenStudio Standards Building Type	n/a



Space Type Breakdown - view table

Space Type Name	Floor Area (ft^2)	Standards Building Type	Standards Space Type
189.1-2009 - Office - ClosedOffice - CZ1-3	20,225	Office	ClosedOffice
189.1-2009 - Office - Corridor - CZ1-3	2,466	Office	Corridor
189.1-2009 - Office - Lobby - CZ1-3	1,047	Office	Lobby
189.1-2009 - Office - Restroom - CZ1-3	1,047	Office	Restroom
189.1-2009 - Office - Storage - CZ1-3	1,047	Office	Storage



GROUND FLOOR

Zone Summary

	Area (ft^2)	Conditioned (Y/N)	Part of Total Floor Area (Y/N)	Volume (ft^3)	Multiplier	Above Ground Gross Wall Area (ft^2)	Underground Gross Wall Area (ft^2)	Window Glass Area (ft^2)	Lighting (W/ft^2)	People (ft^2/person)	Plug and Process (W/ft^2)
THERMAL ZONE 1	20225.28	Yes	Yes	202253.1	1.00	9842.52	0.0	3937.01	0.99	210.54	0.64
THERMAL ZONE 2	1047.44	Yes	Yes	10474.33	1.00	656.17	0.0	262.42	1.17	100.0	0.07
THERMAL ZONE 3	2465.8	Yes	Yes	24657.41	1.00	0.0	0.0	0.0	0.45	999.97	0.16
THERMAL ZONE 4	1047.44	Yes	Yes	10474.33	1.00	656.17	0.0	262.42	0.72	0.0	0.0
THERMAL ZONE 5	1047.44	Yes	Yes	10474.33	1.00	656.17	0.0	262.42	0.81	100.0	0.07
Total	25833.39			258333.86		11811.02	0.0	4724.39	0.93	216.25	0.52
Conditioned Total	25833.39			258333.86		11811.02	0.0	4724.39	0.93	216.25	0.52

Site and Source Energy

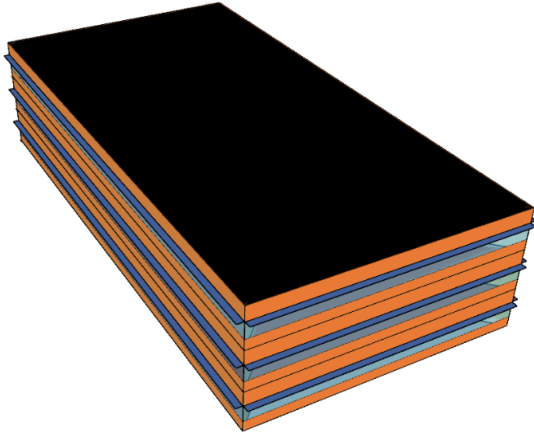
	Total Energy (kBtu)	Energy Per Total Building Area (kBtu/ft^2)	Energy Per Conditioned Building Area (kBtu/ft^2)
Total Site Energy	1128073.0	43.7	43.7
Net Site Energy	1128073.0	43.7	43.7
Total Source Energy	3387773.3	131.1	131.1
Net Source Energy	3387773.3	131.1	131.1

Window-to-Wall and Skylight-to-Roof area Ratios

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	40.0	40.0	40.0	40.0	40.0
Gross Window-Wall Ratio (Conditioned)	40.0	40.0	40.0	40.0	40.0
Skylight-Roof Ratio	0.0				

Electric Plug Load Consumption

	Electricity Annual Value (kWh)
InteriorEquipment:Electricity:Zone:THERMAL ZONE 1	61311.11
InteriorEquipment:Electricity:Zone:THERMAL ZONE 3	1869.44
InteriorEquipment:Electricity:Zone:THERMAL ZONE 2	347.22
InteriorEquipment:Electricity:Zone:THERMAL ZONE 5	347.22



OPEN STUDIO – BUILDING SIMULATION PROJECT

SIMULATION OF BUILDING IN MILANO, ITALY

The city of Milan is located in the north of Italy, with an latitude of 45.62 N and a longitude of 9.19 E with an elevation of 120 m.

Weather Summary

	Value
Weather File	MILAN - ITA IWEC Data WMO#=160660
Latitude	45.62
Longitude	8.73
Elevation	692 (ft)
Time Zone	1.00
North Axis Angle	0.00
ASHRAE Climate Zone	

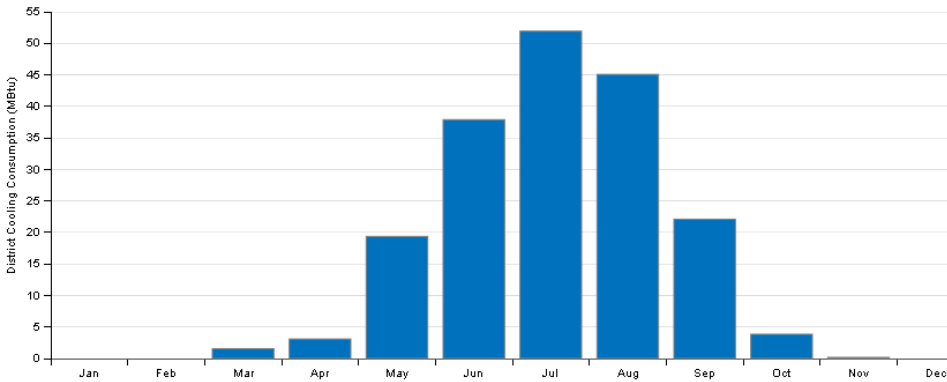
Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
MILANO-LINATE ANN CLG .4% CONDNS DB=>MWB	91.4	18.36	75.38	Wetbulb [F]	5.14	220.0
MILANO-LINATE ANN CLG .4% CONDNS DP=>MDB	83.3	18.36	74.3	Dewpoint [F]	5.14	220.0
MILANO-LINATE ANN CLG .4% CONDNS ENTH=>MDB	87.8	18.36	33.32	Enthalpy [Btu/lb]	5.14	220.0
MILANO-LINATE ANN CLG .4% CONDNS WB=>MDB	87.8	18.36	77.36	Wetbulb [F]	5.14	220.0
MILANO-LINATE ANN HTG 99.6% CONDNS DB	22.82	0.0	22.82	Wetbulb [F]	0.89	240.0
MILANO-LINATE ANN HTG WIND 99.6% CONDNS WS=>MCDB	47.84	0.0	47.84	Wetbulb [F]	23.04	240.0
MILANO-LINATE ANN HUM_N 99.6% CONDNS DP=>MCDB	36.14	0.0	11.3	Dewpoint [F]	0.89	240.0

