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POLITECNICO DI MILANO

SUSTAINABLE ARCHITECTURE AND LANDSCAPE DESIGN

TECHNICAL ENVIRONMENTAL SYSTEMS

Study on Enery-performance in the buildings

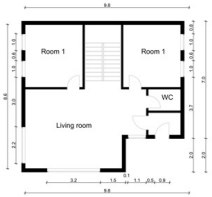
2017/2018

Building

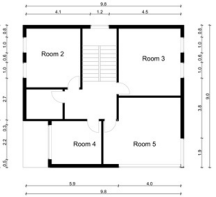
The chosen building represents the residential typology of buildings.

This house includes two floors: Ground floor and 1st floor. Total area per sqm: 164.

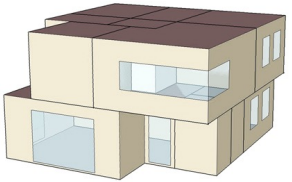
A composition such as this,makes it possible to have varieties of its form and shape.



ground floor



1st floor



3D view

Location

Quebec, Canada

Geneva, Switzerland

Sydney, Australia

The locations were chosen mainly based on the climate zone criteria.

These zones vary as it follows:
Warm zone: Australia- CLIMATE ZONE 3
Average zone: Switzerland- CLIMATE ZONE 5
Cold zone: Canada- CLIMATE ZONE 7

Materials

In order to measure the energy-loss of the building, it was decided to test 3different materials with different resistents.

Using these types of materials, how the results of each reaction will be, it is demonstrated in the following pages of this assigment

Nonres Ext. Wall Wood-Framed

WOOD

Nonres Ext. Wall Steel-Framed

STEEL

ASHRAE Ext. Wall Mass

CONCRETE

Units

The standard units for Open Studio are the BRITISH units.

This table-sheet stands for converting BRITISH units into INTERNATIONAL ones.

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

Study procedure

1. The software was used in order to calculate the heating and cooling consumption of the building in the yearly period of time.

2. A parametric study is needed to follow the effect of changing the position and wall characteristics on the chosen building of the energy based on yearly consumption.

3. Additionally, this simmulation should be performed in three different cities and three types of materials as shown in previous page in order to do the comparison with the basic case.

Locations background

According to the ASHREA- Climate Zone, we have chosen three different cities with different climate-zones.

Table (1) shows the condition of each zone.

Table (2) shows the cities we chose and the climate-zone they belong at.

Table (3) is generated by Open Studio software, showing the weather/climate condition based on periods of the year.

International Climate Zone Definitions (Table 3)

Zone Number	Zone Name	Thermal Criteria (I-P Units)	Thermal Criteria (SI Units)
1A and 1B	Very Hot –Humid (1A) Dry (1B)	9000 < CDD50°F	5000 < CDD10°C
2A and 2B	Hot-Humid (2A) Dry (2B)	6300 < CDD50°F ≤ 9000	3500 < CDD10°C ≤ 5000
3A and 3B	Warm – Humid (3A) Dry (3B)	4500 < CDD50°F ≤ 6300	2500 < CDD10°C < 3500
3C	Warm – Marine (3C)	CDD50°F ≤ 4500 AND HDD65°F ≤ 3600	CDD10°C ≤ 2500 AND HDD18°C ≤ 2000
4A and 4B	Mixed-Humid (4A) Dry (4B)	CDD50°F ≤ 4500 AND 3600 < HDD65°F ≤ 5400	CDD10°C ≤ 2500 AND HDD18°C ≤ 3000
4C	Mixed – Marine (4C)	3600 < HDD65°F ≤ 5400	2000 < HDD18°C ≤ 3000
5A, 5B, and 5C	Cool-Humid (5A) Dry (5B) Marine (5C)	5400 < HDD65°F ≤ 7200	3000 < HDD18°C ≤ 4000
6A and 6B	Cold – Humid (6A) Dry (6B)	7200 < HDD65°F ≤ 9000	4000 < HDD18°C ≤ 5000
7	Very Cold	9000 < HDD65°F ≤ 12600	5000 < HDD18°C ≤ 7000
8	Subarctic	12600 < HDD65°F	7000 < HDD18°C

Quebec (PQ)	
Bagotville A	7
Drummondville	6
Granby	6
Montreal Dorval Int'l A	6
Quebec A	7

Australia	
Adelaide (SA)	4
Alice Springs (NT)	2
Brisbane (AL)	2
Darwin Airport (NT)	1
Perth/Guildford (WA)	3
Sydney/KSmith (NSW)	3

Switzerland	
Zurich	5

Syria	
Damascus Airport	3

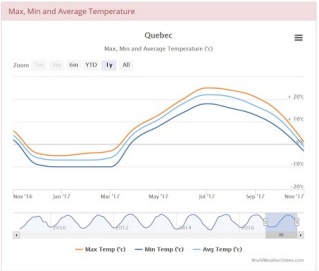
(Table 2)

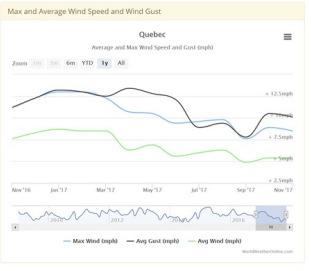
Sizing Period Design Days (Table 3)

