ENERGY PERFORMANCE

TECHNICAL ENVIRONMENT SYSTEMS
STUDY ON ENERGY PERFORMANCE OF BUILDINGS

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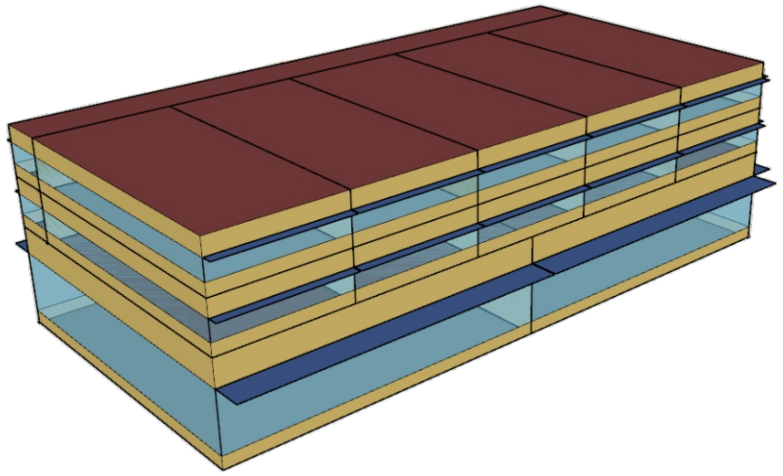
INTRODUCTION

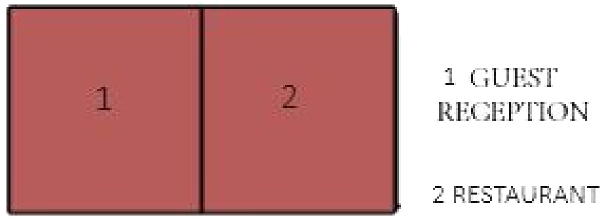
OBJECTIVE

The objective of the experiment is to analyse the energy performance of a building in different conditions.

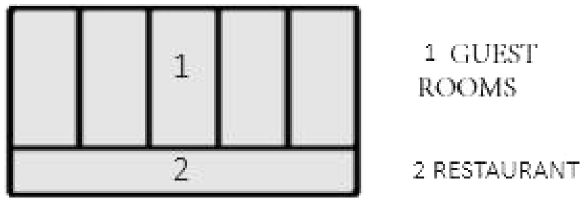
The experiment is performed by calculating the energy consumption in different locations and material and then comparing the result to determine the important factors in energy performance.

BUILDING

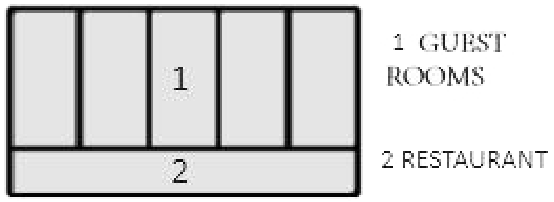




PLAN OF 1ST. FLOOR



PLAN OF 3RD. FLOOR



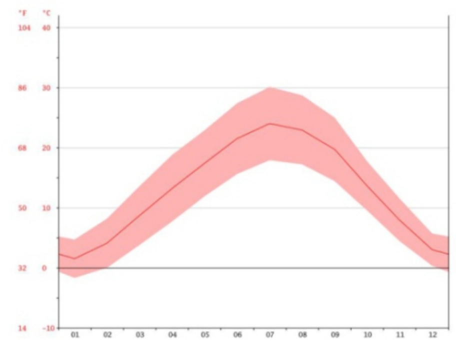
PLAN OF 2ND. FLOOR

The building is a small three-story hotel, with functional division such as service and residence, each funcion has different spatial forms.

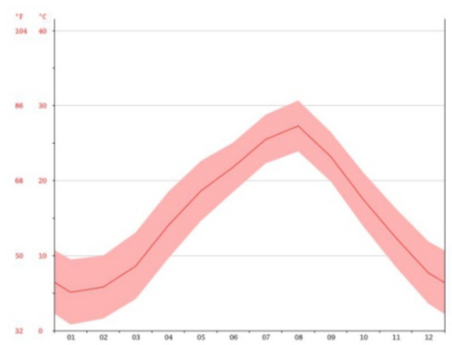
The first floor consist of a guest reception and restaurant. Then on the second floor and third floor there are guest rooms and corridor. The window openings are also different for each type of function.

LOCATION

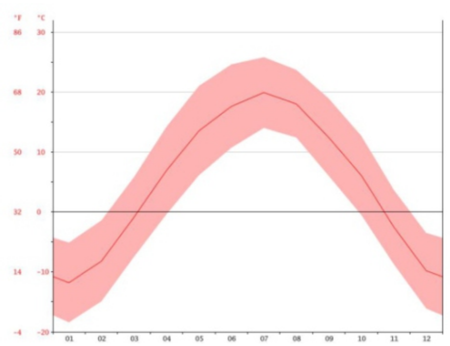
PIACENZA



DALIAN



TOKYO



MATERIAL

The experiment will be performed on the following materials :
1. Solid Concrete with Steel Frame
2. Metal
3. Wood

ABOUT EXPERIMENT

PROCEDURE

The experiment is performed through the following steps :

1. Calculation of yearly energy consumption for heating and cooling of the defined building, in its original state.
2. Calculation of yearly energy consumption of the same building, with changes in the location and building material. Performed in three locations and three types of building materials.
3. Comparison of energy consumption between the original state and the different configurations.