District Cooling Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating													
Cooling			1.57	3.1	19.37	37.89	51.93	45.08	22.11	3.85	0.18		185.07

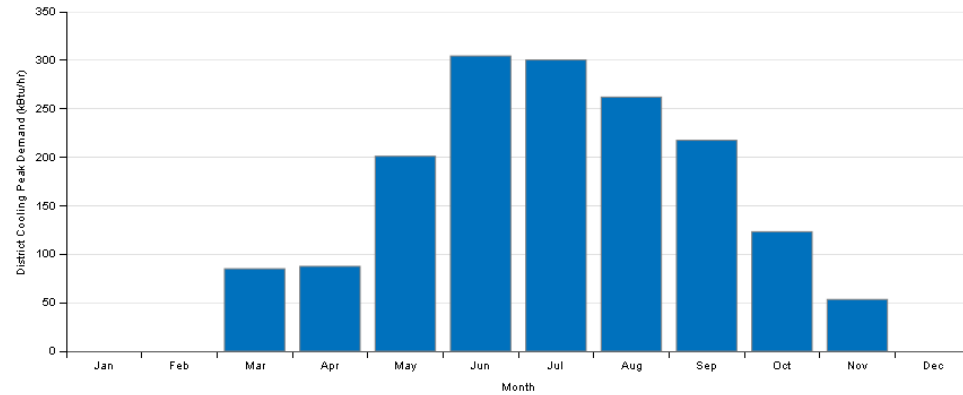
District Cooling Consumption (MBtu) - view table



District Cooling Peak Demand (kBtu/hr) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Heating											
Cooling			85.0242	87.5067	201.0073	304.4213	300.3302	262.0398	217.4922	123.2045	53.3665
Total			85.02	87.51	201.01	304.42	300.33	262.04	217.49	123.2	53.37

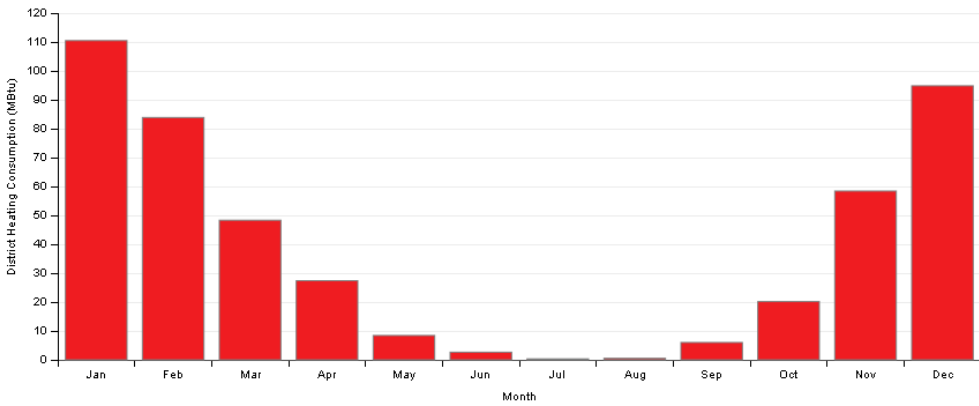
District Cooling Peak Demand (kBtu/hr) - view table



District Heating Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating	110.48	83.87	48.32	27.38	8.42	2.64	0.32	0.52	6.01	20.16	58.41	94.83	461.37

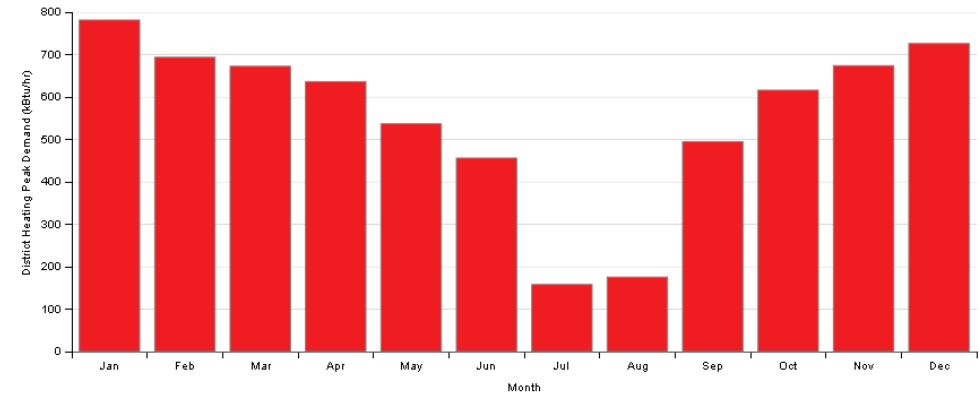
District Heating Consumption (MBtu) - view table



