POLITECNICO DI MILANO
SUSTAINABLE ARCHITECURE AND LANDSCAPE DESIGN

ENERGY PERFORMANCE

TECHNICAL ENVIRONMENT SYSTEMS
STUDY ON ENEGY PERFORMANCE OF BUIDINGS

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1.1 EXPERIMENTAL OBJECTIVE & REQUIREMENT

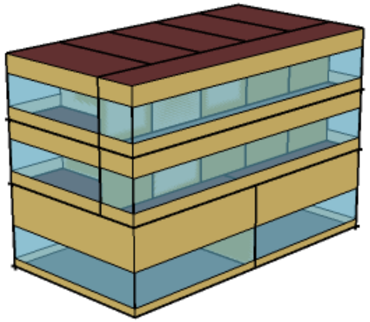
Experimental Objective: Analysis the energy performance of the same building in different cities.

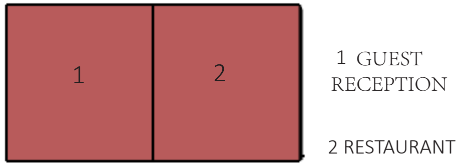
Experimental Requirement: 1)using the sofrware to calculate the yearly heating and cooling consumption of the building for a base case.
2) a parametric study, should be conducted in order to investigate the effect of changing the position and wall characteristics on the building's yearly energy consumption.
3) 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.

1.2 OVERALL INTRODUCTION

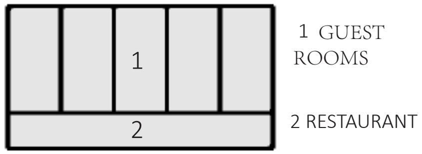
BUILDING

We chose a small three-story hotel as our research object for the study of energy of buildings. According to the functional division,for example service and residence, we make a variety of spatial forms.

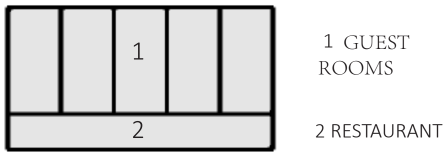




PLAN OF 1ST. FLOOR



PLAN OF 2ND. FLOOR



PLAN OF 3RD. FLOOR

At the first floor, there is a guest reception and restaurant, t. On the second floor and the third floor, there are the guset rooms and corridor.
Also the opening of the windows is different according to the usage of different.

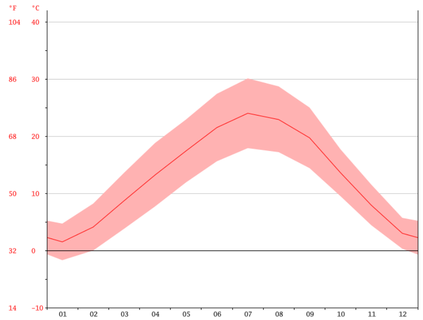
LOCATION

3 TYPE MATERIALS

----SOLID CONCREAT WITH STEEL FRAME
----METAL
----WOODEN FRANME

CITIES BACKGROUND

PIACENZA



CLIMATE TABLE//HISTORICAL WEATHER

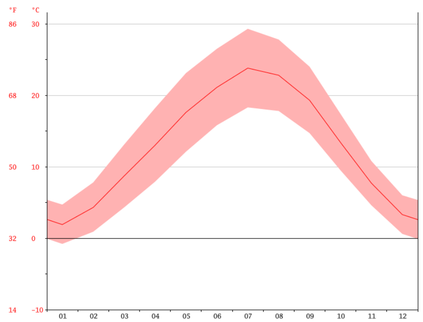
JULY IS THE WARMEST MONTH OF THE YEAR. THE TEMPERATURE IN JULY AVERAGES 24.0 °C. THE LOWEST AVERAGE TEMPERATURES IN THE YEAR OCCUR IN JANUARY, WHEN IT IS AROUND 1.5 °C

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	1.5	4.1	8.7	13.2	17.4	21.5	24	22.9	19.7	13.6	7.9	3
Min. Temperature (°C)	-1.7	0	3.8	7.7	11.9	15.6	17.9	17.2	14.4	9.5	4.4	0.3
Max. Temperature (°C)	4.7	8.2	13.6	18.8	22.9	27.4	30.1	28.7	25	17.7	11.5	5.7
Avg. Temperature (°F)	34.7	39.4	47.7	55.8	63.3	70.7	75.2	73.2	67.5	56.5	46.2	37.4
Min. Temperature (°F)	28.9	32.0	38.8	45.9	53.4	60.1	64.2	63.0	57.9	49.1	39.9	32.5
Max. Temperature (°F)	40.5	46.8	56.5	65.8	73.2	81.3	86.2	83.7	77.0	63.9	52.7	42.3
Precipitation / Rainfall (mm)	53	47	54	69	73	47	51	62	70	103	85	67

THERE IS A DIFFERENCE OF 56 MM OF PRECIPITATION BETWEEN THE DRIEST AND WETTEST MONTHS. THE VARIATION IN TEMPERATURES THROUGHOUT THE YEAR IS 22.5 °C.