UNIT OF MEASUREMENT

The Open Studio software is using British Standard Unit, below is the conversion between 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

PERFORMANCE OF 3 DIFFERENT MATERIALS IN PIACENZA

CONCRETE, METAL, AND WOOD

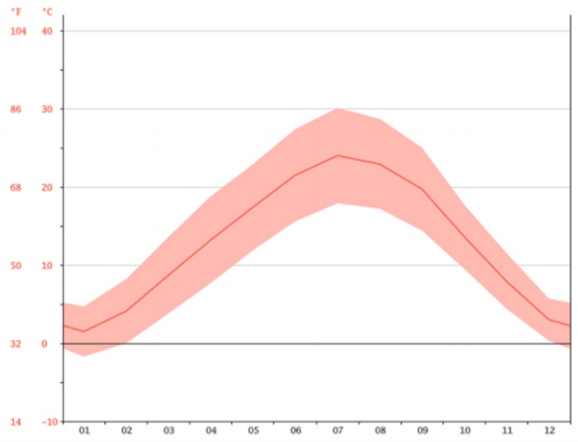
RESULT | 3 materials in Piacenza

HVAC LOAD PROFILES

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

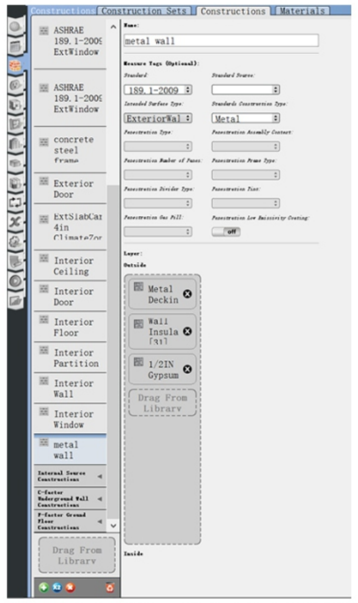
THERE IS A DIFFERENCE OF 56 MM OF PRECIPITATION BETWEEN THE DRIEST AND WETTEST MONTHS. THE VARIATION IN TEMPERATURES THROUGHOUT THE YEAR IS 22.5 °C.

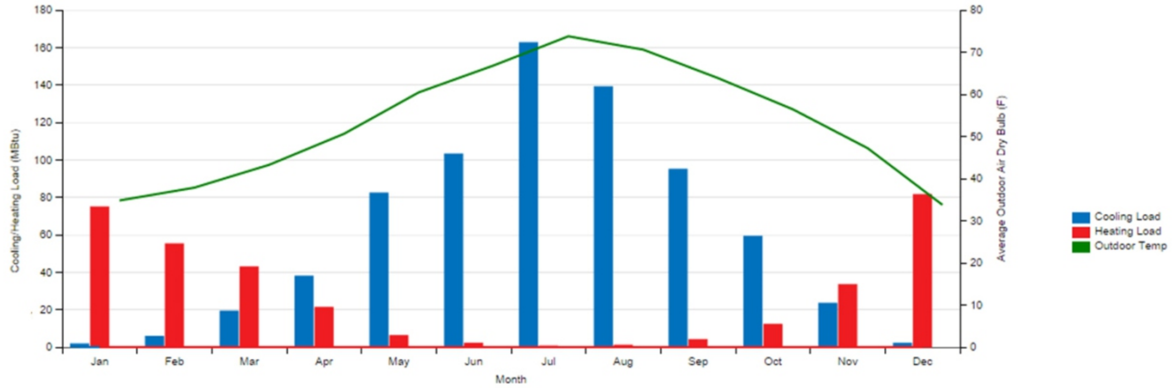


JULY IS THE WARMEST MONTH OF THE YEAR. THE TEMPERATURE IN JULY AVERAGES 24.0 °C. THE LOWEST AVERAGE TEMPERATURES IN THE YEAR OCCUR IN JANUARY, WHEN IT IS AROUND 1.5 °C

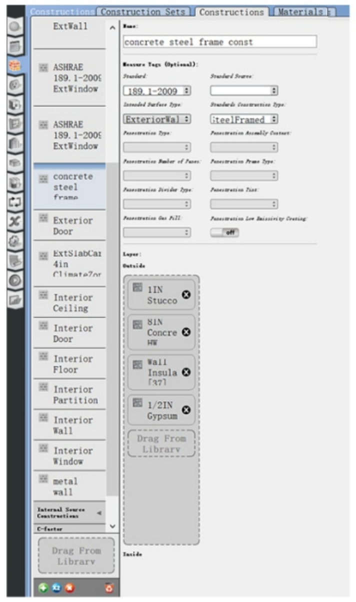
From the data of monthly load profiles about the three buildings with different materials and construction, we could find that the heating and cooling load of HVAC is almost the same, and the cosumption of heating load is higher in winter while colling machine is used more in summer .

