Technical Environmental Systems

Building Performance Analysis by Open Studio

Group T5

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17th December 2019

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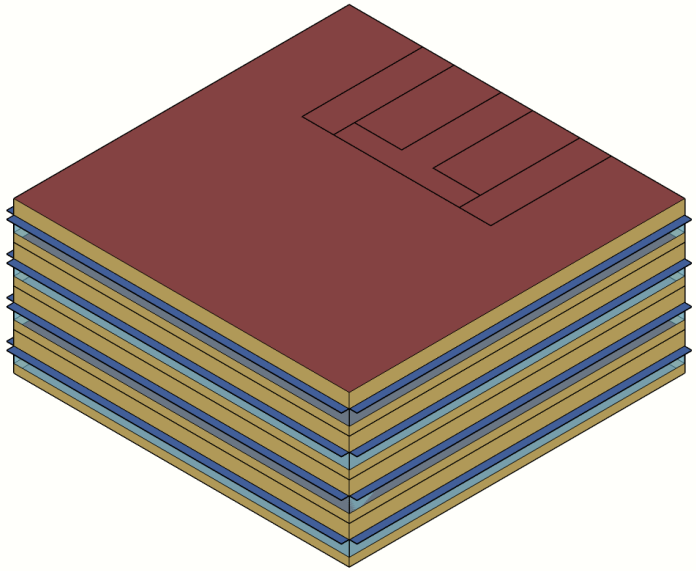
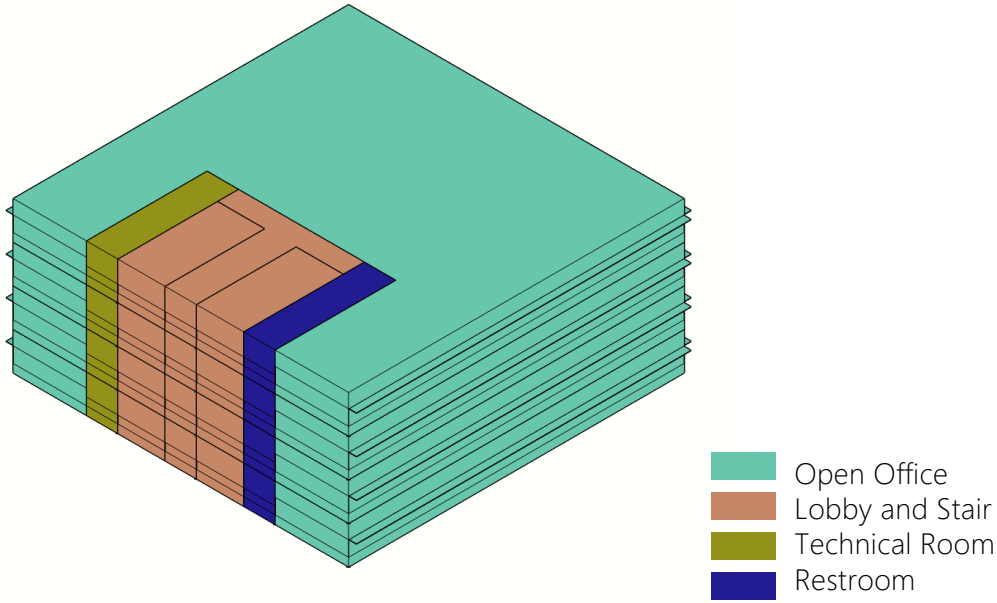
APENDIX

BASE CASE





The building is a 4-level office located in Milan, Italy, with open office space with square floor plan (32x32m). The service core (stair, office lobby, restroom and technical room) is located on the North side.

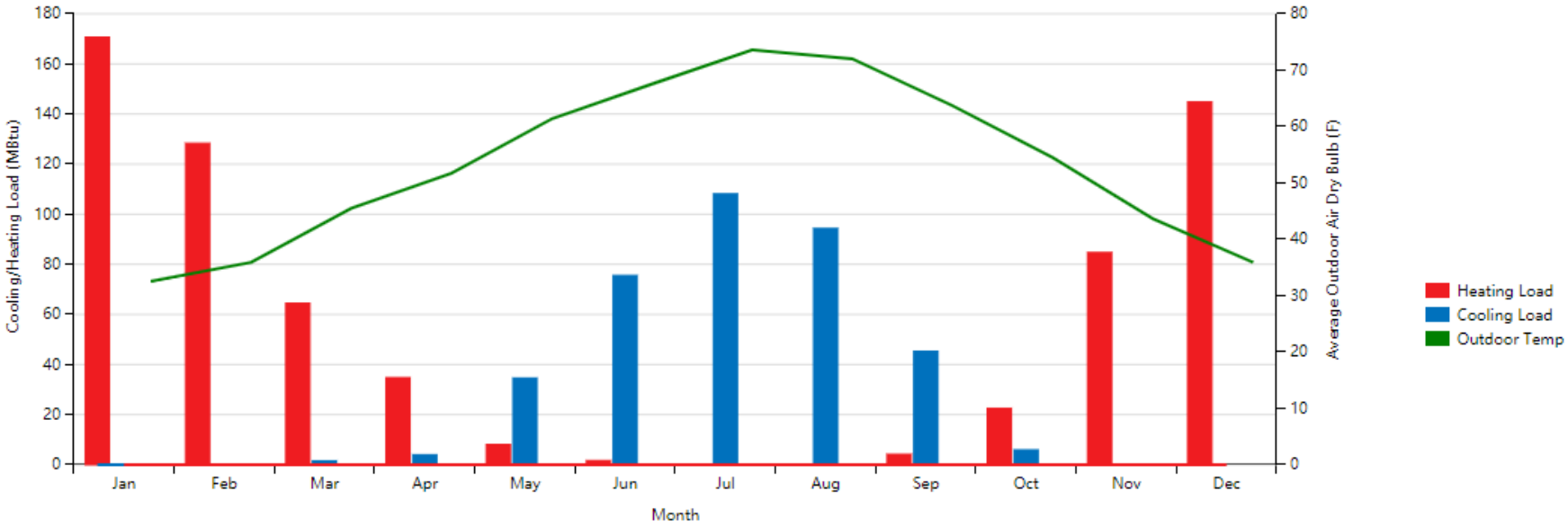
Typical Floor Area	1024 sqm, including:
▪ Open Office Area	817 sqm (~80%)
▪ Service Core Area	207 sqm (~20%)