MILANO

LATITUDE :44.92 LONGITUDE:9.73 ELEVATION:440 (FT) TIME ZONE:1.00



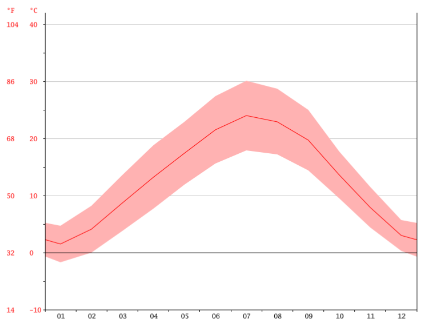
CLIMATE TABLE//HISTORICAL WEATHER

WITH AN AVERAGE OF 23.8 °C, JULY IS THE WARMEST MONTH. AT 1.9 °C ON AVERAGE, JANUARY IS THE COLDEST MONTH OF THE YEAR.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	1.9	4.3	8.7	13	17.6	21.1	23.8	22.8	19.3	13.4	7.7	3.3
Min. Temperature (°C)	-0.8	0.9	4.3	7.9	12.1	15.8	18.3	17.8	14.7	9.5	4.6	0.6
Max. Temperature (°C)	4.7	7.8	13.1	18.2	23.1	26.5	29.3	27.8	24	17.4	10.8	6
Avg. Temperature (°F)	35.4	39.7	47.7	55.4	63.7	70.0	74.8	73.0	66.7	56.1	45.9	37.9
Min. Temperature (°F)	30.6	33.6	39.7	46.2	53.8	60.4	64.9	64.0	58.5	49.1	40.3	33.1
Max. Temperature (°F)	40.5	46.0	55.6	64.8	73.6	79.7	84.7	82.0	75.2	63.3	51.4	42.8
Precipitation / Rainfall (mm)	55	62	79	92	94	97	67	90	78	118	110	71

THE PRECIPITATION VARIES 63 MM BETWEEN THE DRIEST MONTH AND THE WETTEST MONTH. THE VARIATION IN ANNUAL TEMPERATURE IS AROUND 21.9 °C.

DALIAN



CLIMATE TABLE//HISTORICAL WEATHER

THE TEMPERATURES ARE HIGHEST ON AVERAGE IN AUGUST, AT AROUND 24.4 °C. JANUARY HAS THE LOWEST AVERAGE TEMPERATURE OF THE YEAR. IT IS-4.0 °C.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	1.9	4.3	8.7	13	17.6	21.1	23.8	22.8	19.3	13.4	7.7	3.3
Min. Temperature (°C)	-0.8	0.9	4.3	7.9	12.1	15.8	18.3	17.8	14.7	9.5	4.6	0.6
Max. Temperature (°C)	4.7	7.8	13.1	18.2	23.1	26.5	29.3	27.8	24	17.4	10.8	6
Avg. Temperature (°F)	35.4	39.7	47.7	55.4	63.7	70.0	74.8	73.0	66.7	56.1	45.9	37.9
Min. Temperature (°F)	30.6	33.6	39.7	46.2	53.8	60.4	64.9	64.0	58.5	49.1	40.3	33.1
Max. Temperature (°F)	40.5	46.0	55.6	64.8	73.6	79.7	84.7	82.0	75.2	63.3	51.4	42.8
Precipitation / Rainfall (mm)	55	62	79	92	94	97	67	90	78	118	110	71

THE VARIATION IN THE PRECIPITATION BETWEEN THE DRIEST AND WETTEST MONTHS IS 165 MM. DURING THE YEAR, THE AVERAGE TEMPERATURES VARY BY 28.4 °C.

2.1 EXPERIMENTAL PROCEDURE

1)using the sofrware to calculate the yearly heating and cooling consumption of the building for a base case.
2) a parametric study, should be conducted in order to investigate the effect of changing the position and wall characteristics on the building's yearly energy consumption.
3) 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.

2.2 ABOUT THE UNITS

The units for openstudio software is british standard, and i will show the conversion between the british unit and international unit.

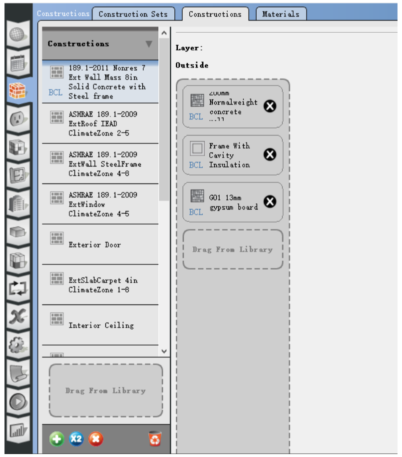
TYPE	BRITISH UNIT	INTERNATIONAL UNIT
ELEVATION	1 ft	0.3048 m
AREA	1 ft^2	0.092903 m^2
ENERGY	1 Btu	1055.056 J
ENERGY	1 mBtu	1055.056 J*10^6
ENERGY	1 kBtu	1055.056 J*10^3