District Heating Peak Demand (kBtu/hr) - view table

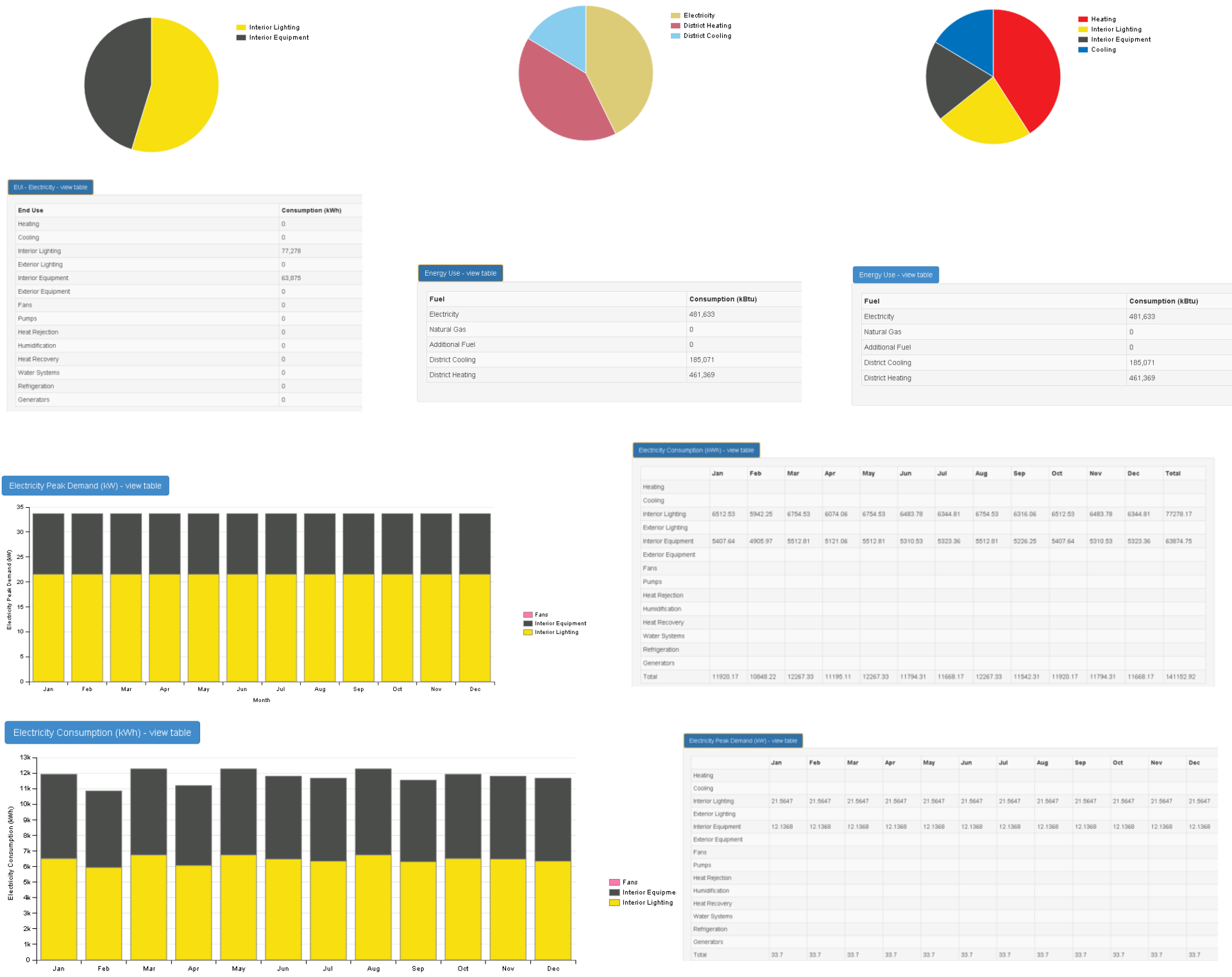
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heating	781.3524	693.6175	672.4036	636.2008	536.7877	456.0186	158.0201	175.4386	494.8185	616.0531	673.8814	726.0024
Total	781.35	693.62	672.4	636.2	536.79	456.02	158.02	175.44	494.82	616.05	673.88	726.0

District Heating Peak Demand (kBtu/hr) - view table



OPEN STUDIO – BUILDING SIMULATION PROJECT

SIMULATION OF BUILDING IN MILANO, ITALY



RESULTS

In the city of Milano, the building wall composition tests resulted in the total District Heating Consumption being read as 461.37 MBtu, while the District Cooling Consumption was 185.07 MBtu. Regarding the District Heating peak demand, the need is highest in the months of January and December - the demand in January being 781.35 kBtu/hr and in December the demand is 726.0 kBtu/hr. Relating to the District Cooling Peak demand periods, the highest demands exist in the months of June at 304.42 kBtu/hr, July at 300.33 kBtu/hr. The electricity consumption, relating to interior lighting was calculated as 77278.17 kWh. The consumption relating to interior equipment was calculated as 63874.75 kWh. The electricity demand in terms of interior lighting and equipment was the same in each month. At the end, it is discovered with the walls of the building containing the material of stucco, concrete, wall insulation at 25 cm, and gypsum, heating consumption exceeds the cooling consumption and interior lighting consumes less electricity than the interior equipment.