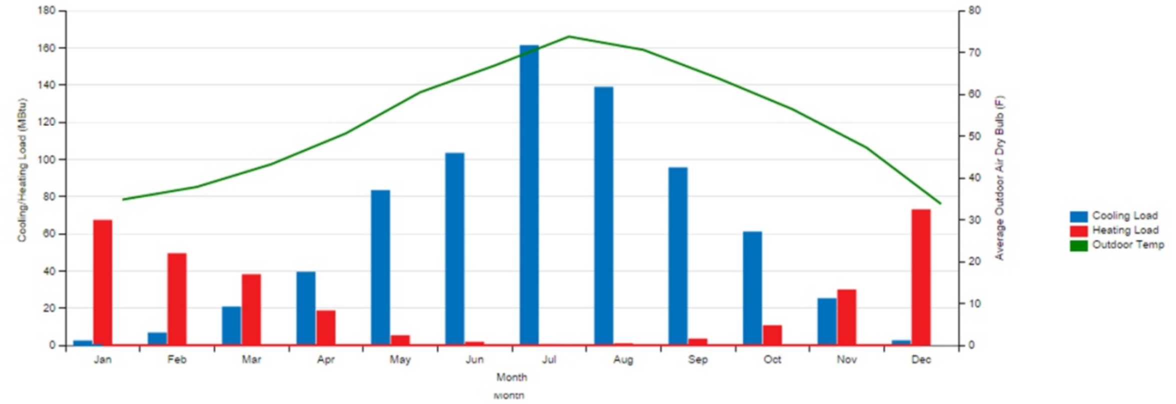
METAL



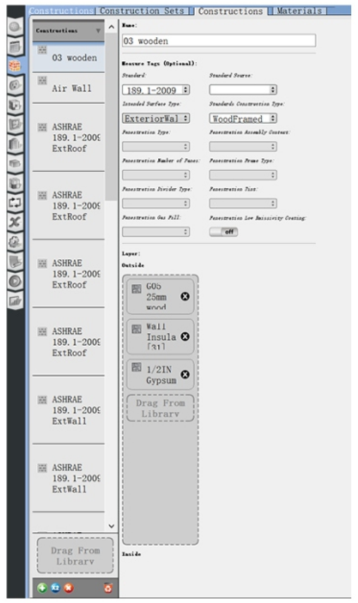


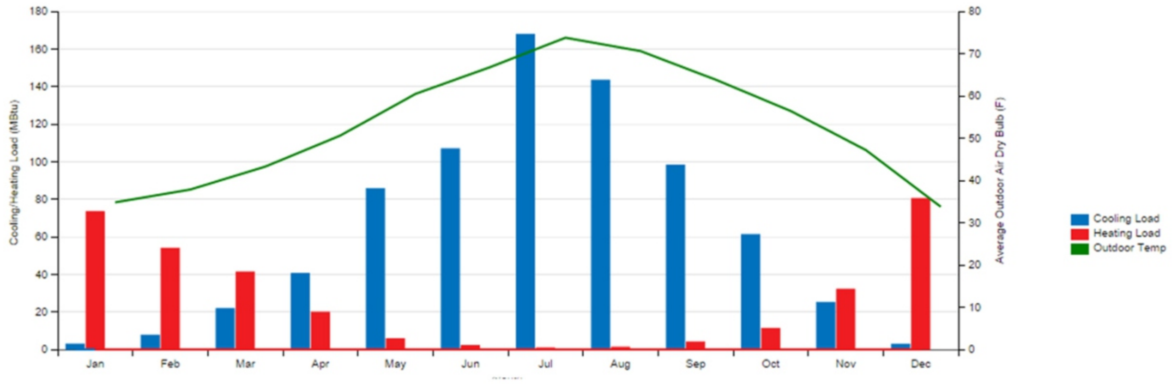
MASS 8IN SOLID CONCRETE WITH STEEL FRAME(BASIC ONE)