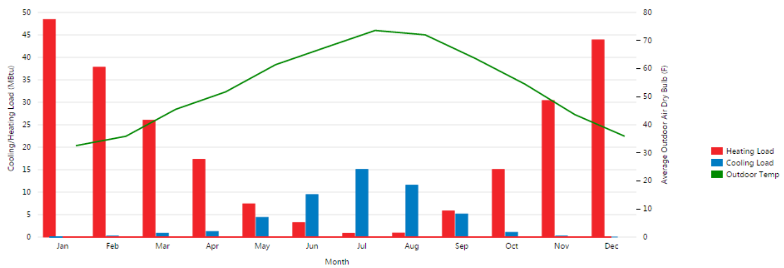
EXPERIMENTAL RESULT-ONE PLACE USING 3 MATERIALS IN PIACENZA

USING CONCRET,METAL,WOODEN MATERIALS

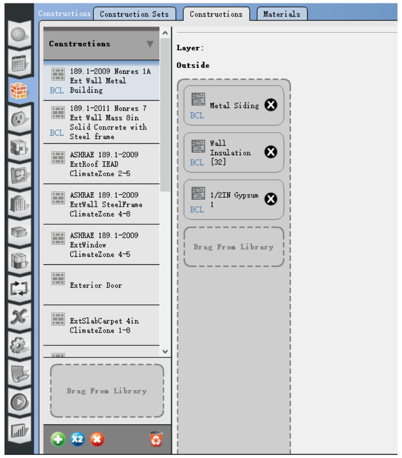
2.3 EXPERIMENTAL RESULT-ONE PLACE USING 3 MATERIALS

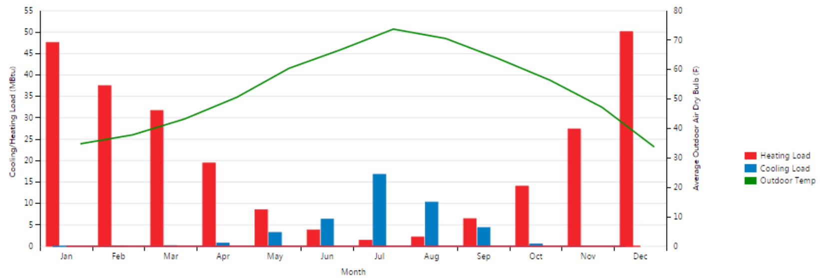
MASS 8IN SOLID CONCRETE WITH STEEL FRAME(BASIC ONE)



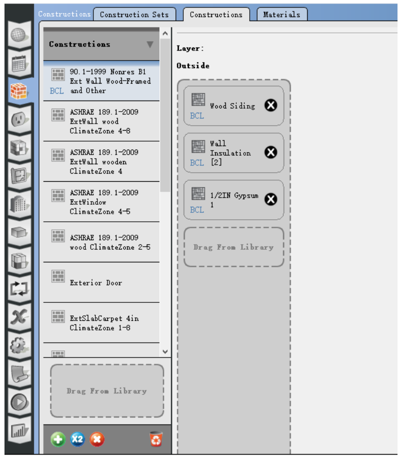


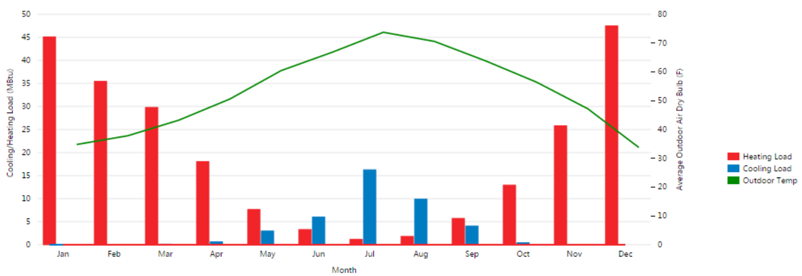
METAL





WOOD





LOCATION:PIACENZA

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	1.5	4.1	8.7	13.2	17.4	21.5	24	22.9	19.7	13.6	7.9	3
Min. Temperature (°C)	-1.7	0	3.8	7.7	11.9	15.6	17.9	17.2	14.4	9.5	4.4	0.3
Max. Temperature (°C)	4.7	8.2	13.6	18.8	22.9	27.4	30.1	28.7	25	17.7	11.5	5.7
Avg. Temperature (°F)	34.7	39.4	47.7	55.8	63.3	70.7	75.2	73.2	67.5	56.5	46.2	37.4
Min. Temperature (°F)	28.9	32.0	38.8	45.9	53.4	60.1	64.2	63.0	57.9	49.1	39.9	32.5
Max. Temperature (°F)	40.5	46.8	56.5	65.8	73.2	81.3	86.2	83.7	77.0	63.9	52.7	42.3
Precipitation / Rainfall (mm)	53	47	54	69	73	47	51	62	70	103	85	67

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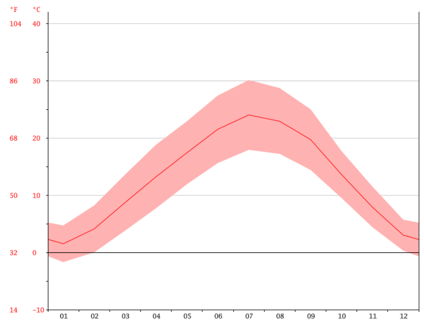

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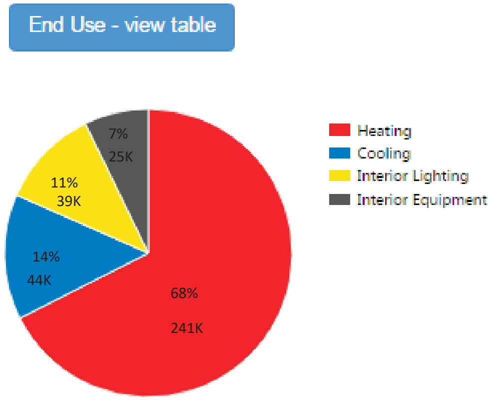
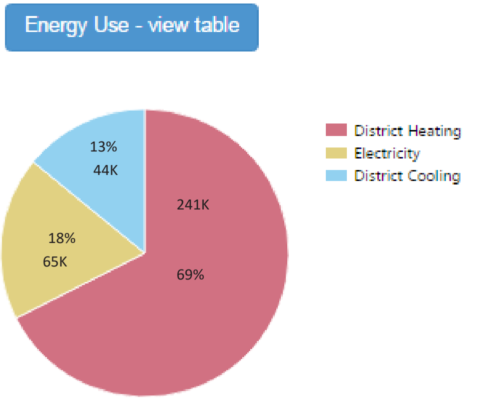
CLIMATE TABLE//HISTORICAL WEATHER DATA

From the data of monthly load profiles about the three buildings with different materials and construction, we could find that the heating and cooling load of HVAC is almost the same, and the cosumption of heating load is higher in winter while colling machine is used more in summer .