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
BAGOTVILLE ANN CLG .4% CONDNS DB=>MWB	84.56	18.9	66.92	Wetbulb [F]	9.84	270.0
BAGOTVILLE ANN CLG .4% CONDNS DP=>MDB	73.94	18.9	66.92	Dewpoint [F]	9.84	270.0
BAGOTVILLE ANN CLG .4% CONDNS ENTH=>MDB	79.88	18.9	26.7	Enthalpy [Btu/lb]	9.84	270.0
BAGOTVILLE ANN CLG .4% CONDNS WB=>MDB	79.7	18.9	69.98	Wetbulb [F]	9.84	270.0
BAGOTVILLE ANN HTG 99.6% CONDNS DB	-22.18	0.0	-22.18	Wetbulb [F]	5.59	270.0
BAGOTVILLE ANN HTG WIND 99.6% CONDNS WS=>MCDB	4.64	0.0	4.64	Wetbulb [F]	31.54	270.0
BAGOTVILLE ANN HUM_N 99.6% CONDNS DP=>MCDB	-21.1	0.0	-28.84	Dewpoint [F]	5.59	270.0
GENEVA ANN CLG .4% CONDNS DB=>MWB	87.44	20.7	66.74	Wetbulb [F]	7.61	230.0
GENEVA ANN CLG .4% CONDNS DP=>MDB	72.86	20.7	64.04	Dewpoint [F]	7.61	230.0
GENEVA ANN CLG .4% CONDNS ENTH=>MDB	82.58	20.7	25.8	Enthalpy [Btu/lb]	7.61	230.0
GENEVA ANN CLG .4% CONDNS WB=>MDB	82.22	20.7	68.36	Wetbulb [F]	7.61	230.0
GENEVA ANN HTG 99.6% CONDNS DB	19.58	0.0	19.58	Wetbulb [F]	5.14	240.0
GENEVA ANN HTG WIND 99.6% CONDNS WS=>MCDB	34.88	0.0	34.88	Wetbulb [F]	25.28	240.0
GENEVA ANN HUM_N 99.6% CONDNS DP=>MCDB	23.36	0.0	12.2	Dewpoint [F]	5.14	240.0
SYDNEY ANN CLG .4% CONDNS DB=>MWB	87.98	10.8	68.0	Wetbulb [F]	0.0	0.0
SYDNEY ANN CLG .4% CONDNS DP=>MDB	77.18	10.8	71.24	Dewpoint [F]	0.0	0.0
SYDNEY ANN CLG .4% CONDNS ENTH=>MDB	81.14	10.8	29.54	Enthalpy [Btu/lb]	0.0	0.0
SYDNEY ANN CLG .4% CONDNS WB=>MDB	80.78	10.8	73.58	Wetbulb [F]	0.0	0.0
SYDNEY ANN HTG 99.6% CONDNS DB	44.96	0.0	44.96	Wetbulb [F]	0.0	0.0
SYDNEY ANN HUM_N 99.6% CONDNS DP=>MCDB	60.08	0.0	26.6	Dewpoint [F]	0.0	0.0

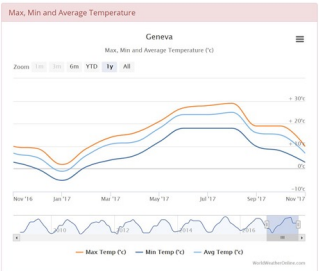
Locations background

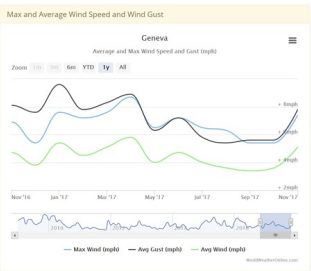
Quebec



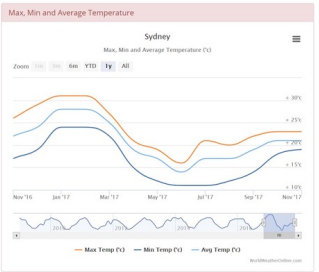


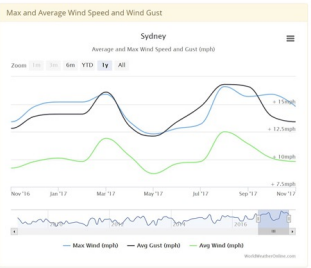
Geneva





Sydney

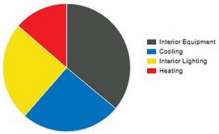




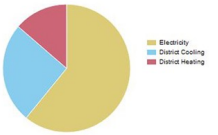
Annual Overview

SYDNEY- AUSTRALIA

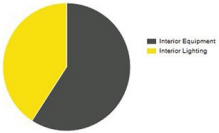
End Use - view table



Energy Use - view table



EUI - Electricity - view table



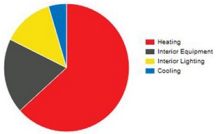
EUI - Gas - view table

Site and Source Energy

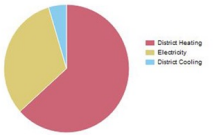
	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	68.65	490.69	490.69
Net Site Energy	68.65	490.69	490.69
Total Source Energy	183.92	1314.69	1314.69
Net Source Energy	183.92	1314.69	1314.69

GENEVA-SWITZERLAND

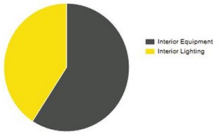
End Use - view table



Energy Use - view table



EUI - Electricity - view table



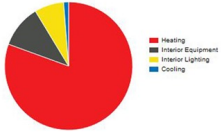
EUI - Gas - view table

Site and Source Energy

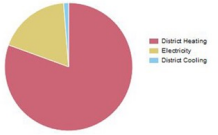
	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	192.78	1377.99	1377.99
Net Site Energy	192.78	1377.99	1377.99
Total Source Energy	668.49	4778.35	4778.35
Net Source Energy	668.49	4778.35	4778.35

QUEBEC -CANADA

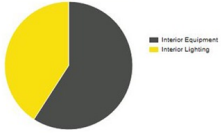
End Use - view table



Energy Use - view table



EUI - Electricity - view table



EUI - Gas - view table

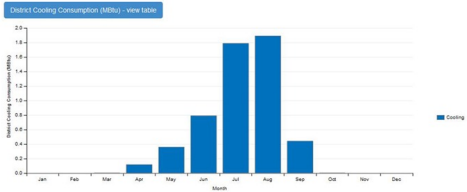
Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	112.97	807.49	807.49
Net Site Energy	112.97	807.49	807.49
Total Source Energy	371.23	2653.52	2653.52
Net Source Energy	371.23	2653.52	2653.52

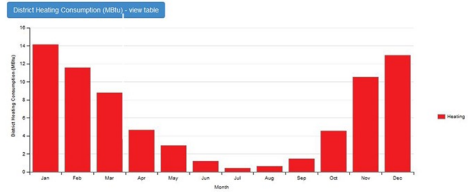
In the diagrams above it is demonstrated how the energy is consumed in diferent locations. In Australia, where the cliamte is warmer more energy is spent on cooling than heating. In Switzerland % Canada which are colder regions most of the energy during the year is spent on heating the building.