Facade at Open Office area has window to floor area at 0.8
Facade at Open Office area has window to floor area at 0.2
All windows (except windows on the North side) have shading overhang extruding 750mm

	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	701.29	389.88			1091.17	2023.74
			495.39	437.18	932.57	

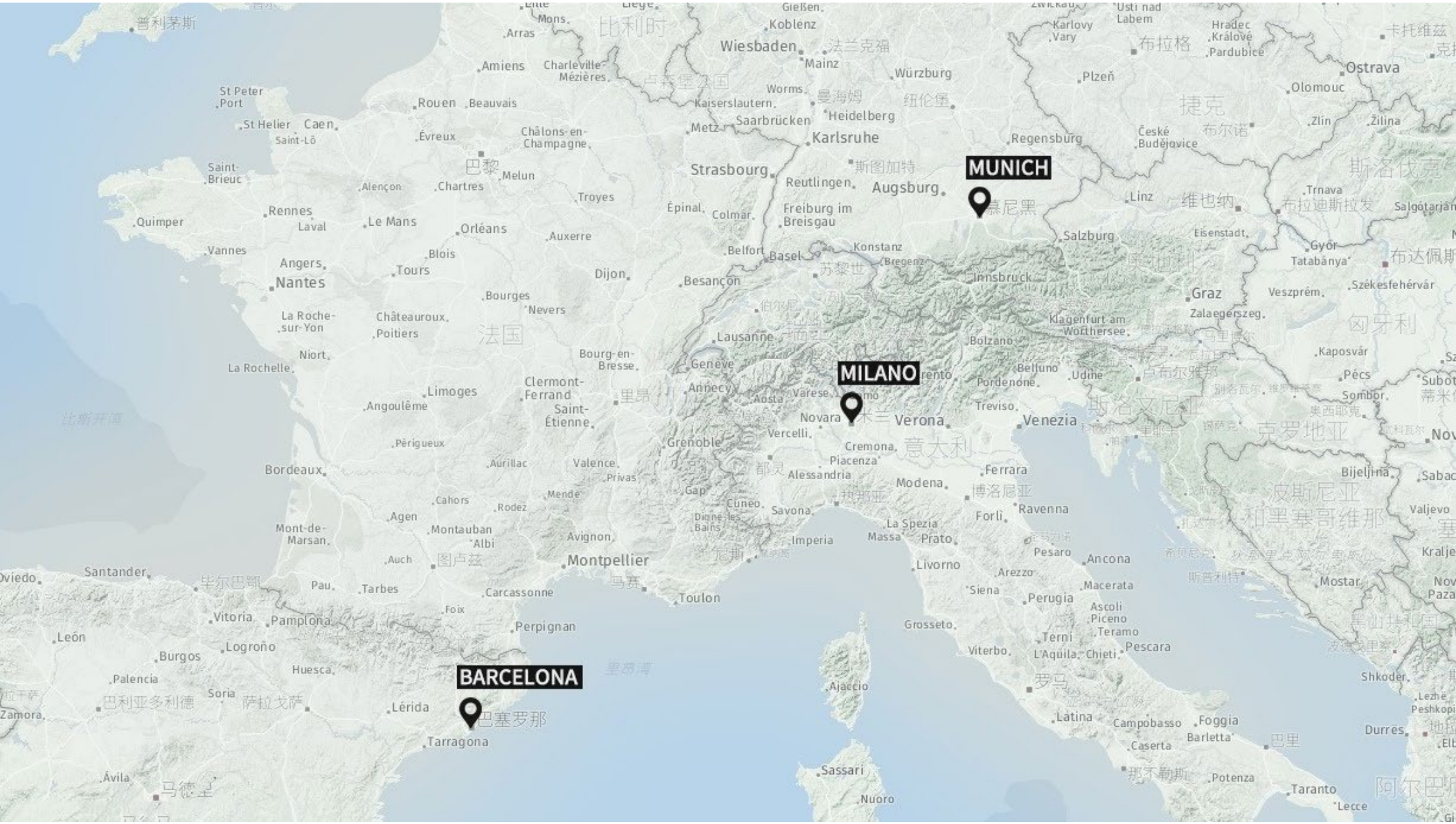
Yearly Energy Load
(EnergyPlus result - SI)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Outdoor Air Dry Bulb (F)	32.6	35.9	45.5	51.7	61.4	67.5	73.6	72.0	63.7	54.5	43.6	35.9
Cooling Load (MBtu)	0.0	0.0	1.54	3.98	34.61	75.55	108.14	94.3	45.27	5.94	0.22	0.0
Heating Load (MBtu)	170.68	128.31	64.49	34.76	8.09	1.65	0.19	0.28	4.17	22.54	84.7	144.83