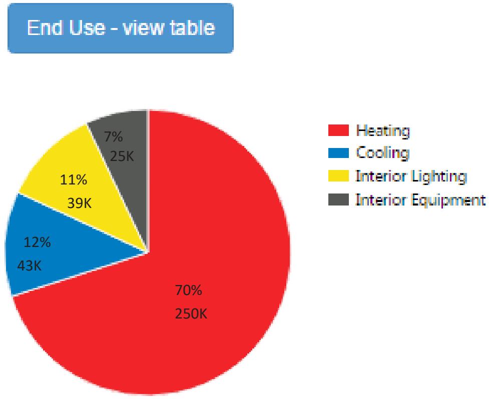
2.2 EXPERIMENTAL RESULT

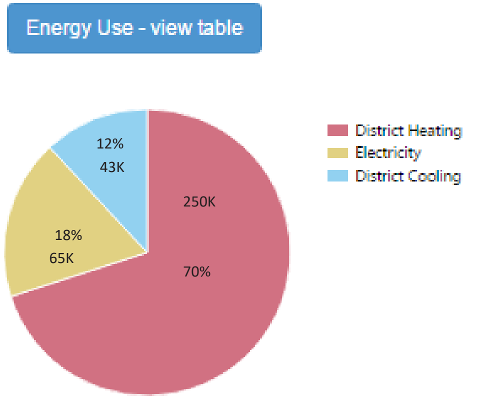
MASS 8IN SOLID CONCRETE WITH STEEL FRAME(BASIC ONE)



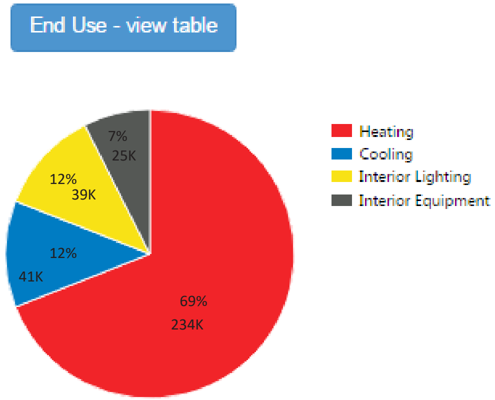


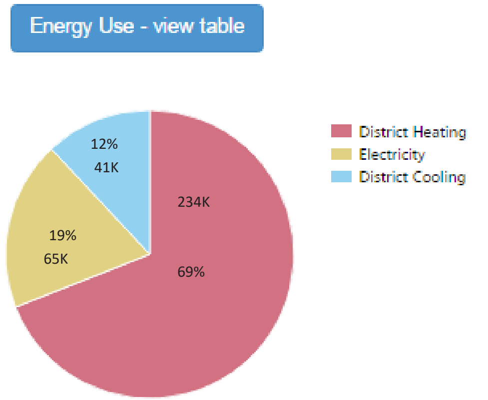
METAL





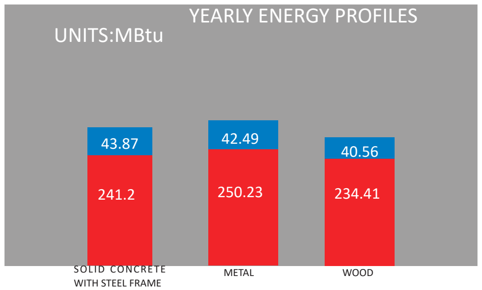
WOOD





The data from these pie charts shows that the energy output of three buildings with three kinds of walls in different materials in the same city,Piacenza,so the weather is the same.

And we can see the consumption of energy is almost the same but still has some differences.For heating,metal consumes most and wood consumpts least.As for cooling,the wood still has a low consumption,but the concret frame has the high one.



The data from the three pie charts shows that the energy output of buildings with different materials in Piacenza is almost the same but a little unequal due to the insulation property of the materials. According to the data of district heating energy, wood building is the lowest while metal building is the highest. When it comes to district cooling, also is the the wood building consume the least and the concrete one cosume the most

2.2 EXPERIMENTAL RESULT

British units international unit
1ft^2*R/Btu = 10m^2*k/w

Base Surface Constructions MASS 8IN SOLID CONCRETE WITH STEEL FRAME(BASIC ONE)

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
189.1-2011 Nonres 7 Ext Wall Mass 8in Solid Concrete with Steel frame	2,674	26	15.82
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 2-5	2,583	8	24.73

Base Surface Constructions WOOD

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
189.1-2009 Nonres 1A Ext Wall Metal Building	2,674	26	11.77
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 2-5	2,583	8	24.73

Base Surface Constructions METAL

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtWall wooden ClimateZone 4	2,674	26	33.25
ASHRAE 189.1-2009 wood ClimateZone 2-5	2,583	8	24.73

From the above data, we can see that, in Piacenza, due to the different constructions of the buildings, the thermal resistances are different. The concret exterior wall has 15.82ft^2*R/Btu thermal resistance, while the value of metal exterial wall is 11.77ft^2*R/Btu, and the wood one is33.25ft^2*R/Btu.