WOOD



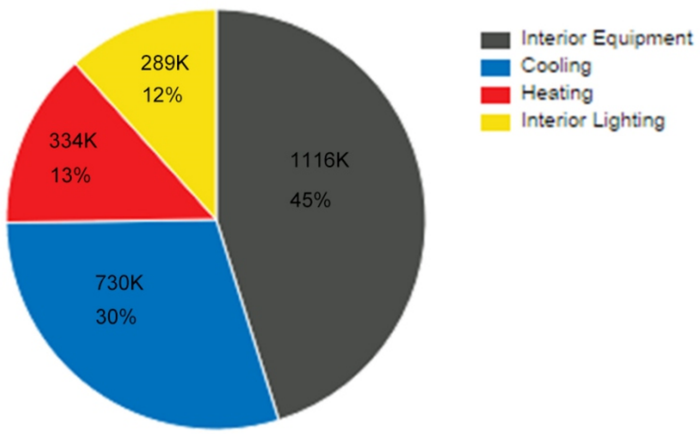


RESULT | 3 materials in Piacenza

ENERGY CONSUMPTION

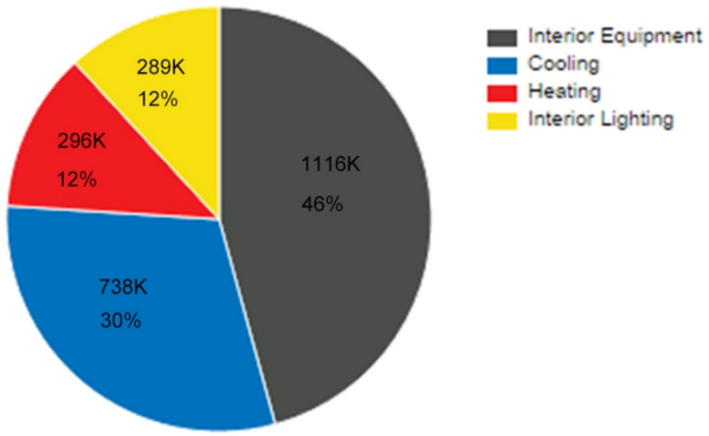
METAL

End Use - view table



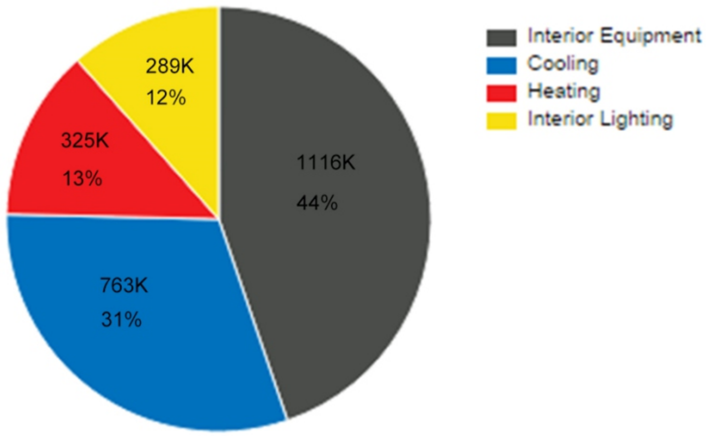
SOLID CONCRETE WITH STEEL FRAME(BASIC ONE)

End Use - view table



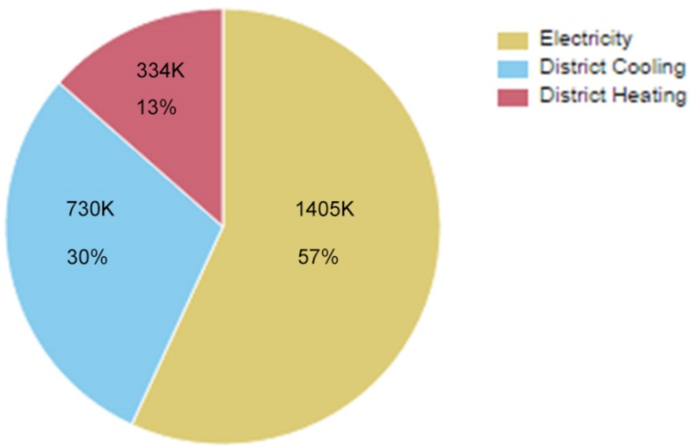
WOOD

End Use - view table

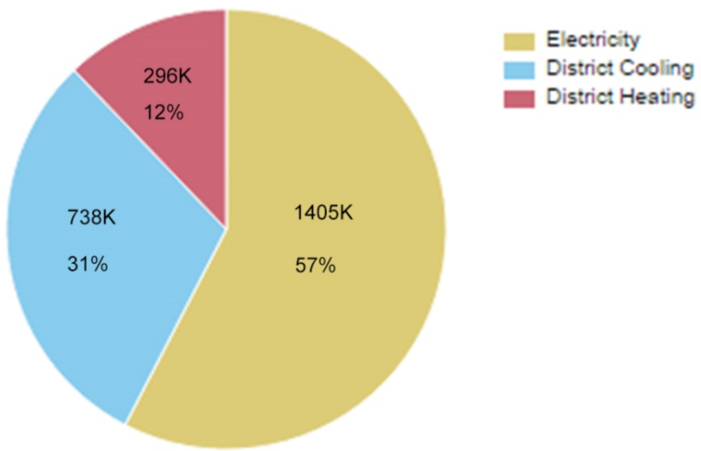


The data from these pie charts shows that the energy output of three buildings with three kinds of walls in different materials in the same city,Piacenza, so the weather is the same.And we can see the consumption of energy is almost the same but still has some differences.For heating,metal consumes most and concrete with steel consumpts least.As for cooling,the metal has a low consumption,but the wood frame has the high one.

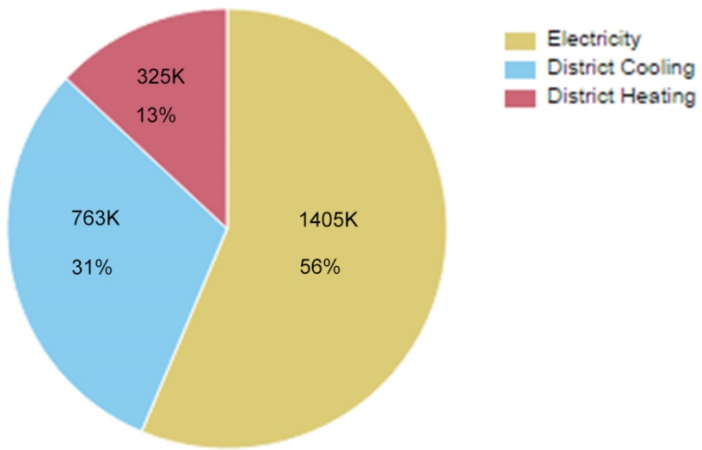
Energy Use - view table



Energy Use - view table



Energy Use - view table



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, concrete with steel building is the lowest while metal building is the highest. When it comes to district cooling, the metal building consume the least and the wood one cosume the most.

RESULT | 3 materials in Piacenza

THERMAL RESISTANCE

Base Surface Constructions METAL

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 2-5	17,222	8	24.74
metal wall	9,300	26	4.89

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

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 2-5	17,222	8	24.74
concrete steel frame const	9,300	26	10.28

Base Surface Constructions WOOD

Construction	Net Area (ft^2)	Surface Count	R Value (ft^2*h*R/Btu)
ASHRAE 189.1-2009 ExtRoof IEAD ClimateZone 1	17,222	8	19.96
ASHRAE 189.1-2009 ExtWall Mass ClimateZone 1	9,300	26	5.76

British units international unit

1ft^2*R/Btu = 10m^2*k/w

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 10.28 ft^2*R/Btu thermal resistance, while the value of metal exterial wall is 4.89 ft^2*R/Btu, and the wood one is 5.76 ft^2*R/Btu.

