ENERGY AND ENVIRONMENTAL TECHNOLOGIES FOR BUILDING SYSTEMS

Master of Science Energy Engineering in Renewables and Environmental Sustainability (RES)

School of Industrial and Information Engineering (Piacenza Campus)

Open Studio Project

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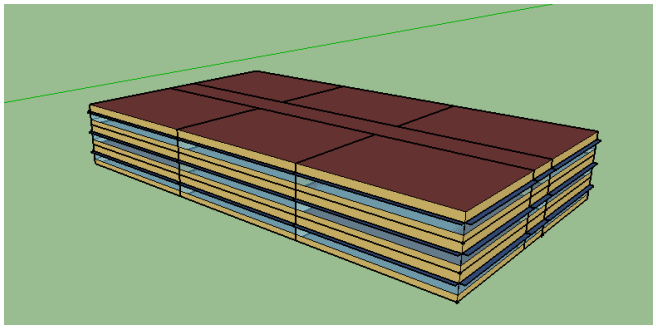
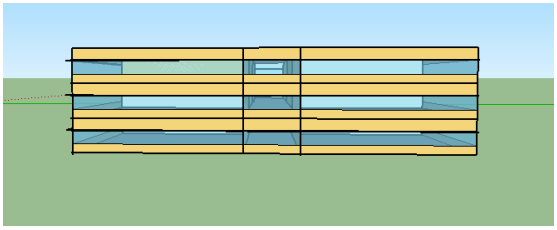
1. Introduction.

We designed an office building of three floors, that consists in six offices for floor and in each floor; there is a corridor, where people working could stretch up or talk with other people that are not in their same office.





In the first part of the project, the main objective is to simulate and run our designed building in three different cities in order to compare the yearly heating and cooling consumptions. The three cities will be:

Naples (Italy)	San Juan (Puerto Rico)	Helsinki (Finland)
○ Latitude: 40.85º ○ Altitude: 14.30º ○ Climatic Zone (CZ): 3	○ Latitude: 18.43º ○ Altitude: -66.0º ○ Climatic Zone (CZ): 1	○ Latitude: 60.32º ○ Altitude: 24.97º ○ Climatic Zone (CZ): 7

We have set Naples as the base case. Then, we will compare the yearly consumptions of the other two cities to the base case.

In the second part of the project, the main objective is to select a base case, that is already selected, which is Naples. This base case will have a wall composition that will give a cooling and heating load. The objective is to change the wall composition and to see how much change our loads by having a worst and best case.

First part: comparison between cities

2. Naples (Italy) - Base case.

2.1. ANNUAL OVERVIEW.

2.1.1. End and energy use.

End Use	Consumption (MBtu)	%
Heating	**73.181**	**3.22**
Cooling	**824.279**	**36.30**
Lighting (interior)	681.234	30.00
Equipment (interior)	692.039	30.48

Energy use	Consumption (MBtu)	%
Electricity	1,373.273	60.48
District Cooling	**824.279**	**36.30**
District Heating	**73.181**	**3.22**

(Note: Lighting and equipment consumptions are default values. They will be the same in all the cities.)

According to the end and energy use, it can be demonstrated that cooling is relatively higher than heating consumption. Moreover, cooling represents approximately one third of the total consumption, whereas heating consumption is less than 5%.

2.2. MONTHLY OVERVIEW.

2.2.1. District Cooling Consumption (MBtu).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
3.75	2.37	13.48	27.74	80.09	128.42	168.49	182.49	115.74	73.05	22.65	5.8	**824.28**

2.2.2. District Heating Consumption (MBtu).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
18.88	13.52	11.28	3.02	1.0	0.17	0.03	0.0.	0.19	0.91	6.36	17.78	**73.18**

2.2.3. District Cooling Peak Demand (kBtu/hr).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
103.22	115.56	194.42	307.20	470.06	719.78	721.18	731.38	596.33	527.47	330.28	154.35

2.2.4. District Heating Peak Demand (kBtu/hr).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
853.88	687.27	686.80	365.04	202.65	43.53	8.0	7.32	54.76	266.4	610.55	1008.52

The following conclusions are reached according to the monthly overview:

- Related to district cooling, the highest consumptions take place between May-October (agreeing with Spring and Summer seasons in the north hemisphere, when temperatures are higher). The highest peak demand takes place in August.
- Related to district heating, the highest consumptions take place between November-March (agreeing with Autumn and Winter seasons in the north hemisphere, when temperatures are lower). The highest peak demand takes place in January. However, the peak is much smaller than cooling peak.