EXPERIMENTAL RESULT -ONE MATIERIAL IN 3 CITIES----
USING THE MASS 8IN SOLID CONCRETE WITH STEEL FRAME EXT WALL

INPIACENZA,MILANO,DALIAN

2.3 EXPERIMENTAL RESULT -ONE MATIERIAL IN 3 CITIES----

USING THE MASS 8IN SOLID CONCRETE WITH STEEL FRAME EXT WALL

Weather Summary

	Value
Weather File	Piacenza - ITA IGDG WMO#=160840
Latitude	44.92
Longitude	9.73
Elevation	440 (ft)
Time Zone	1.00
North Axis Angle	0.00
ASHRAE Climate Zone	

WEATHER SUMMARY IN PIACENZA

Building Summary

Information	Value	Units
Building Name	Building 1	building_name
Net Site Energy	349,688	kBtu
Total Building Area	3,875	ft^2
EUI (Based on Net Site Energy and Total Building Area)	90.24	kBtu/ft^2
OpenStudio Standards Building Type		

BUILDING SUMMARY IN PIACENZA

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	

WEATHER SUMMARY IN MILANO

Building Summary

Information	Value	Units
Building Name	Building 1	building_name
Net Site Energy	351,166	kBtu
Total Building Area	3,875	ft^2
EUI (Based on Net Site Energy and Total Building Area)	90.62	kBtu/ft^2
OpenStudio Standards Building Type		

BUILDING SUMMARY IN MILANO

Weather Summary

	Value
Weather File	Dalian Liaoning CHN CSWD WMO#=546620
Latitude	38.90
Longitude	121.63
Elevation	300 (ft)
Time Zone	8.00
North Axis Angle	0.00
ASHRAE Climate Zone	

WEATHER SUMMARY IN DALIAN

Building Summary

Information	Value	Units
Building Name	Building 1	building_name
Net Site Energy	381,733	kBtu
Total Building Area	3,875	ft^2
EUI (Based on Net Site Energy and Total Building Area)	98.51	kBtu/ft^2
OpenStudio Standards Building Type		

BUILDING SUMMARY IN DALIAN

From the above data, we can see that, due to the different climatic conditions in the three locations, the same type of construction results in a large difference in the energy consumption of the building, in the same case that the materials of wall is SOLID CONCRET.

PIACENZA belongs to a temperate maritime climate, with an elevation of 440, which the Net Site energy and the EUI is the lowest among the three locations.

MILANO belongs to a maritime subtropical monsoon climate with an elevation of 692, which the Net Site energy and the EUI is in a medium position of Net Site energy and the EUI.

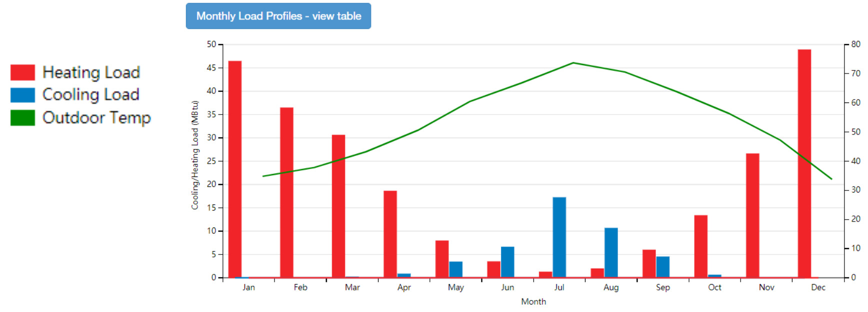
DALIAN belongs to a temperate climate with an elevation of 300, which the EUI is highest among the three locations.

2.3 EXPERIMENTAL RESULT

Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
PIACENZA ANN CLG .4% CONDNS DB=>MWB	91.58	21.42	72.86	Wetbulb [F]	5.14	90.0
PIACENZA ANN CLG .4% CONDNS DP=>MDB	81.32	21.42	73.4	Dewpoint [F]	5.14	90.0
PIACENZA ANN CLG .4% CONDNS ENTH=>MDB	86.54	21.42	32.2	Enthalpy [Btu/lb]	5.14	90.0
PIACENZA ANN CLG .4% CONDNS WB=>MDB	86.18	21.42	76.28	Wetbulb [F]	5.14	90.0
PIACENZA ANN HTG 99.6% CONDNS DB	21.02	0.0	21.02	Wetbulb [F]	4.47	250.0
PIACENZA ANN HTG WIND 99.6% CONDNS WS=>MCDB	42.44	0.0	42.44	Wetbulb [F]	19.91	250.0
PIACENZA ANN HUM_N 99.6% CONDNS DP=>MCDB	38.3	0.0	11.66	Dewpoint [F]	4.47	250.0