OPEN STUDIO – BUILDING SIMULATION PROJECT

SIMULATION OF BUILDING IN BARCELONA, SPAIN

The city of Barcelona is located in Catalonia, Spain. It is located 41.39 N latitude and 2.16 E longitude and it is situated at elevation 47 meters above sea level.

Weather Summary

	Value
Weather File	BARCELONA - ESP IWECC Data WMO#081810
Latitude	41.28
Longitude	2.07
Elevation	20 (ft)
Time Zone	1.00
North Axis Angle	0.00
ASHRAE Climate Zone	

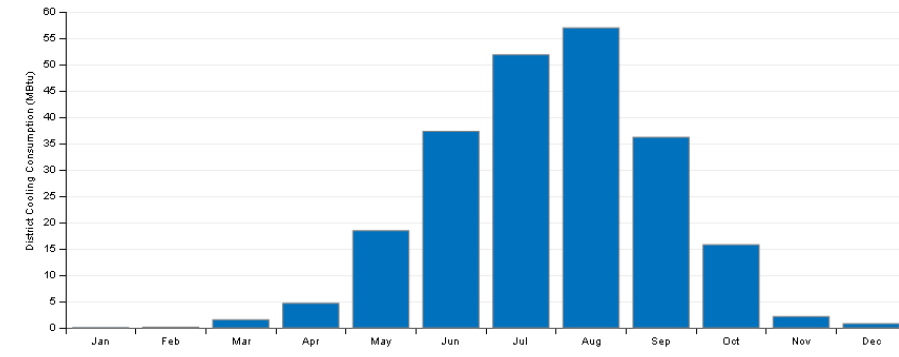
Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
BARCELONA ANN CLG .4% CONDNS DB=>MWB	86.36	13.86	74.84	Wetbulb [F]	9.84	210.0
BARCELONA ANN CLG .4% CONDNS DP=>MDB	82.04	13.86	75.56	Dewpoint [F]	9.84	210.0
BARCELONA ANN CLG .4% CONDNS ENTH=>MDB	84.02	13.86	33.4	Enthalpy [Btu/lb]	9.84	210.0
BARCELONA ANN CLG .4% CONDNS WB=>MDB	83.66	13.86	77.72	Wetbulb [F]	9.84	210.0
BARCELONA ANN HTG 99.6% CONDNS DB	33.62	0.0	33.62	Wetbulb [F]	9.62	350.0
BARCELONA ANN HTG WIND 99.6% CONDNS WS=>MCDB	52.16	0.0	52.16	Wetbulb [F]	24.38	350.0
BARCELONA ANN HUM_N 99.6% CONDNS DP=>MCDB	41.9	0.0	19.22	Dewpoint [F]	9.62	350.0
MILANO-LINATE ANN CLG .4% CONDNS DB=>MWB	91.4	18.36	75.38	Wetbulb [F]	5.14	220.0
MILANO-LINATE ANN CLG .4% CONDNS DP=>MDB	83.3	18.36	74.3	Dewpoint [F]	5.14	220.0
MILANO-LINATE ANN CLG .4% CONDNS ENTH=>MDB	87.8	18.36	33.32	Enthalpy [Btu/lb]	5.14	220.0
MILANO-LINATE ANN CLG .4% CONDNS WB=>MDB	87.8	18.36	77.36	Wetbulb [F]	5.14	220.0
MILANO-LINATE ANN HTG 99.6% CONDNS DB	22.82	0.0	22.82	Wetbulb [F]	0.89	240.0
MILANO-LINATE ANN HTG WIND 99.6% CONDNS WS=>MCDB	47.84	0.0	47.84	Wetbulb [F]	23.04	240.0
MILANO-LINATE ANN HUM_N 99.6% CONDNS DP=>MCDB	36.14	0.0	11.3	Dewpoint [F]	0.89	240.0

District Cooling Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating													
Cooling	0.04	0.12	1.53	4.64	18.44	37.3	51.84	56.96	36.18	15.77	2.14	0.78	225.75
Interior 1 Inhabitants													

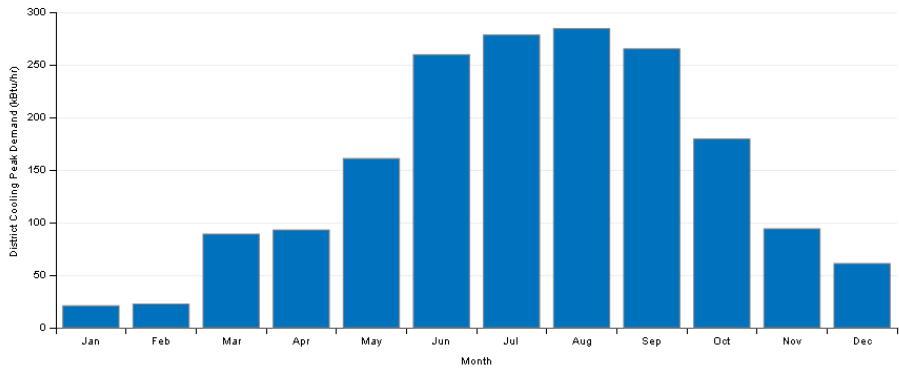
District Cooling Consumption (MBtu) - view table



District Cooling Peak Demand (kBtu/hr) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heating												
Cooling	20.8461	22.4816	88.9911	92.9071	160.8201	259.6023	278.3128	284.296	265.128	179.4406	94.0013	60.9689
Total	20.85	22.48	88.99	92.91	160.82	259.6	278.31	284.3	265.13	179.44	94.0	60.97