EXPERIMENTAL RESULT

PERFORMANCE OF ONE MATERIAL IN THREE DIFFERENT CITIES

SOLID CONCRETE WITH STEEL FRAME EXT WALLS

RESULT | solid concrete with steel frame ext walls in 3 cities

DATA SUMMARY

Building Summary PIACENZA

Data	Value
Building Name	Building 1
Total Site Energy	2,439,624 kBtu
Total Building Area	25,833 ft^2
Total Site EUI	94.44 kBtu/ft^2
OpenStudio Standards Building Type	n/a

Weather Summary PIACENZA

	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	

Building Summary DALIAN

Data	Value
Building Name	Building 1
Total Site Energy	2,635,699 kBtu
Total Building Area	25,833 ft^2
Total Site EUI	102.03 kBtu/ft^2
OpenStudio Standards Building Type	n/a

Weather Summary DALIAN

	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	

Building Summary TOKYO

Data	Value
Building Name	Building 1
Total Site Energy	2,530,785 kBtu
Total Building Area	25,833 ft^2
Total Site EUI	97.97 kBtu/ft^2
OpenStudio Standards Building Type	n/a

Weather Summary TOKYO

	Value
Weather File	TOKYO HYAKURI - JPN IWEC Data WMO#=477150
Latitude	36.18
Longitude	140.42
Elevation	115 (ft)
Time Zone	9.00
North Axis Angle	0.00
ASHRAE Climate Zone	

WEATHER **BUILDING**

The data shows that, due to different climatic conditions in the three locations, same type of construction results in a large difference in building energy consumption, in this case the material is SOLID CONCRETE.

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

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

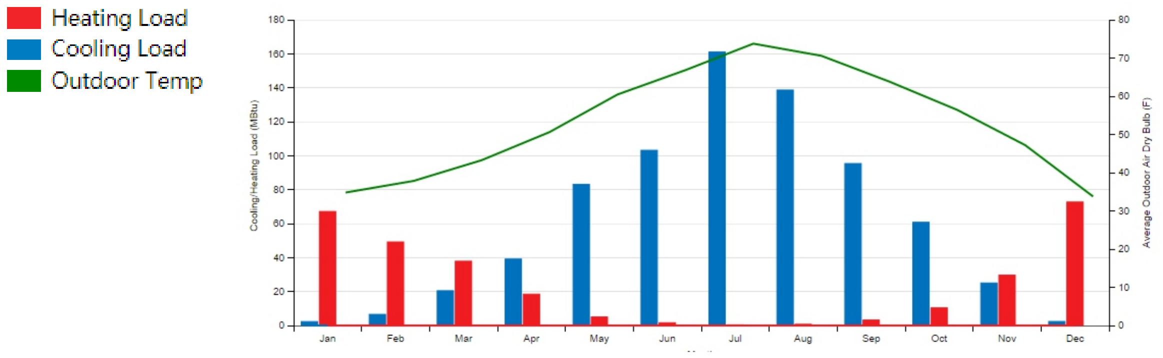
TOKYO belongs to a maritime subtropical monsoon climate with an elevation of 115 in which the Net Site energy and the EUI is in a medium position.

RESULT | solid concrete with steel frame ext walls in 3 cities

SIZING PERIOD DESIGN IN PIACENZA

Sizing Period Design Days

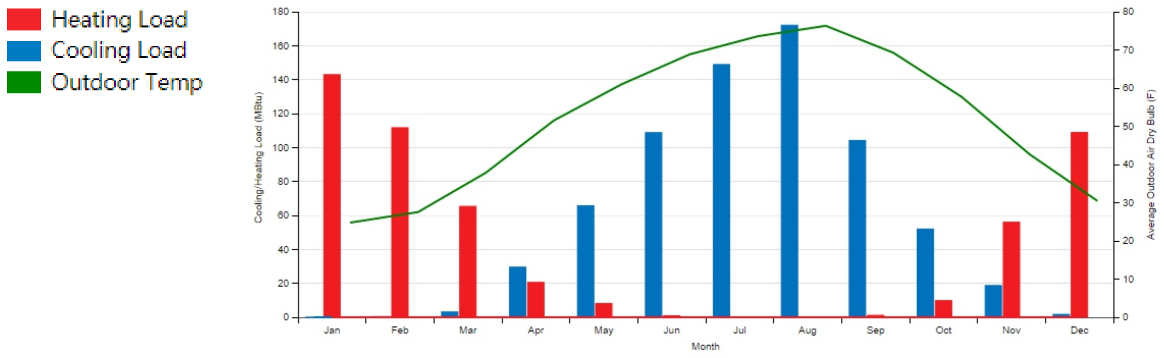
	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
PIACENZA ANN CLG .4% CONDNS DB=>MWB	91.58	21.42	72.86	Wetbulb [F]	5.14	90.0
PIACENZA ANN CLG .4% CONDNS DP=>MDB	81.32	21.42	73.4	Dewpoint [F]	5.14	90.0
PIACENZA ANN CLG .4% CONDNS ENTH=>MDB	86.54	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 DALIAN