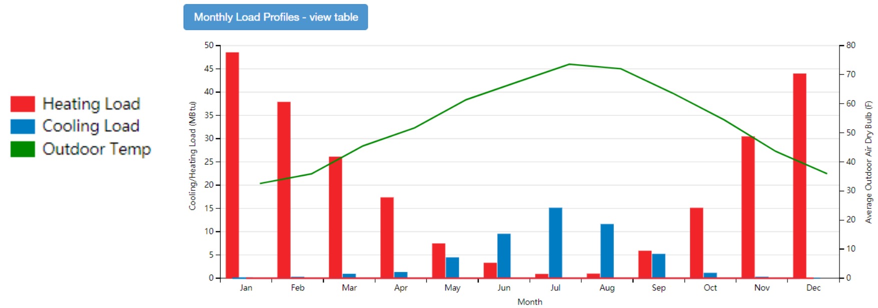
SIZING PERIOD DESIGN IN PIACENZA



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

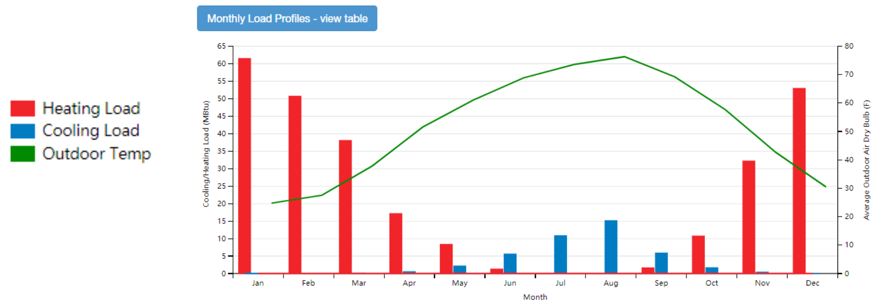
SIZING PERIOD DESIGN IN MILANO

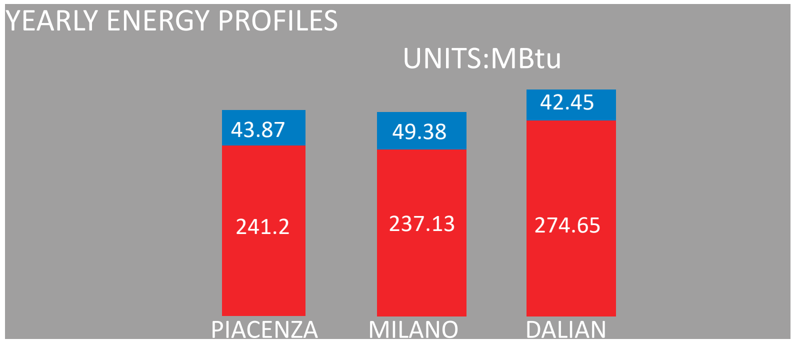


Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
DALIAN ANN CLG .4% CONDNS DB=>MWB	87.98	11.16	74.12	Wetbulb [F]	8.05	180.0
DALIAN ANN CLG .4% CONDNS DP=>MDB	81.32	11.16	77.36	Dewpoint [F]	8.05	180.0
DALIAN ANN CLG .4% CONDNS ENTH=>MDB	83.12	11.16	35.12	Enthalpy [Btu/lb]	8.05	180.0
DALIAN ANN CLG .4% CONDNS WB=>MDB	83.66	11.16	78.8	Wetbulb [F]	8.05	180.0
DALIAN ANN HTG 99.6% CONDNS DB	10.04	0.0	10.04	Wetbulb [F]	11.41	0.0
DALIAN ANN HTG WIND 99.6% CONDNS WS=>MCDB	15.62	0.0	15.62	Wetbulb [F]	29.53	0.0
DALIAN ANN HUM_N 99.6% CONDNS DP=>MCDB	17.6	0.0	-8.5	Dewpoint [F]	11.41	0.0

SIZING PERIOD DESIGN IN DALIAN

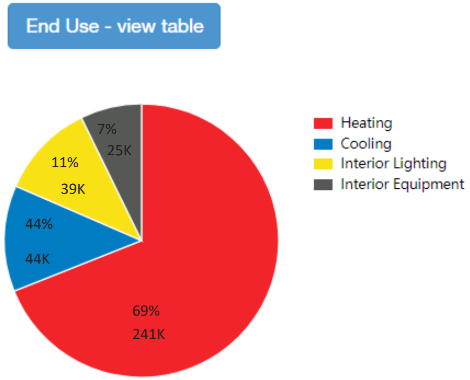




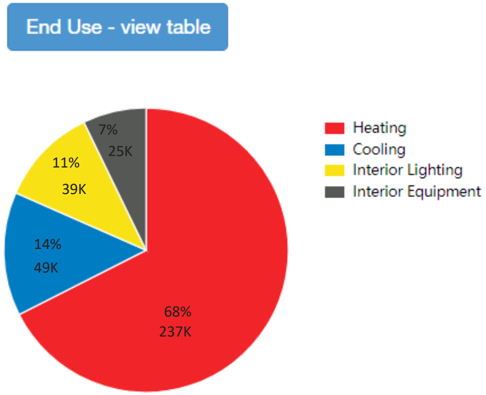
As can be seen from the data, the daily temperature range is influenced by lots of factors, the wind speed and the wind direction. The daily temperature range in Piacenza is almost tiwce of DALIAN.
From the data of monthly load profiles in three sites, we could find that the heating and cooling load connect closely to the outdoor temperature. According to the EUI and the Net Site Energy, we could find that the extreme temperature changes over the course of the year necessitated an increase in both heating and cooling, resulting in an increase in building energy consumption.