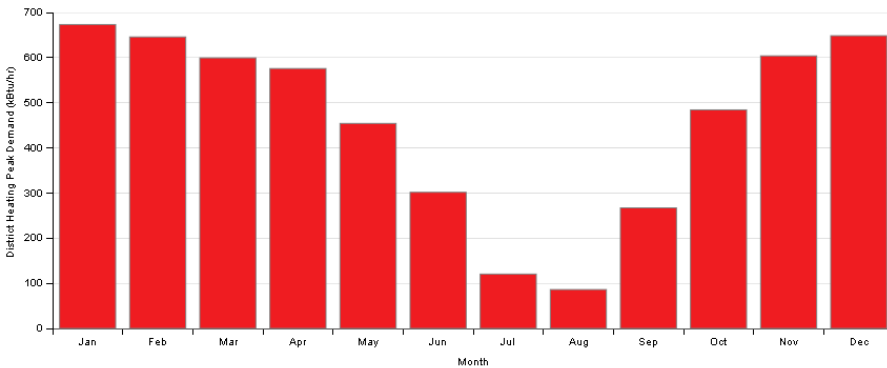
District Cooling Peak Demand (kBtu/hr) - view table



District Heating Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating	49.35	34.19	26.57	16.45	6.14	0.95	0.21	0.2	0.87	6.68	24.72	39.54	205.87

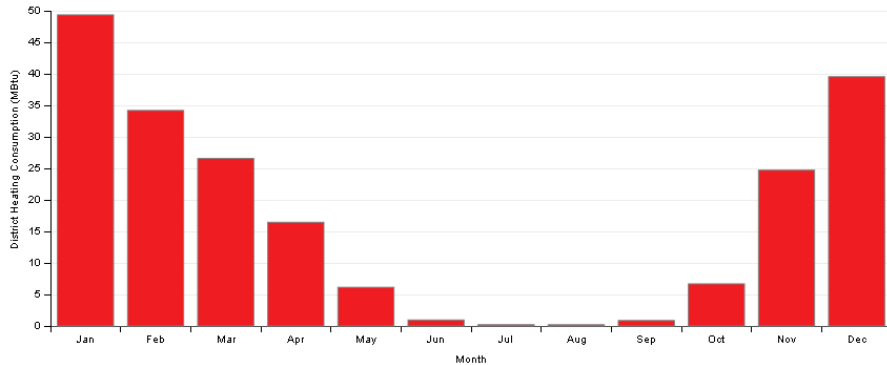
District Heating Peak Demand (kBtu/hr) - view table



District Heating Peak Demand (kBtu/hr) - view table

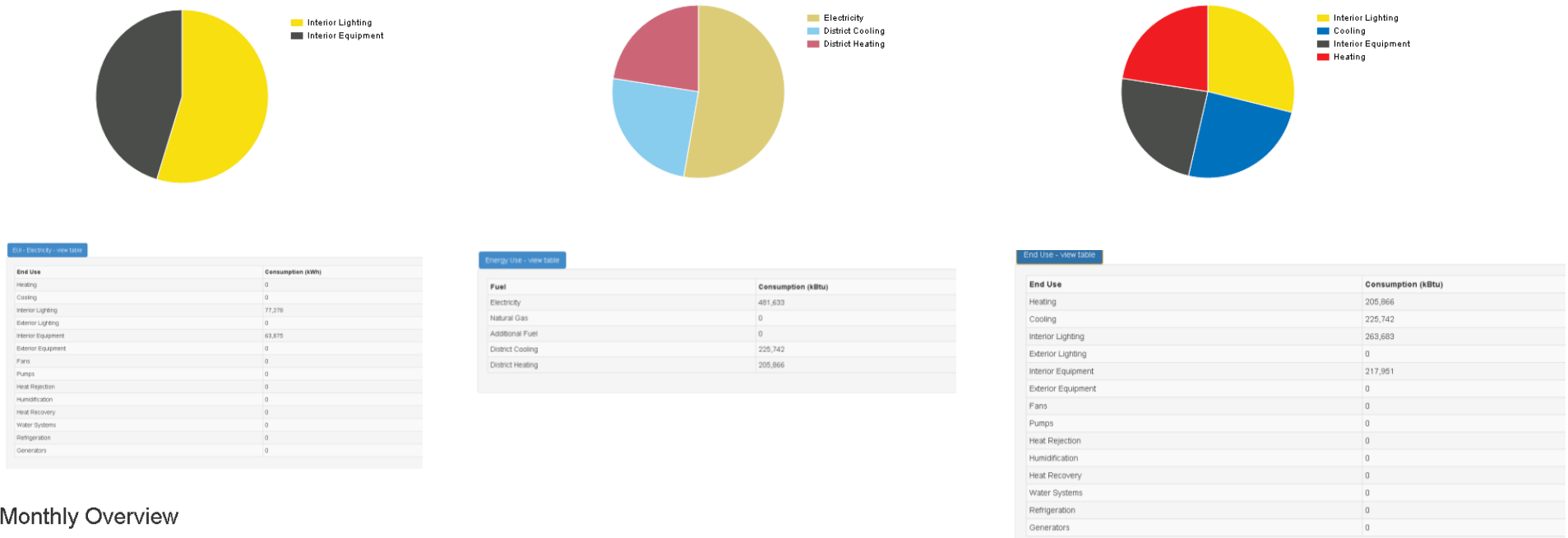
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heating	673.2822	645.82	599.4707	575.8016	454.2421	301.6395	120.4669	86.1202	267.1724	484.2362	603.8804	648.5178
Total	673.28	645.82	599.47	575.8	454.24	301.64	120.47	86.12	267.17	484.24	603.88	648.52