District cooling & heating consumption

Geneva

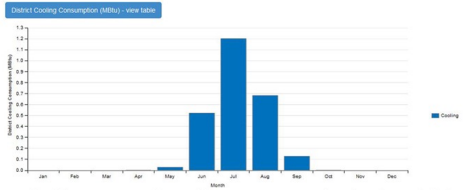


In the diagram we see the monthly energy consumption that is needed for cooling the building. The highest amount of energy is consumed in August since that is the hottest month in Switzerland.

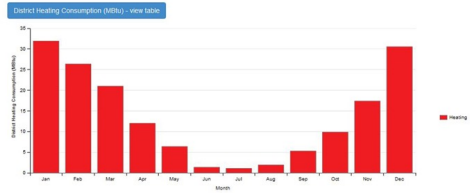


In the diagram we see the monthly energy consumption that is needed for heating the building. The highest amount of energy is consumed in January since that is the coldest month in Switzerland.

Quebec

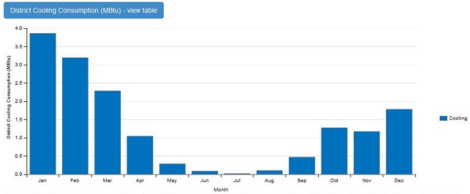


In the diagram we see the monthly energy consumption that is needed for cooling the building. The highest amount of energy is consumed in July since that is the hottest month in Canada.

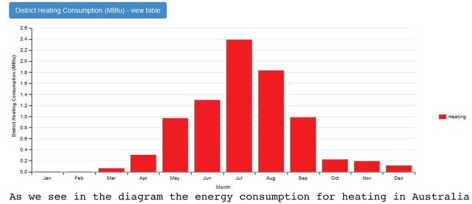


As we see in the diagram the energy consuption for heating the building is 2 times higher in Canada than Switzerland, since that is a colder region.The coldest month is January.

Sydney



Australia is a warmer country compared than the first two so the energy consumtion for cooling is 3 times higher. The monthly energy consumption here is oposite to the first two because the warmest month is January.

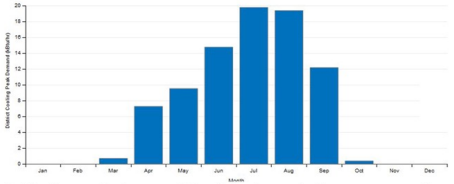


As we see in the diagram the energy consumption for heating in Australia is 6 times lower than Switzerland and 12 times lower than Canada. The coldest month is July.

District cooling & heating consumption

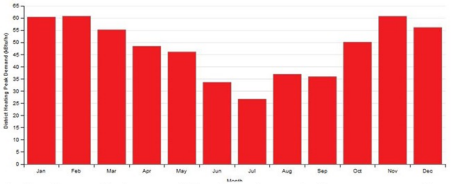
Geneva

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



In the diagram it is assumed the highest amount of energy consumption that could be consumed for cooling the building in a specific month.

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



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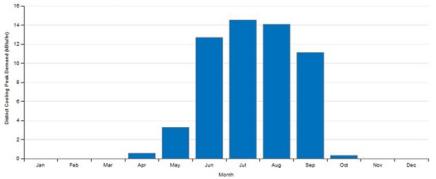
Quebec

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



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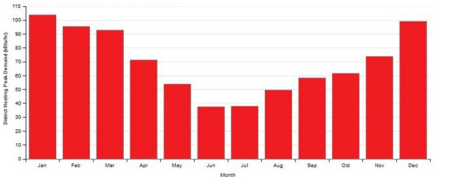
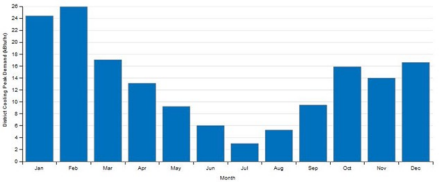
District Heating Peak Demand (kBtu/hr) - view table



In the diagram it is assumed the highest amount of energy consumption that could be consumed for heating the building in a specific month.

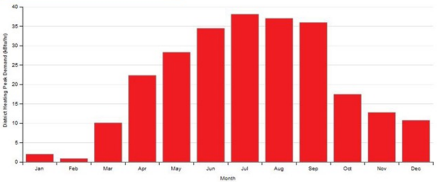
Sydney

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



In the diagram it is assumed the highest amount of energy consumption that could be consumed for cooling the building in a specific month.

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



In the diagram it is assumed the highest amount of energy consumption that could be consumed for heating the building in a specific month.

cooling

heating

Experimental results

The generated results from the software OpenStudio.

Geneva

Base Surface Constructions

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 5	1,506	11	19.96
ASHRAE 189.1-2009 ExtWall Mass ClimateZone 5	1,962	23	11.76

Table (1) - shows the calculation of external surfaces of the building. The construction is concrete structure with insulation.
In the table, it is also shown the area in the R Value.

Sub Surface Constructions

Construction	Area (ft^2)	Surface Count	U-Factor (Btu/ft^2*h*R)
ASHRAE 189.1-2009 ExtWindow ClimateZone 1	460	15	

Table (2) - shows the area of windows in the building.

WWR & Skylight Ratio

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	18.98	4.45	15.02	25.9	31.19
Gross Window-Wall Ratio (Conditioned)	18.98	4.45	15.02	25.9	31.19
Skylight-Roof Ratio	0.0				

Table (3) - shows position & orientation in percentage of the windows in the building.