Sizing Period Design Days

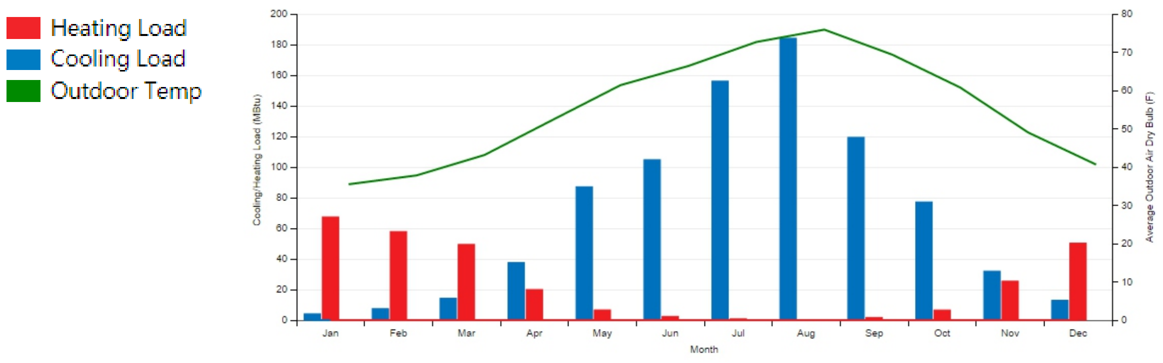
	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
DALIAN ANN CLG .4% CONDNS DB=>MWB	87.98	11.16	74.12	Wetbulb [F]	8.05	180.0
DALIAN ANN CLG .4% CONDNS DP=>MDB	81.32	11.16	77.36	Dewpoint [F]	8.05	180.0
DALIAN ANN CLG .4% CONDNS ENTH=>MDB	83.12	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 TOKYO

Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction
TOKYO HYAKURI ANN CLG .4% CONDNS DB=>MWB	89.78	13.86	78.8	Wetbulb [F]	10.74	210.0
TOKYO HYAKURI ANN CLG .4% CONDNS DP=>MDB	84.74	13.86	78.8	Dewpoint [F]	10.74	210.0
TOKYO HYAKURI ANN CLG .4% CONDNS ENTH=>MDB	87.08	13.86	36.46	Enthalpy [Btu/lb]	10.74	210.0
TOKYO HYAKURI ANN CLG .4% CONDNS WB=>MDB	87.08	13.86	80.24	Wetbulb [F]	10.74	210.0
TOKYO HYAKURI ANN HTG 99.6% CONDNS DB	19.58	0.0	19.58	Wetbulb [F]	2.46	0.0
TOKYO HYAKURI ANN HTG WIND 99.6% CONDNS WS=>MCDB	42.98	0.0	42.98	Wetbulb [F]	22.82	0.0
TOKYO HYAKURI ANN HUM_N 99.6% CONDNS DP=>MCDB	33.8	0.0	8.96	Dewpoint [F]	2.46	0.0



As can be seen from the data, the daily temperature range is influenced by various factors, such as wind speed and wind direction. The daily temperature range in Piacenza is almost twice of Dalian, and more than Tokyo.

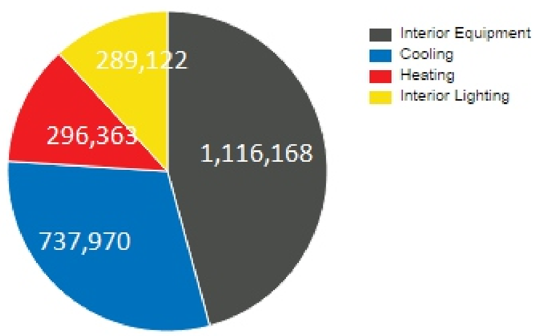
From the data of monthly load profiles in three cities, it can be seen that the heating and cooling load is related to the outdoor temperature. According to the EUI and Net Site Energy, the extreme temperature changes throughout the year requires increased energy consumption in both heating and cooling, which then increased the building energy consumption.