District Heating Consumption (MBtu) - view table

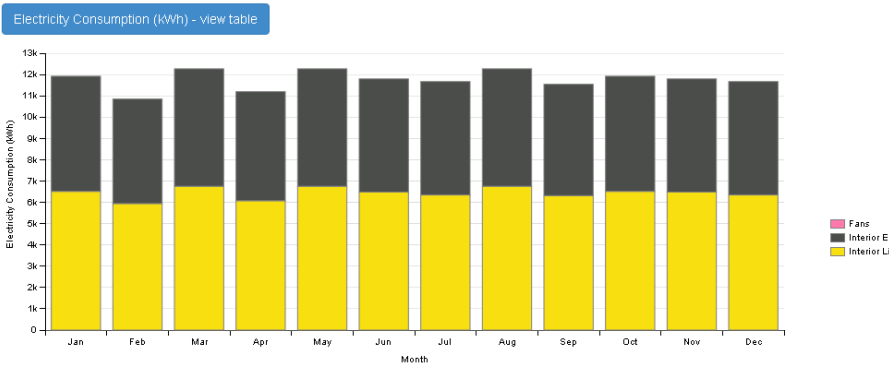


OPEN STUDIO – BUILDING SIMULATION PROJECT

SIMULATION OF BUILDING IN BARCELONA, SPAIN

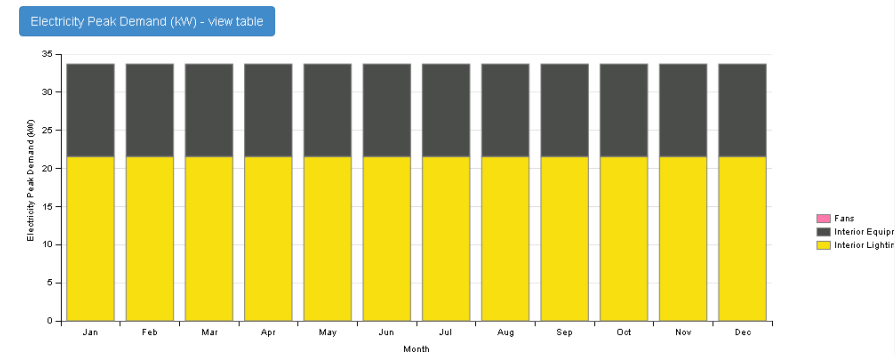


Monthly Overview



Electricity Consumption (kWh) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating													
Cooling													
Interior Lighting	6512.53	5942.25	6754.53	6074.06	6754.53	6483.78	6344.81	6754.53	6316.06	6512.53	6483.78	6344.81	77278.17
Exterior Lighting													
Interior Equipment	5407.64	4905.97	5512.81	5121.06	5512.81	5310.53	5323.36	5512.81	5226.25	5407.64	5310.53	5323.36	63874.75
Exterior Equipment													
Fans													
Pumps													
Heat Rejection													
Humidification													
Heat Recovery													
Water Systems													
Refrigeration													
Generators													
Total	11920.17	10848.22	12267.33	11195.11	12267.33	11794.31	11668.17	12267.33	11542.31	11920.17	11794.31	11668.17	141152.92



Electricity Peak Demand (kW) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Heating													
Cooling													
Interior Lighting	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647	21.5647
Exterior Lighting													
Interior Equipment	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368	12.1368
Exterior Equipment													
Fans													
Pumps													
Heat Rejection													
Humidification													
Heat Recovery													
Water Systems													
Refrigeration													
Generators													
Total	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7

RESULTS

In the city of Barcelona, the building wall composition tests resulted in the total District Heating Consumption being read as 205.87MBtu, while the District Cooling Consumption was 225.75 MBtu. Regarding the District Heating peak demand, the need is highest in the months of January and December - the demand in January being 673.29 kBtu/hr and in December the demand is 648.52 kBtu/hr. Relating to the District Cooling Peak demand periods, the highest demands exist in the months of July at 278.31 kBtu/hr and August at 264.3 kBtu/hr. The electricity consumption, relating to interior lighting was calculated as 77278.17 kWh. The consumption relating to interior equipment was calculated as 63874.75 kWh. The electricity demand in terms of interior lighting and equipment was the same in each month. At the end, it is discovered with the walls of the building containing the material of stucco, concrete, wall insulation at 25 cm, and gypsum, heating consumption exceeds the cooling consumption and interior lighting consumes less electricity than the interior equipment.

OPEN STUDIO – BUILDING SIMULATION PROJECT

SIMULATION OF BUILDING IN LONDON, UK

The city of London is located in south east of UK. It is located 51.5074° N latitude and 0.1278° W longitude and it is situated at elevation 11 meters above sea level.