Sydney

Base Surface Constructions

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 1	1,506	11	19.96
ASHRAE 189.1-2009 ExtWall Mass ClimateZone 3	1,962	23	15.84

Sub Surface Constructions

Construction	Area (ft^2)	Surface Count	U-Factor (Btu/ft^2*h*R)
ASHRAE 189.1-2009 ExtWindow ClimateZone 1	460	15	

WWR & Skylight Ratio

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	18.98	4.45	15.02	25.9	31.19
Gross Window-Wall Ratio (Conditioned)	18.98	4.45	15.02	25.9	31.19
Skylight-Roof Ratio	0.0				

Quebec

Base Surface Constructions

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 2-5 1	1,506	11	24.73
ASHRAE 189.1-2009 ExtWall Mass ClimateZone 7	1,962	23	8.77

Sub Surface Constructions

Construction	Area (ft^2)	Surface Count	U-Factor (Btu/ft^2*h*R)
ASHRAE 189.1-2009 ExtWindow ClimateZone 7	460	15	

WWR & Skylight Ratio

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	18.98	4.45	15.02	25.9	31.19
Gross Window-Wall Ratio (Conditioned)	18.98	4.45	15.02	25.9	31.19
Skylight-Roof Ratio	0.0				

RESULTS COMPARISON

The calculated R Value of the building in three different cities shows that the building located in the coldest city- Quebec, has the lowest R Value of 8.77 ft^2- converting 0.814(K. m2/W).
On the other hand, the highest R value is Sydney with 15.84 ft^2 converting 1.55(K.m2/W).

This is an outcome of the high amount of insulation used in Quebec, Canada, belonging the climate-zone 7.

Geneva, Switzerland

Concrete exterior wall

Base Surface Constructions

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 5	1,506	11	19.96
ASHRAE 189.1-2009 ExtWall Mass ClimateZone 5	1,962	23	11.76

Sub Surface Constructions

Construction	Area (ft^2)	Surface Count	U-Factor (Btu/ft^2*h*R)
ASHRAE 189.1-2009 ExtWindow ClimateZone 1	460	15	

WWR & Skylight Ratio

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	18.98	4.45	15.02	25.9	31.19
Gross Window-Wall Ratio (Conditioned)	18.98	4.45	15.02	25.9	31.19
Skylight-Roof Ratio	0.0				

Wood exterior wall

Base Surface Constructions

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
90.1-1999 Nonres B7 Ext Wall Wood-Framed and Other	1,962	23	10.39
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 1	1,506	11	19.96

Sub Surface Constructions

Construction	Area (ft^2)	Surface Count	U-Factor (Btu/ft^2*h*R)
ASHRAE 189.1-2009 ExtWindow ClimateZone 1	460	15	

WWR & Skylight Ratio

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	18.98	4.45	15.02	25.9	31.19
Gross Window-Wall Ratio (Conditioned)	18.98	4.45	15.02	25.9	31.19
Skylight-Roof Ratio	0.0				

Metal exterior wall

Base Surface Constructions

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
90.1-1999 Nonres B5 Ext Wall Metal Building	1,962	23	8.01
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 1	1,506	11	19.96

Sub Surface Constructions

Construction	Area (ft^2)	Surface Count	U-Factor (Btu/ft^2*h*R)
ASHRAE 189.1-2009 ExtWindow ClimateZone 1	460	15	

WWR & Skylight Ratio

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	18.98	4.45	15.02	25.9	31.19
Gross Window-Wall Ratio (Conditioned)	18.98	4.45	15.02	25.9	31.19
Skylight-Roof Ratio	0.0				

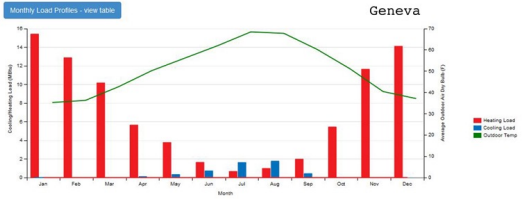
CONCLUSION

In the city of Geneva we have used three different materials for the exterior wall of the building, and the above tables are a result from Open Studio software calculations. As we can notice, the R Value for Concrete is 11.76 ft^2 converting 1.09 (K.m2/W); The R Value of Wood is 10.39 ft^2 converting 0.695 (K.m2/W); The R Value of Steel is 8.01 ft^2 converting 7.44 (K.m2/W).

Although, Steel has a very low resistance, the R Value is better than the other two materials. Such a result, is because the construction set in Open Studio has better insulation added to the steel-framed material, considering insulation is the main factor preventing the energy-loss in the building.

Building loads

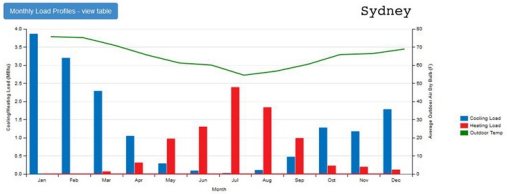
HVAC Load Profiles



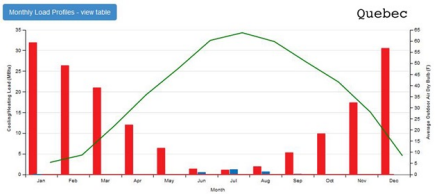
In the diagrams below we see the monthly heating and cooling loads of the building in comparision to the outter temperature. As we can see, in Canada there is a lot of energy consumed on heating during the winter, whereas in Australia cooling the building is a higher priority than heating.

In the table below we see the general statistics of each city such as: Dryness, Daily temperature, humidity, wind speed and wind direction.