RESULT | solid concrete with steel frame ext walls in 3 cities

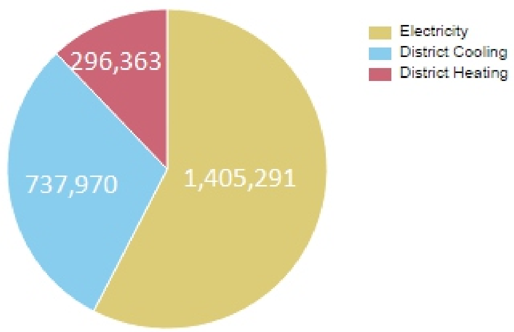
ENERGY CONSUMPTION

PIACENZA

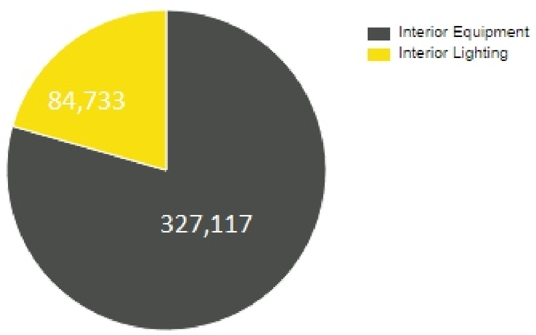
END-USE



ENERGY USE

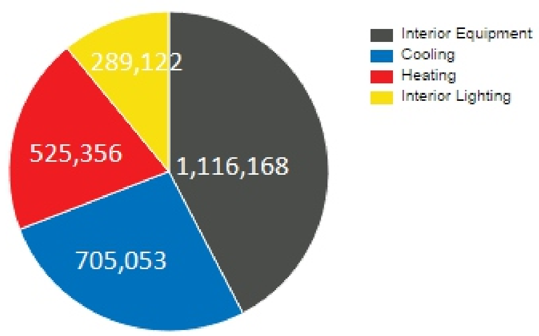


ELECTRICITY

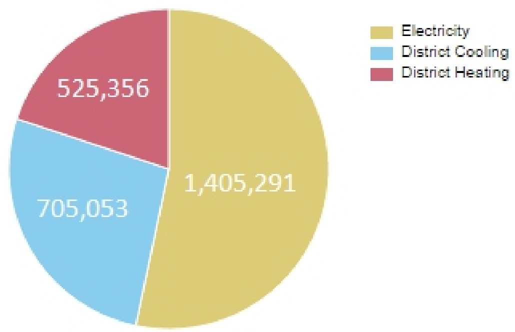


DALIAN

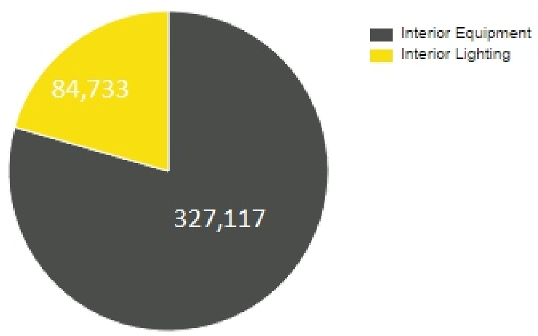
END-USE



ENERGY USE

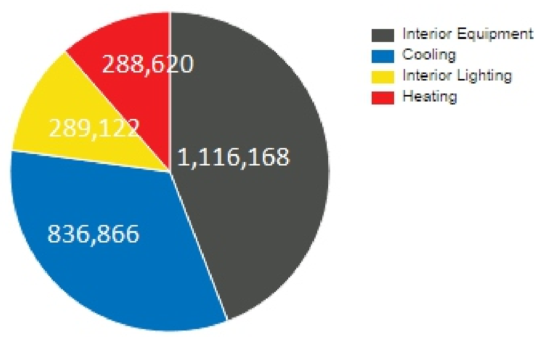


ELECTRICITY

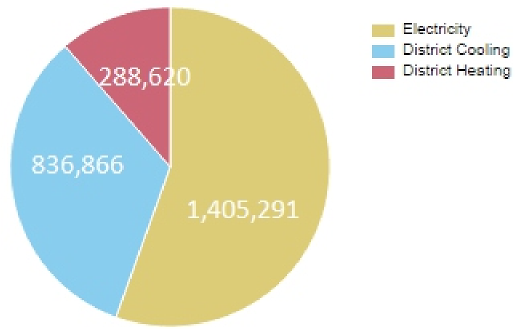


TOKYO

END-USE



ENERGY USE



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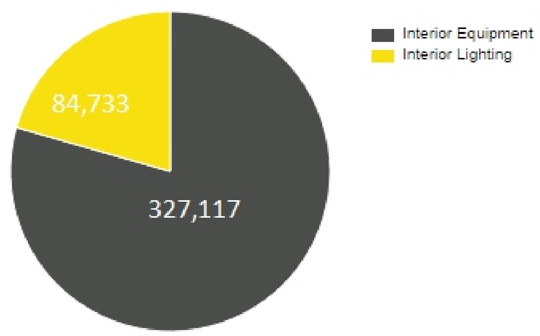


The data shows that the energy output is similar in different cities, but there are some differences due to the weather and temperature.

Average temperature of Piacenza is higher than Dalian, so the heating energy is higher in Dalian. Meanwhile, Tokyo is not too different with Piacenza, so the cooling and heating end use is similar, with heating higher in Piacenza and cooling higher in Tokyo.

Distribution of energy is concentrated due to the change of climate and the control of indoor temperature. Proportion of interior equipments, lighting, and facilities are stable in three sites, but different cities has different needs. Again, its similar between Tokyo and Piacenza, but Dalian has a higher need of heating.

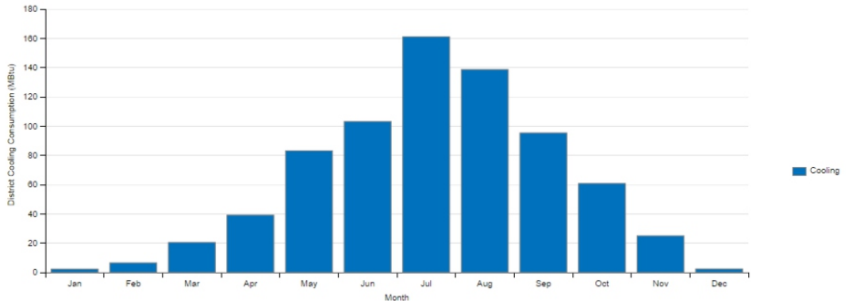
It can be seen from the charts that at the EUI of three sites are almost the same, with similar proportion of electricity.

Proportion of heating and cooling in the end use and energy use charts are the same. But because the use of interior equipment needs electricity, the proportion in energy use is a little bit more than proportion in other charts.