3. San Juan (Puerto Rico).

3.1. ANNUAL OVERVIEW.

3.1.1. End and energy use.

End Use	Consumption (MBtu)	%
Heating	**95**	**2.51**
Cooling	**2,316.730**	**61.21**
Lighting (interior)	681.234	18.00
Equipment (interior)	692.039	18.28

Energy use	Consumption (MBtu)	%
Electricity	1,373.273	36.28
District Cooling	**2,316.730**	**61.21**
District Heating	**95**	**2.51**

According to the end and energy use, cooling is much higher than heating consumption. Moreover, cooling represents approximately two thirds of the total consumption, whereas heating consumption is less than 5% (almost equal to the base case).

Comparing to the base case (Naples), cooling consumption is duplicated as heating consumption maintains almost the same value.

3.2. MONTHLY OVERVIEW.

3.2.1. District Cooling Consumption (MBtu).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
158.94	142.48	172.22	171.42	204.46	220.3	219.14	232.47	221.79	214.53	190.71	168.27	**2316.73**

3.2.2. District Heating Consumption (MBtu).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
0.03	0.03	0.01	0	-	-	0	0	-	-	0	0.03	**0.1**

3.2.3. District Cooling Peak Demand (kBtu/hr).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
651.45	651.81	690.49	765.12	739.03	838.71	858.81	820.40	840.43	804.85	783.70	769.19

3.2.4. District Heating Peak Demand (kBtu/hr).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.86	6.00	1.97	3.42	-	-	2.39	0.52	-	-	0.76	7.05

The following conclusions are reached from the monthly overview:

- The performance shows an almost equilibrated cooling consumption during all the year, being the highest value only 30% more than the lowest. The highest peak demand takes place in July. Comparing to the base case, the total cooling consumption is three times more than the base case.
- Related to district heating, the consumption values are very small, almost negligible if it is compared with the base case.

4. Helsinki (Finland).

4.1. ANNUAL OVERVIEW.

4.1.1. End and energy use.

End Use	Consumption (MBtu)	%
Heating	**445.408**	**21.04**
Cooling	**297.690**	**14.07**
Lighting (interior)	681.234	32.19
Equipment (interior)	692.039	32.70

Energy use	Consumption (MBtu)	%
Electricity	1.373,273	64.89
District Cooling	**297.690**	**14.07**
District Heating	**445.408**	**21.04**

According to the end and energy use, heating represents around the 20% of the total (considerably bigger than in the other two cases). Cooling energy represents around the 15% (considerably lower than in the base case)

4.2. MONTHLY OVERVIEW.

4.2.1. District Cooling Consumption (MBtu).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
-	-	0.01	5.78	35.05	65.27	84.68	80.33	24.43	2.17	-	-	**297.69**

4.2.2. District Heating Consumption (MBtu).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
96.67	90.64	53.24	16.9	3.17	0.81	0.51	0.75	4.21	16.57	71.13	90.8	**445.41**

4.2.3. District Cooling Peak Demand (kBtu/hr).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	-	6.15	196.35	355.52	414.68	548.19	525.49	326.35	69.66	-	-

4.2.4. District Heating Peak Demand (kBtu/hr).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1402.40	1479.90	1338.05	1062.33	513.03	298.91	107.50	121.71	765.19	1036.63	1510.77	1440.81

The following conclusions are reached from the monthly overview:

- Cooling consumption takes places between May and August, but the consumption quantity is considerably fewer than Naples case. The highest peak demand takes place in July. Comparing to the base case, the total cooling consumption is less than a half of the base case total consumption.
- Related to district heating, the consumption increases during the Autumn-Winter period (from November to March), where the heating consumption values are bigger than cooling. The peak demand during November-March is really high, tripling the peak demand values of the base case.