Weather Summary

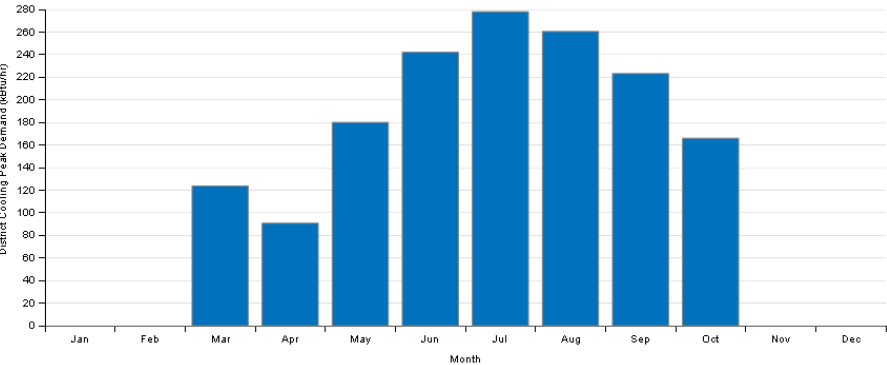
	Value
Weather File	London ON CAN WYEC2-B-94805 WMO#=716230
Latitude	43.03
Longitude	-81.2
Elevation	912 (ft)
Time Zone	-5.0
North Axis Angle	0.00
ASHRAE Climate Zone	

Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
LONDON ANN CLG 4% CONDNS DB=>MWB	86.18	18.36	72.14	Wetbulb [F]	10.51	260.0
LONDON ANN CLG 4% CONDNS DP=>MDB	78.98	18.36	71.78	Dewpoint [F]	10.51	260.0
LONDON ANN CLG 4% CONDNS ENTH=>MDB	83.12	18.36	30.91	Enthalpy [Btu/lb]	10.51	260.0
LONDON ANN CLG 4% CONDNS WB=>MDB	82.76	18.36	74.48	Wetbulb [F]	10.51	260.0
LONDON ANN HTG 99.6% CONDNS DB	-0.94	0.0	-0.94	Wetbulb [F]	7.61	260.0
LONDON ANN HTG WIND 99.6% CONDNS WS=>MCDB	19.58	0.0	19.58	Wetbulb [F]	29.97	260.0
LONDON ANN HUM_N 99.6% CONDNS DP=>MCDB	0.32	0.0	-9.76	Dewpoint [F]	7.61	260.0

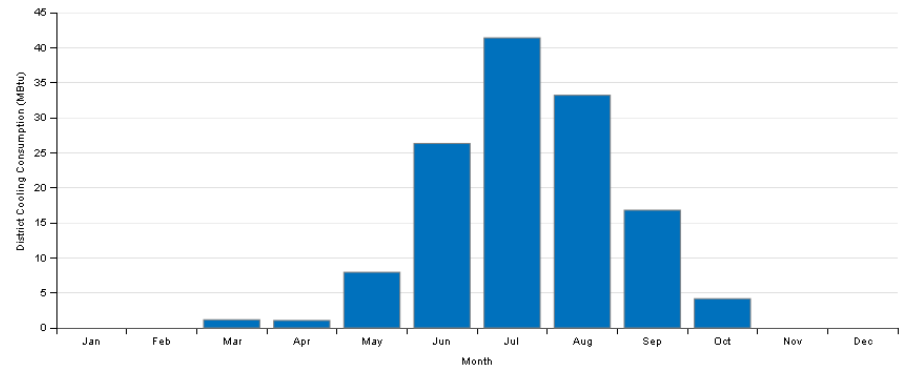
District Cooling Peak Demand (kBtu/hr) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Heating										
Cooling			123.6322	90.7138	179.9791	242.0752	277.9827	260.4817	223.2043	165.9424
Total			123.63	90.71	179.98	242.08	277.98	260.48	223.2	165.94



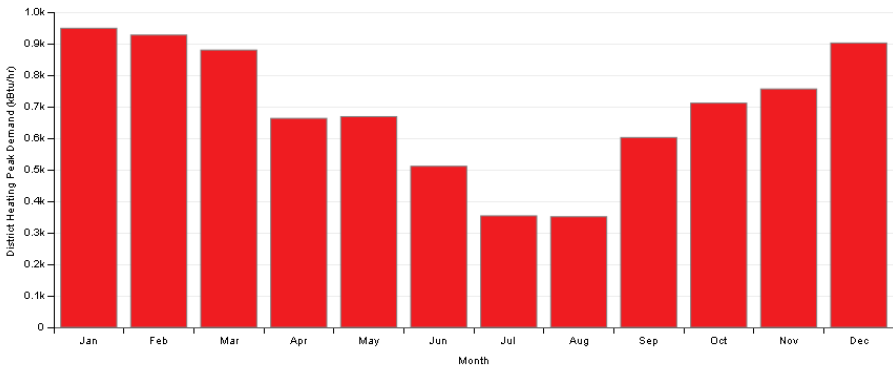
District Cooling Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating													
Cooling			1.16	1.06	7.94	26.32	41.39	33.2	16.8	4.17			132.05



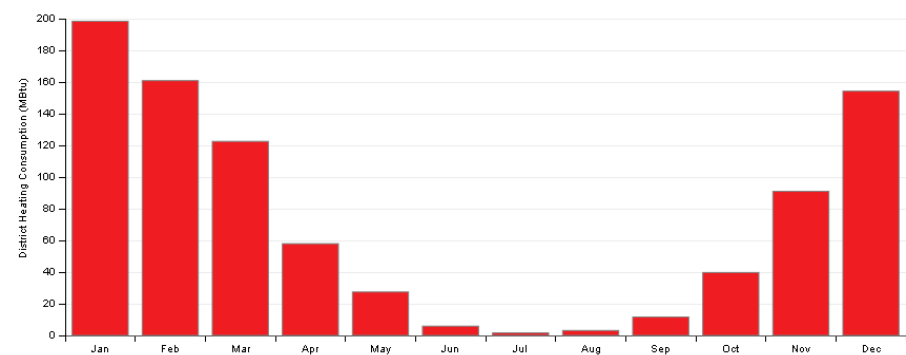
District Heating Peak Demand (kBtu/hr) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heating	949.7811	927.2614	879.5609	662.8695	668.4018	510.9656	353.5528	350.785	602.1622	711.3386	756.1535	901.9828
Total	949.78	927.26	879.56	662.87	668.4	510.97	353.55	350.79	602.16	711.34	756.15	901.98