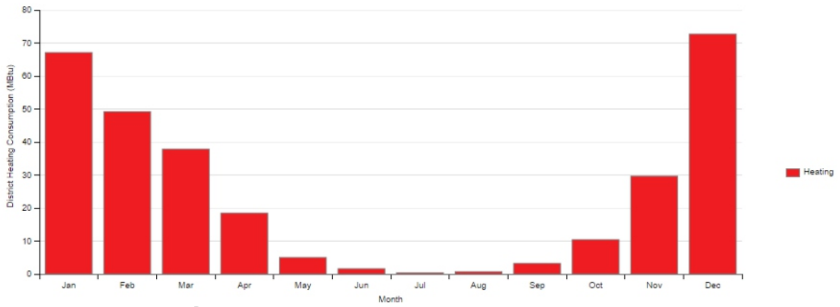
RESULT | solid concrete with steel frame ext walls in 3 cities

ENERGY CONSUMPTION

PIACENZA

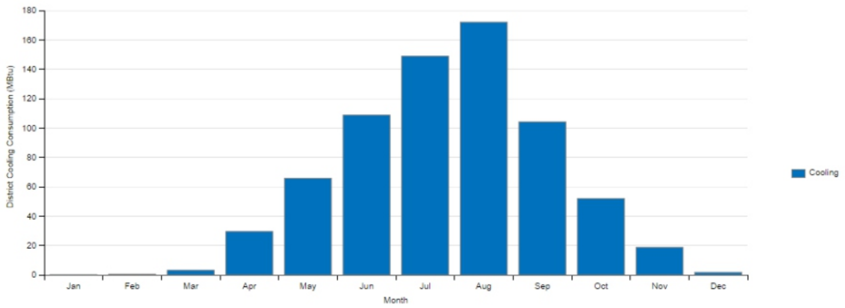


COOLING

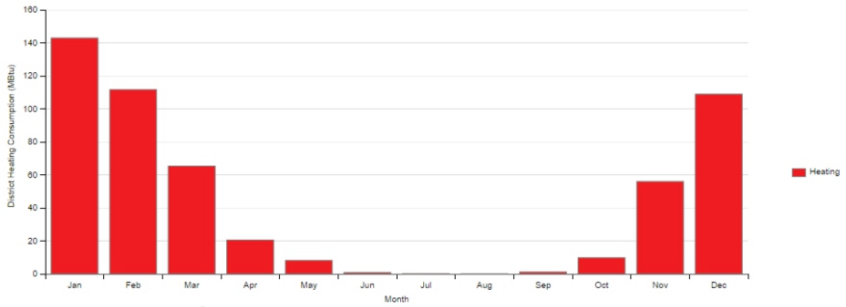


HEATING

DALIAN

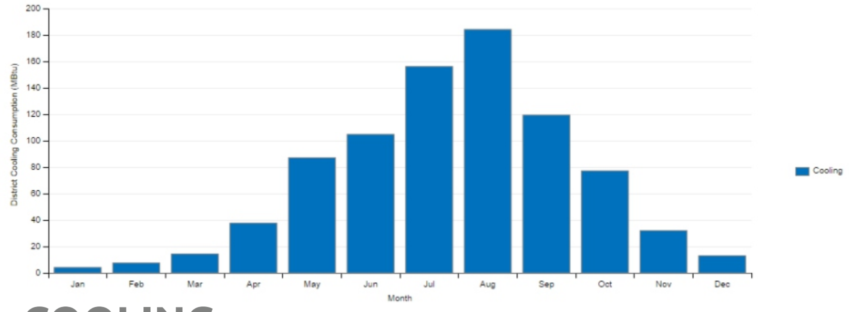


COOLING

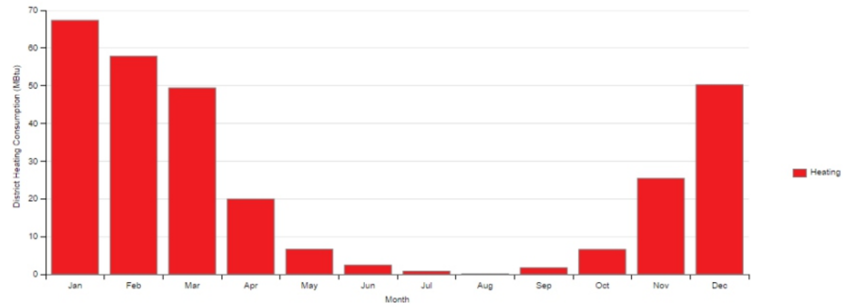


HEATING

TOKYO



COOLING



HEATING

The cooling consumption in three cities are normal due to seasonal variation. Normally its higher in March till November and will peak in July - August. In other months are more uniform. The little difference is that Dalian has no cooling needs in January and February.

Consumption of heating load is continuous in every city. But the trend is the same, during summer the load is extremely low than other months. Dalian has the lowest consumption in the summer.

CONCLUSION

THREE MATERIALS IN PIACENZA

Material		Piacenza	Total
Concrete	Cooling	737.97	1034.27
	Heating	296.36	
Metal	Cooling	730.86	1065.42
	Heating	334.56	
Wood	Cooling	763.13	1088.38
	Heating	325.25	

Regarding the energy performance of the building with different construction properties, it can be seen that using CONCRETE overall has the lowest energy consumption. But metal is the best for cooling.
The energy saved will result in lower cost in the long run.

The other materials, metal is better than wood in cooling and wood is better in heating.

CONCRETE WITH STEEL IN THREE CITIES

There are differences in loads in the three cities even with the same elements. Weather is most important variable that caused the variety. A place that is too cold or too hot will cost more energy. For cooling, Tokyo has the lowest requirement, while Dalian is the highest. As for the heating, Tokyo is the highest and Dalian is the lowest, almost the same value as Piacenza.

in kBtu			
	Piacenza	Dalian	Tokyo
Cooling	737.97	836.866	705.05
Heating	296.36	288.62	525.35
Total	1034.27	1125.48	1230.40

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