HVAC Load Profiles



HVAC Load Profiles



Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
BAGOTVILLE ANN CLG .4% CONDNS DB=>MWB	84.56	18.9	66.92	Wetbulb [F]	9.84	270.0
BAGOTVILLE ANN CLG .4% CONDNS DP=>MDB	73.94	18.9	66.92	Dewpoint [F]	9.84	270.0
BAGOTVILLE ANN CLG .4% CONDNS ENTH=>MDB	79.88	18.9	26.7	Enthalpy [Btu/lb]	9.84	270.0
BAGOTVILLE ANN CLG .4% CONDNS WB=>MDB	79.7	18.9	69.98	Wetbulb [F]	9.84	270.0
BAGOTVILLE ANN HTG 99.6% CONDNS DB	-22.18	0.0	-22.18	Wetbulb [F]	5.59	270.0
BAGOTVILLE ANN HTG WIND 99.6% CONDNS WS=>MCDB	4.64	0.0	4.64	Wetbulb [F]	31.54	270.0
BAGOTVILLE ANN HUM_N 99.6% CONDNS DP=>MCDB	-21.1	0.0	-28.84	Dewpoint [F]	5.59	270.0
GENEVA ANN CLG .4% CONDNS DB=>MWB	87.44	20.7	66.74	Wetbulb [F]	7.61	230.0
GENEVA ANN CLG .4% CONDNS DP=>MDB	72.86	20.7	64.04	Dewpoint [F]	7.61	230.0
GENEVA ANN CLG .4% CONDNS ENTH=>MDB	82.58	20.7	25.8	Enthalpy [Btu/lb]	7.61	230.0
GENEVA ANN CLG .4% CONDNS WB=>MDB	82.22	20.7	68.36	Wetbulb [F]	7.61	230.0
GENEVA ANN HTG 99.6% CONDNS DB	19.58	0.0	19.58	Wetbulb [F]	5.14	240.0
GENEVA ANN HTG WIND 99.6% CONDNS WS=>MCDB	34.88	0.0	34.88	Wetbulb [F]	25.28	240.0
GENEVA ANN HUM_N 99.6% CONDNS DP=>MCDB	23.36	0.0	12.2	Dewpoint [F]	5.14	240.0
SYDNEY ANN CLG .4% CONDNS DB=>MWB	87.98	10.8	68.0	Wetbulb [F]	0.0	0.0
SYDNEY ANN CLG .4% CONDNS DP=>MDB	77.18	10.8	71.24	Dewpoint [F]	0.0	0.0
SYDNEY ANN CLG .4% CONDNS ENTH=>MDB	81.14	10.8	29.54	Enthalpy [Btu/lb]	0.0	0.0
SYDNEY ANN CLG .4% CONDNS WB=>MDB	80.78	10.8	73.58	Wetbulb [F]	0.0	0.0
SYDNEY ANN HTG 99.6% CONDNS DB	44.96	0.0	44.96	Wetbulb [F]	0.0	0.0
SYDNEY ANN HUM_N 99.6% CONDNS DP=>MCDB	60.08	0.0	26.6	Dewpoint [F]	0.0	0.0

Geneva

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 56 (F)	56-61 (F)	61-66 (F)	66-68 (F)	68-70 (F)	70-72 (F)	72-74 (F)	74-76 (F)	76-78 (F)	78-83 (F)	>= 88 (F)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (F)
THERMAL ZONE 1	0	0	0	2138	998	261	3020	700	461	1101	41	31	0	0	0	67.6 (F)
THERMAL ZONE 2	0	0	0	2752	602	196	4101	362	263	425	40	19	0	0	0	66.7 (F)
THERMAL ZONE 3	0	0	0	1996	969	255	3560	610	560	1153	41	36	0	0	0	67.8 (F)
THERMAL ZONE 4	0	0	0	1871	1139	318	4126	666	403	227	10	0	0	0	0	67.1 (F)
THERMAL ZONE 5	0	0	0	1420	1485	395	4143	724	432	159	2	0	0	0	0	67.3 (F)

Humidity (Table values represent hours spent in each Humidity range)

Zone	< 30 (%)	30-35 (%)	35-40 (%)	40-45 (%)	45-50 (%)	50-55 (%)	55-60 (%)	60-65 (%)	65-70 (%)	70-75 (%)	>= 80 (%)	Mean Relative Humidity (%)
THERMAL ZONE 1	1706	1197	1099	1139	990	745	590	537	437	194	113	43.1 (%)
THERMAL ZONE 2	2388	1021	843	896	767	712	587	498	486	322	162	42.5 (%)
THERMAL ZONE 3	2088	1219	985	1236	894	728	581	558	286	142	43	41.2 (%)
THERMAL ZONE 4	2532	996	884	879	783	704	649	636	420	190	71	41.2 (%)
THERMAL ZONE 5	2352	1101	874	868	779	738	642	672	416	221	77	41.9 (%)

Quebec

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 56 (F)	56-61 (F)	61-66 (F)	66-68 (F)	68-70 (F)	70-72 (F)	72-74 (F)	74-76 (F)	76-78 (F)	78-83 (F)	>= 88 (F)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (F)
THERMAL ZONE 1	0	0	0	2835	675	201	3567	483	328	651	0	0	0	0	0	66.6 (F)
THERMAL ZONE 2	0	0	0	3256	492	127	4368	211	142	154	0	0	0	0	0	66.0 (F)
THERMAL ZONE 3	0	0	0	2706	723	210	3523	563	370	664	1	0	0	0	0	66.8 (F)
THERMAL ZONE 4	0	0	0	2536	956	246	4354	435	185	48	0	0	0	0	0	66.3 (F)
THERMAL ZONE 5	0	0	0	2156	1239	326	4357	461	195	26	0	0	0	0	0	66.5 (F)

Humidity (Table values represent hours spent in each Humidity range)

Zone	< 30 (%)	30-35 (%)	35-40 (%)	40-45 (%)	45-50 (%)	50-55 (%)	55-60 (%)	60-65 (%)	65-70 (%)	70-75 (%)	>= 80 (%)	Mean Relative Humidity (%)
THERMAL ZONE 1	4472	615	599	569	589	520	397	281	232	215	144	32.6 (%)
THERMAL ZONE 2	4779	544	540	452	478	426	388	275	284	187	152	31.3 (%)
THERMAL ZONE 3	4676	592	606	596	606	482	375	276	216	170	109	30.8 (%)
THERMAL ZONE 4	4879	535	540	515	497	475	348	278	235	194	141	30.2 (%)
THERMAL ZONE 5	4766	584	522	522	564	517	350	279	214	204	157	30.9 (%)