Second part: comparison between walls composition

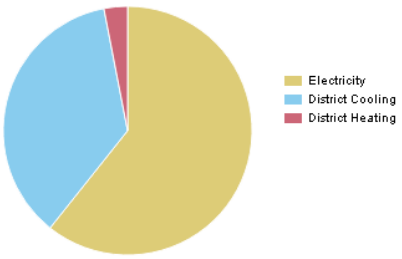
5. Base Case- Naples (Italy).

5.1. Wall Composition.

Base Case	Thickness(m)	Conductivity (W/m.K)
1 in stucco	0.0253	0.6918
8 in concrete HW	0.2033	1.7296
Wall Insultation [31]	0.0337	0.0432
½ in Gypsum	0.0127	0.16

For this composition, OpenStudio shows a value of **R= 8.77 ft^2*h*R/Btu** and this correspond to **U= 0.1140 Btu/ ft^2*h*R.**

5.2. Consumption over the year.



Energy use	Consumption (MBtu)	%
Electricity	1,373.273	60.48
District Cooling	**824.279**	**36.30**
District Heating	**73.181**	**3.22**

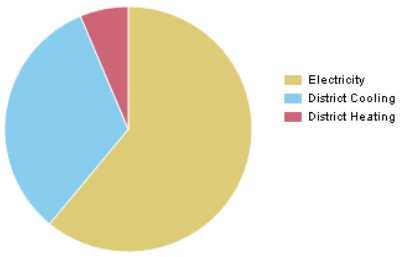
6. Best Case- Naples (Italy).

6.1. Wall Composition.

Best Case	Thickness(m)	Conductivity (W/m.K)
G05 25 mm wood	0.0254	0.15
8 in concrete HW	0.2033	1.7296
Wall Insultation [44]	0.1104	0.0432
½ in Gypsum	0.0127	0.16

For this composition, OpenStudio show a value of **R= 16.59 ft^2*h*R/Btu** and this correspond to **U= 0.0603 Btu/ ft^2*h*R.**

6.2. Consumption over the year.



Energy use	Consumption (MBtu)	%
Electricity	1,373.273	60.97
District Cooling	**736.710**	**32.71**
District Heating	**142.419**	**6.32**

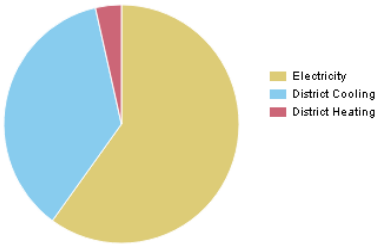
7. Worst Case- Naples (Italy).

7.1. Wall Composition.

Worst Case	Thickness(m)	Conductivity (W/m.K)
1 in stucco	0.0253	0.6918
Mat 4 HW concrete	0.1016	1.311
Wall Insultation [31]	0.0337	0.0432
½ in Gypsum	0.0127	0.16

For this composition, OpenStudio shows a value of **R= 5.53 ft^2*h*R/Btu** and this correspond to **U= 0.1808 Btu/ ft^2*h*R.**

7.2. Consumption over the year.



Energy use	Consumption (MBtu)	%
Electricity	1,373.273	59.98
District Cooling	**834.619**	**36.46**
District Heating	**81.522**	**3.56**

8. Conclusions.

Conclusion: For our ***base case***, we got an **U=0.1140 Btu/ ft^2*h*R,** and we can greatly see that for ***best case*** is reduced and the value is **U= 0.0603 Btu/ ft^2*h*R**, therefore, we will have less consumption and this is good mainly for our ***cooling load***, because the location that we chose need more cooling than heating. As we can see, in the ***base case*** we have a district cooling consumption of **824.279** and for the ***best case*** **is 736.710.** In the case of the ***worst case*** the **U=0.1808 Btu/ ft^2*h*R**, therefore we will have more consumption, and these will cause more cost to our system, since in this case our district consumption is **834.619.** So, choosing the best material for our walls, is important for our loads and for economic benefits.