2.3EXPERIMENTAL RESULT

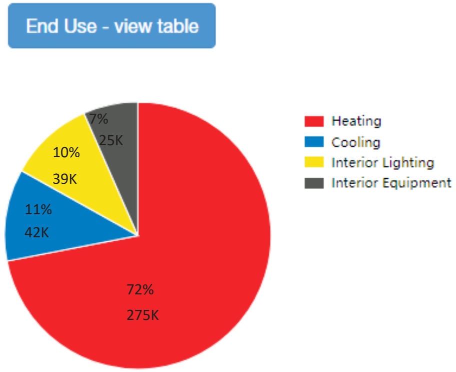
PIACENZA



MILANO



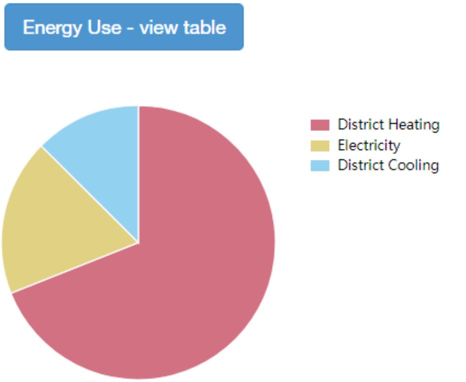
DALIAN



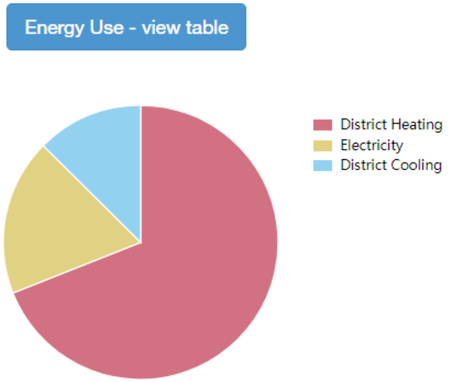
The data from the three pie charts shows that the energy output of the same building in different sites is simlar but also has some difference due to the weather and the temperature.
The weather in PIACENZA is similar with MILANO,so the cooling and heating end use is also very similar. But the average temperature in DALIAN is lower than the other cities,so the heating use is the highests.

The distribution of energy is concentrated due to the change of climate and the control of indoor temperature. The proportion of interior equipment and the interior lighting, as the internal needs, are stable in three sites.The different cities has different needs.

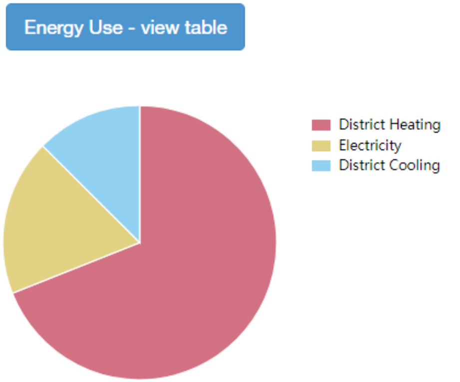
PIACENZA

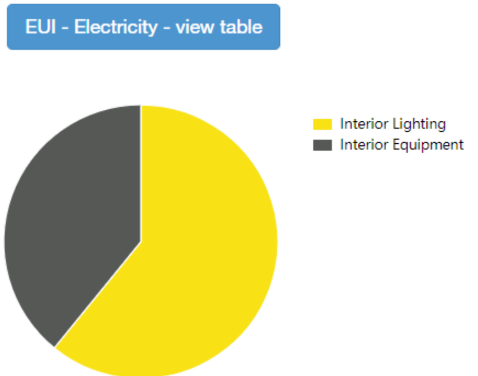


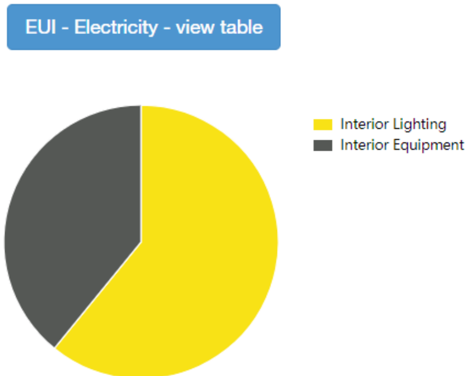
MILANO

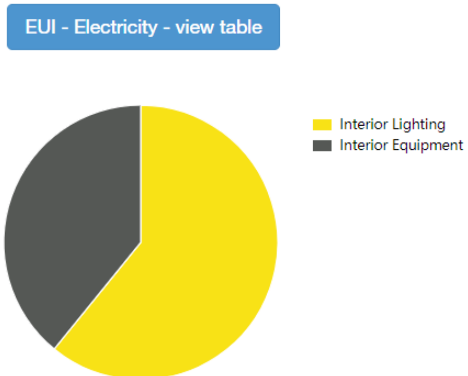


DALIAN



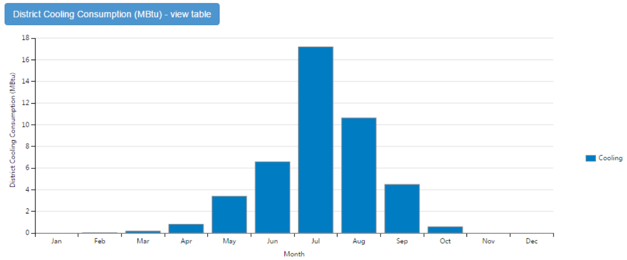




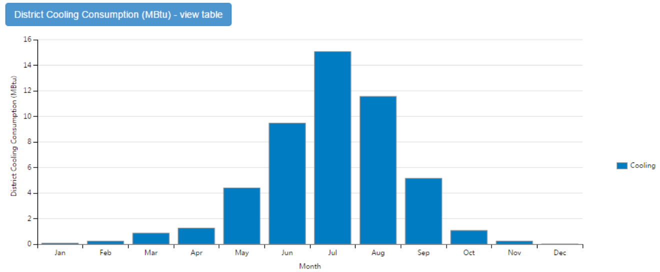


The data from the three pie charts shows that at the situation that the EUI of three sites are almost the same, the proportion of the electricity in 3 sites are almost the same (Helsinki 10%; Hongkong 13%; Piacenza 12%). The proportion of heating and cooling in both end use and the energy use are same. But because the use of interior equipment also need the eletricity, the proportion in Energy use is a little bit more than the proportion in End use pie chart.