Sydney

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 56 (F)	56-61 (F)	61-66 (F)	66-68 (F)	68-70 (F)	70-72 (F)	72-74 (F)	74-76 (F)	76-78 (F)	78-83 (F)	>= 88 (F)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (F)
THERMAL ZONE 1	0	0	0	185	1112	681	1214	1413	1265	2775	79	36	0	0	0	71.0 (F)
THERMAL ZONE 2	0	0	0	790	1202	514	3035	925	891	1269	69	45	0	0	0	69.2 (F)
THERMAL ZONE 3	0	0	0	50	817	539	943	1236	1217	3624	240	94	0	0	0	72.1 (F)
THERMAL ZONE 4	0	0	0	22	570	686	2137	1863	1771	1345	53	13	0	0	0	70.6 (F)
THERMAL ZONE 5	0	0	0	15	1079	845	2870	2041	1437	467	6	0	0	0	0	69.8 (F)

Humidity (Table values represent hours spent in each Humidity range)

Zone	< 30 (%)	30-35 (%)	35-40 (%)	40-45 (%)	45-50 (%)	50-55 (%)	55-60 (%)	60-65 (%)	65-70 (%)	70-75 (%)	>= 80 (%)	Mean Relative Humidity (%)
THERMAL ZONE 1	484	506	615	810	1243	1169	1106	876	649	578	368	53.6 (%)
THERMAL ZONE 2	672	449	528	689	781	925	893	926	911	791	581	56.0 (%)
THERMAL ZONE 3	741	589	733	1231	1585	1064	841	611	581	396	259	49.5 (%)
THERMAL ZONE 4	842	595	636	797	924	996	939	840	710	616	434	52.9 (%)
THERMAL ZONE 5	697	499	609	670	790	944	940	785	764	706	603	55.9 (%)

In these tables we see how the temperature and humidity behawes in each thermal zone.

In Geneva & Quebec it is shown the average temperature for each zone is 20-21 °C, whereas humidity is lower than 30%. In Sydney these values are less clear depending onthe thermal zones.The humidity of each thermal zone in Sydney has a higher percentage (above 50%) compared to the two colder cities.

Concrete

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 56 (F)	56-61 (F)	61-66 (F)	66-68 (F)	68-70 (F)	70-72 (F)	72-74 (F)	74-76 (F)	76-78 (F)	78-83 (F)	>= 88 (F)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (F)
THERMAL ZONE 1	0	0	0	2138	998	261	3029	700	461	1101	41	31	0	0	0	67.6 (F)
THERMAL ZONE 2	0	0	0	2152	602	196	4101	362	263	425	40	19	0	0	0	66.7 (F)
THERMAL ZONE 3	0	0	0	1996	989	255	2960	810	560	1113	41	36	0	0	0	67.8 (F)
THERMAL ZONE 4	0	0	0	1871	1139	318	4126	666	403	227	10	0	0	0	0	67.1 (F)
THERMAL ZONE 5	0	0	0	1420	1485	395	4143	724	432	159	2	0	0	0	0	67.3 (F)

Humidity (Table values represent hours spent in each Humidity range)

Zone	< 30 (%)	30-35 (%)	35-40 (%)	40-45 (%)	45-50 (%)	50-55 (%)	55-60 (%)	60-65 (%)	65-70 (%)	70-75 (%)	>= 80 (%)	Mean Relative Humidity (%)
THERMAL ZONE 1	1708	1197	1089	1139	990	745	590	537	437	194	113	43.1 (%)
THERMAL ZONE 2	2388	1021	843	896	767	712	587	498	486	322	162	42.5 (%)
THERMAL ZONE 3	2068	1219	985	1236	894	728	581	558	286	142	43	41.2 (%)
THERMAL ZONE 4	2532	996	884	879	783	704	649	636	420	190	71	41.2 (%)
THERMAL ZONE 5	2352	1101	874	865	779	738	642	672	416	221	77	41.9 (%)

Steel

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 56 (F)	56-61 (F)	61-66 (F)	66-68 (F)	68-70 (F)	70-72 (F)	72-74 (F)	74-76 (F)	76-78 (F)	78-83 (F)	>= 88 (F)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (F)
THERMAL ZONE 1	0	0	0	2138	942	254	3088	633	417	1021	36	29	0	0	0	67.3 (F)
THERMAL ZONE 2	0	0	0	2090	594	161	4116	326	227	391	35	18	0	0	0	66.5 (F)
THERMAL ZONE 3	0	0	0	2191	968	258	3170	656	476	976	30	35	0	0	0	67.4 (F)
THERMAL ZONE 4	0	0	0	2048	1116	309	4156	584	340	196	9	0	0	0	0	66.9 (F)
THERMAL ZONE 5	0	0	0	1536	1471	408	4158	669	380	137	1	0	0	0	0	67.2 (F)

Humidity (Table values represent hours spent in each Humidity range)

Zone	< 30 (%)	30-35 (%)	35-40 (%)	40-45 (%)	45-50 (%)	50-55 (%)	55-60 (%)	60-65 (%)	65-70 (%)	70-75 (%)	>= 80 (%)	Mean Relative Humidity (%)
THERMAL ZONE 1	1709	1184	1059	1133	934	748	539	515	441	266	154	43.7 (%)
THERMAL ZONE 2	2386	1019	832	891	757	683	579	479	439	308	220	42.9 (%)
THERMAL ZONE 3	2076	1206	965	1156	861	688	558	525	367	232	100	42.0 (%)
THERMAL ZONE 4	2522	995	869	843	775	705	583	619	430	256	111	41.7 (%)
THERMAL ZONE 5	2346	1102	854	851	772	736	592	670	438	256	109	42.3 (%)

Wood

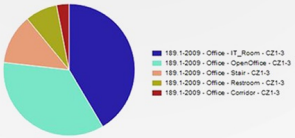
Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 56 (F)	56-61 (F)	61-66 (F)	66-68 (F)	68-70 (F)	70-72 (F)	72-74 (F)	74-76 (F)	76-78 (F)	78-83 (F)	>= 88 (F)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (F)
THERMAL ZONE 1	0	0	0	2246	966	265	3995	612	422	1166	42	46	0	0	0	67.5 (F)
THERMAL ZONE 2	0	0	0	2622	616	159	4024	343	249	480	33	34	0	0	0	66.6 (F)
THERMAL ZONE 3	0	0	0	2078	986	274	2939	702	496	1199	32	54	0	0	0	67.7 (F)
THERMAL ZONE 4	0	0	0	1925	1120	337	4033	634	382	305	12	3	0	0	0	67.1 (F)
THERMAL ZONE 5	0	0	0	1461	1467	403	4083	711	414	217	4	0	0	0	0	67.3 (F)