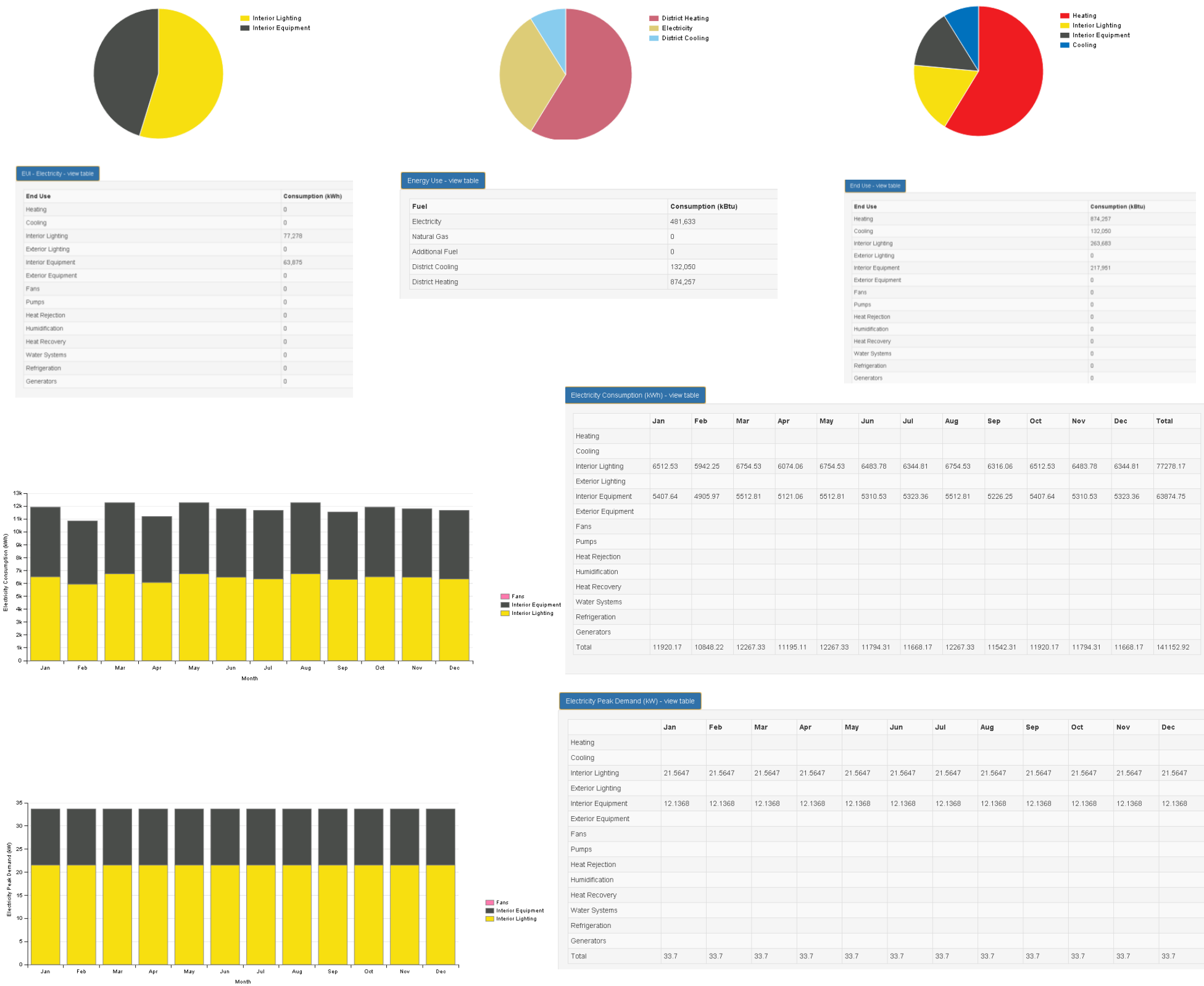
District Heating Consumption (MBtu) - view table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Heating	198.35	160.87	122.52	57.92	27.44	5.87	1.6	3.12	11.62	39.74	90.97	154.22	874.26



OPEN STUDIO – BUILDING SIMULATION PROJECT

SIMULATION OF BUILDING IN LONDON, UK



RESULTS

In the city of London, the building wall composition tests resulted in the total District Heating Consumption being read as 874.26 MBtu, while the District Cooling Consumption was 132.05 MBtu. Regarding the District Heating peak demand, the need is highest in the months of January and December - the demand in January being 948.78 kBtu/hr and in December the demand is 901.98 kBtu/hr. Relating to the District Cooling Peak demand periods, the highest demands exist in the months of June at 242.08 kBtu/hr, July at 277.98 kBtu/hr. The electricity consumption, relating to interior lighting was calculated as 77278.17 kWh. The consumption relating to interior equipment was calculated as 63874.75 kWh. The electricity demand in terms of interior lighting and equipment was the same in each month. At the end, it is discovered with the walls of the building containing the material of stucco, concrete, wall insulation at 25 cm, and gypsum, heating consumption exceeds the cooling consumption and interior lighting consumes less electricity than the interior equipment.