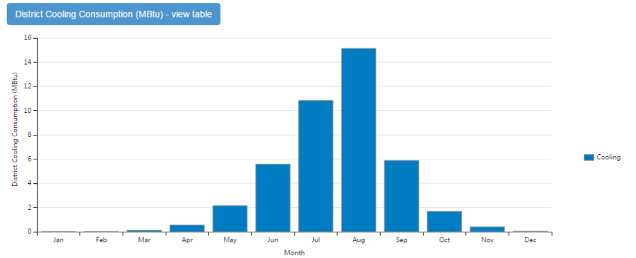
2.3 EXPERIMENTAL RESULT



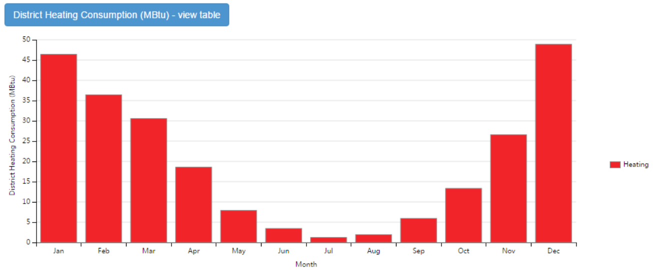
DISTRICTION COOLINGIN CONSUMPTION IN PIACENZA



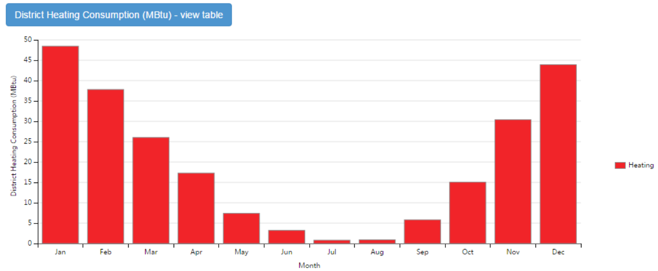
DISTRICTION COOLINGIN CONSUMPTION IN MILANO



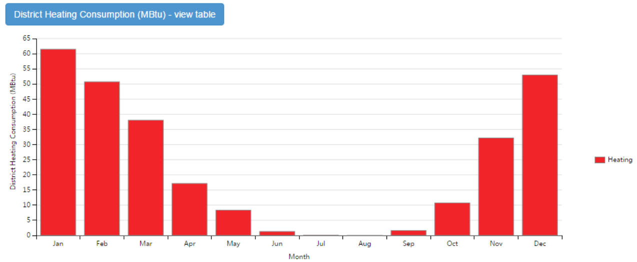
DISTRICTION COOLINGIN CONSUMPTION IN DALIAN



DISTRICTION HEATING CONSUMPTION IN PIACENZA



DISTRICTION COOLINGIN CONSUMPTION IN MILANO



DISTRICTION COOLINGIN CONSUMPTION IN DALIAN

The consumption of cooling load in Milan is normal due to the temperature difference and seasonal variation. Normally it can reach a peak of energy consumption in August. The distribution of the remaining months are more uniform. For Piacenza,it has the same tendency with Milan. The distribution also reach the peak of energy consumption,but the only difference is other 11 months have a lower consumption. As for Dalian, the peak of energy consumption is also August.

The consumption of heating load in Milan is continuous. Even during the summer, there would still be little heating load due to the windy weather there. Normally it can reach a peak of energy consumption from December to Feberary. For Piacenza, it has a similar situation with Mlian,but during spring and sumer it has a more rapid desrease,and during autumn it has a faster increase. The consumption of heating load in Dalian still has the similar tendency with Milan and Piacenza,but heating load will nearly stop from July to August.

3.CONCLUSION

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

ACCORDING TO THE 2 EXPERIMENT, WE MAILY STUDY 2 VERY IMPORTANT ELEMENTS WHICH EFFECT THE ENERGY COMSUMPTION OF A BUILDING,THE WEATHER(MAINLIY THE TEMPERATURE) AND THE MATERIALS PROPERTIES (MAINLY THE THERMAL RESISTANCE) OF THE EXTERIOR WALL OF THE BUILDING.

	PIACENZA(kBtu)	MILANO(kBtu)	DALIAN(kBtu)
QUANTITY OF ENERGY FOR COOLING	43.87	49.38	42.45
QUANTITY OF ENERGY FOR HEATING	241.2	237.13	274.65
TOTAL	285.07	286.51	317.3

Accoring to the energy performance of the building with same construction methods but in different places, the weather is the most important effective element. where is too cold and too hot it will cost a lot energy.

	PIACENZA(kBtu)	TOTAL
QUANTITY OF ENERGY FOR COOLING(CONCRET)	43.87	285.07
QUANTITY OF ENERGY FOR HEATING(CONCRET)	241.2	
QUANTITY OF ENERGY FOR COOLING(METAL)	42.49	292.49
QUANTITY OF ENERGY FOR HEATING(METAL)	250	
QUANTITY OF ENERGY FOR COOLING(WOOD)	40.56	274.97
QUANTITY OF ENERGY FOR HEATING(WOOD)	234.41	

Regarding the energy performance of the building with different construction methods, we understand that in most of the cases the one using WOOD is the most CHEAPEST.
For the energy consumption for heating and cooling, for sure the best solution is to use WOOD walls which save energy and money.

And compaire the other 2 matierials ,for heating,the concret wall with the metal is better than the metal one.But the situation is opposite for cooling,the metal is the better one.