Humidity (Table values represent hours spent in each Humidity range)

Zone	< 30 (%)	30-35 (%)	35-40 (%)	40-45 (%)	45-50 (%)	50-55 (%)	55-60 (%)	60-65 (%)	65-70 (%)	70-75 (%)	>= 80 (%)	Mean Relative Humidity (%)
THERMAL ZONE 1	1724	1200	1093	1196	923	718	540	497	413	259	137	43.2 (%)
THERMAL ZONE 2	2390	1033	844	915	777	685	548	482	441	304	200	42.6 (%)
THERMAL ZONE 3	2109	1224	1002	1278	825	663	530	513	348	190	67	41.4 (%)
THERMAL ZONE 4	2530	1012	892	879	789	718	596	607	397	220	85	41.3 (%)
THERMAL ZONE 5	2352	1115	871	865	794	730	619	644	416	238	86	42.0 (%)



These are the results generated by Openstudio for building in Geneva using different materials in the exterior wall.
We can see the general behaviour in each thermal zone with different materials is similar.
We only have some small changes in the values and percentages.

Zone and loads Overview GENEVA

Interior Lighting Summary

Interior Lighting Summary

	Zone	Lighting Power Density (W/ft^2)	Total Power (W)	Schedule Name	Scheduled Hours/Week (hr)	Actual Load Hours/Week (hr)	Return Air Fraction	Consumption (kWh)
THERMAL ZONE 5 189.1-2009 - OFFICE - CORRIDOR - CZ1-3 LIGHTS	THERMAL ZONE 5	0.45	24.22	OFFICE BLDG LIGHT	61.85	61.85	0.0000	77.78
THERMAL ZONE 3 189.1-2009 - OFFICE - IT_ROOM - CZ1-3 LIGHTS	THERMAL ZONE 3	0.99	574.62	OFFICE BLDG LIGHT	61.85	61.85	0.0000	1852.78
THERMAL ZONE 1 189.1-2009 - OFFICE - OPENOFFICE - CZ1-3 LIGHTS	THERMAL ZONE 1	0.99	617.68	OFFICE BLDG LIGHT	61.85	61.85	0.0000	1991.67
THERMAL ZONE 2 189.1-2009 - OFFICE - RESTROOM - CZ1-3 LIGHTS	THERMAL ZONE 2	0.81	112.95	OFFICE BLDG LIGHT	61.85	61.85	0.0000	363.89
THERMAL ZONE 4 189.1-2009 - OFFICE - STAIR - CZ1-3 LIGHTS	THERMAL ZONE 4	0.54	58.45	OFFICE BLDG LIGHT	61.85	61.85	0.0000	188.89

Plug Loads Summary

Electric Plug Load Consumption

	Electricity Annual Value (kWh)
InteriorEquipment:Electricity:Zone:THERMAL ZONE 5	41.67
InteriorEquipment:Electricity:Zone:THERMAL ZONE 3	4288.89
InteriorEquipment:Electricity:Zone:THERMAL ZONE 1	2097.22
InteriorEquipment:Electricity:Zone:THERMAL ZONE 2	47.22

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

Zone overview

Zone Summary

	Area (ft^2)	Conditioned (Y/N)	Part of Total Floor Area (Y/N)	Volume (ft^3)	Multiplier	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	623.88	Yes	Yes	6139.46	1.00	797.61	246.06	0.99	190.52	0.71
THERMAL ZONE 2	139.5	Yes	Yes	1372.33	1.00	273.73	0.0	0.81	100.0	0.07
THERMAL ZONE 3	580.39	Yes	Yes	7202.43	1.00	1188.55	185.46	0.99	199.99	1.56
THERMAL ZONE 4	108.28	Yes	Yes	2130.18	1.00	161.46	27.99	0.54	0.0	0.0
THERMAL ZONE 5	53.82	Yes	Yes	529.72	1.00	0.0	0.0	0.45	999.97	0.16
Total	1505.87			17373.76		2421.23	459.51	0.92	197.41	0.91
Conditioned Total	1505.87			17373.76		2421.23	459.51	0.92	197.41	0.91
Unconditioned Total	0.0			0.0		0.0	0.0	0.0	0.0	0.0
Not Part of Total	0.0			0.0		0.0	0.0	0.0	0.0	0.0

Zone Sensible Cooling and Heating Sensible Sizing

	Heating/Cooling	Calculated Design Load	Design Load With Sizing Factor	Calculated Design Air Flow (ft^3/min)	Design Air Flow With Sizing Factor (ft^3/min)	Date/Time Of Peak	Outdoor Temperature at Peak Load (F)	Outdoor Humidity Ratio at Peak Load (lbWater/lbAir)
THERMAL ZONE 1	Cooling	0.62 (ton)	0.72 (ton)	396.23	455.56	7/21 15:30:00	86.83	0.01
THERMAL ZONE 1	Heating	15.51 (kBtu/h)	19.38 (kBtu/h)	434.37	542.43	1/21 06:00:00	19.58	0.0
THERMAL ZONE 2	Cooling	0.19 (ton)	0.22 (ton)	120.78	137.73	7/21 15:15:00	87.13	0.01
THERMAL ZONE 2	Heating	10.76 (kBtu/h)	13.45 (kBtu/h)	300.88	375.04	1/21 06:00:00	19.58	0.0
THERMAL ZONE 3	Cooling	0.74 (ton)	0.85 (ton)	470.39	540.31	7/21 17:30:00	83.52	0.01
THERMAL ZONE 3	Heating	18.95 (kBtu/h)	23.69 (kBtu/h)	529.72	661.09	1/21 06:00:00	19.58	0.0
THERMAL ZONE 5	Cooling	0.01 (ton)	0.01 (ton)	4.24	6.36	7/21 18:15:00	81.7	0.01
THERMAL ZONE 5	Heating	0.75 (kBtu/h)	0.94 (kBtu/h)	21.19	25.43	1/21 06:00:00	19.58	0.0
THERMAL ZONE 4	Cooling	0.03 (ton)	0.03 (ton)	19.07	21.19	7/21 18:30:00	80.92	0.01
THERMAL ZONE 4	Heating	3.34 (kBtu/h)	4.18 (kBtu/h)	93.23	116.54	1/21 06:00:00	19.58	0.0

In the first tables we have the calculated results for the interior lighting and electricity loads in the building.
The tables below have calculated the general characteristics in the building like the area of each thermal zone, volume, windows area, lighting, people and electricity loads.
The last table has the calculated results for cooling and heating of each thermal zone.

Space Type Summary

189.1-2009 - Office - Corridor - CZ1-3
(1 spaces and 1 thermal zones)

Definition	Value	Unit	Inst. Multiplier
189.1-2009 - Office - Corridor - CZ1-3 People Definition	0.0010	people/ft^2	1.0
189.1-2009 - Office - Corridor - CZ1-3 Electric Equipment Definition	0.1600	W/ft^2	1.0
189.1-2009 - Office - Corridor - CZ1-3 Lights Definition	0.4500	W/ft^2	1.0
189.1-2009 - Office - Corridor - CZ1-3 Infiltration	0.0595	cfm/ext surf area ft^2	
189.1-2009 - Office - Corridor - CZ1-3 Ventilation (outdoor air method Sum)	0.0500	cfm/floor area ft^2	

189.1-2009 - Office - IT_Room - CZ1-3
(5 spaces and 1 thermal zones)

Definition	Value	Unit	Inst. Multiplier
189.1-2009 - Office - IT_Room - CZ1-3 People Definition	0.0050	people/ft^2	1.0
189.1-2009 - Office - IT_Room - CZ1-3 Electric Equipment Definition	1.5600	W/ft^2	1.0
189.1-2009 - Office - IT_Room - CZ1-3 Lights Definition	0.9900	W/ft^2	1.0
189.1-2009 - Office - IT_Room - CZ1-3 Infiltration	0.0595	cfm/ext surf area ft^2	
189.1-2009 - Office - IT_Room - CZ1-3 Ventilation (outdoor air method Sum)	0.0500	cfm/floor area ft^2	

189.1-2009 - Office - OpenOffice - CZ1-3
(2 spaces and 1 thermal zones)

Definition	Value	Unit	Inst. Multiplier
189.1-2009 - Office - OpenOffice - CZ1-3 People Definition	0.0052	people/ft^2	1.0
189.1-2009 - Office - OpenOffice - CZ1-3 Electric Equipment Definition	0.7100	W/ft^2	1.0
189.1-2009 - Office - OpenOffice - CZ1-3 Lights Definition	0.9900	W/ft^2	1.0
189.1-2009 - Office - OpenOffice - CZ1-3 Infiltration	0.0595	cfm/ext surf area ft^2	
189.1-2009 - Office - OpenOffice - CZ1-3 Ventilation (outdoor air method Sum)	20.0000	cfm/person	

189.1-2009 - Office - Restroom - CZ1-3
(3 spaces and 1 thermal zones)

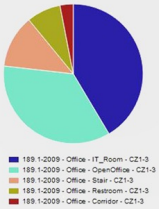
Definition	Value	Unit	Inst. Multiplier
189.1-2009 - Office - Restroom - CZ1-3 People Definition	0.0100	people/ft^2	1.0
189.1-2009 - Office - Restroom - CZ1-3 Electric Equipment Definition	0.0700	W/ft^2	1.0
189.1-2009 - Office - Restroom - CZ1-3 Lights Definition	0.8100	W/ft^2	1.0
189.1-2009 - Office - Restroom - CZ1-3 Infiltration	0.0595	cfm/ext surf area ft^2	
189.1-2009 - Office - Restroom - CZ1-3 Ventilation (outdoor air method Sum)	0.9600	cfm/floor area ft^2	

189.1-2009 - Office - Stair - CZ1-3
(2 spaces and 1 thermal zones)

Definition	Value	Unit	Inst. Multiplier
189.1-2009 - Office - Stair - CZ1-3 Lights Definition	0.5400	W/ft^2	1.0
189.1-2009 - Office - Stair - CZ1-3 Infiltration	0.0595	cfm/ext surf area ft^2	
189.1-2009 - Office - Stair - CZ1-3 Ventilation (outdoor air method Sum)	0.0500	cfm/floor area ft^2	

In the tables above are showed the calculated results for: people definition, electric equipment, lights, infiltration and ventilation for each thermal zone inthe building.

Thermal Zone Characteristic GENEVA



Comments

In this assigment is treated the design of the two-story house and calculated the energy consumption using the OpenStudio software. In order to get a better understanding on how energy-consumption works, we chose three cities belonging to three different climate-zones. The afore-mentioned cities are: Sydney, Australia- CZ 3; Geneva, Switzerland- CZ 5 and Quebec, Canada- CZ 7. Enlightening the results, we discovered in the colder countries the energy-consumption is spent more in heating the building, whereas cooling the building was the main importance in warmer cities such as Sydney, Australia.

Moreover, we chose to work with three different materials in our building as well. In order to have a variety of results, the materials we chose are: Wood, Steel and Concrete. Through the analysis we were able to understand how these materials with a certain ammount of resistant react. Although, they have complitely different resistant, especially Steel- having a low resistant, the results were quite similar, not differing much with each other.

This is an outcome of not putting raw materials in the external wall.
However, we added the insulation to each of the materials mentioned above in order to perceive more stable results that would prevent energy-loss.
ex: if it would have been the raw steel itself without insulation, the energy-loss would have been extremely high as an aftermath.

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POLITECNICO DI MILANO

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