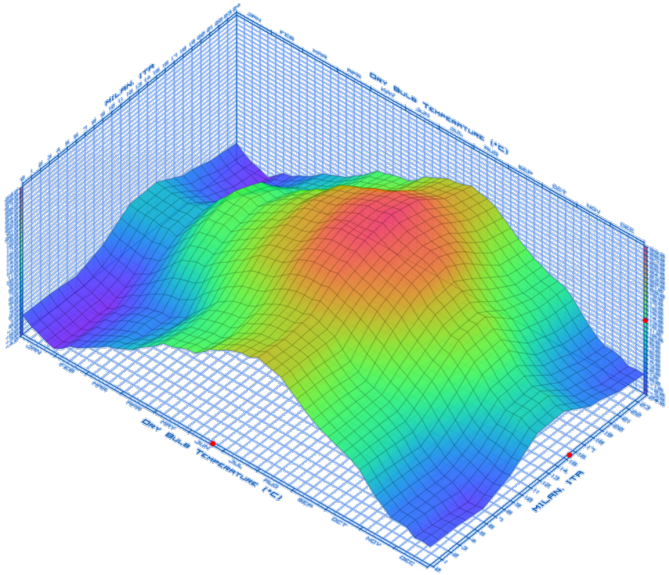


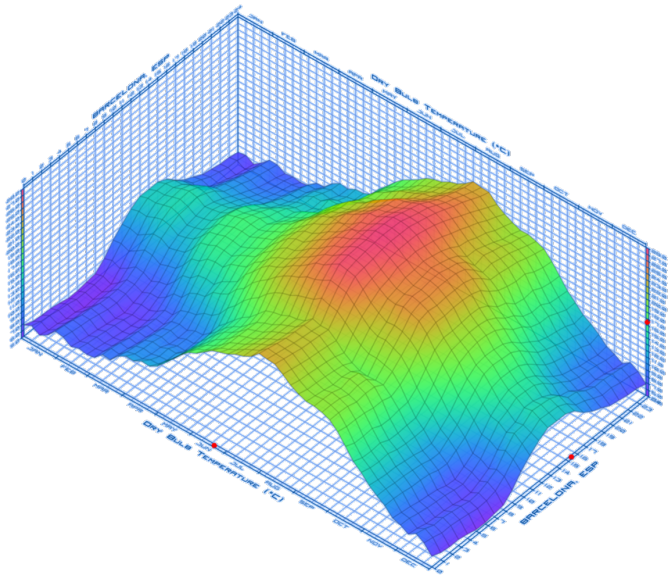
Monthly Energy Load
(Open Studio result)

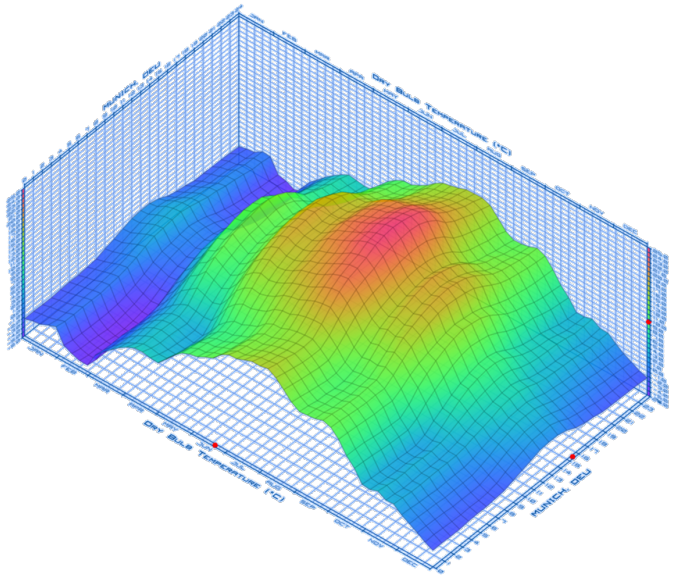
3-CITY ANALYSIS


MUNICH
MILANO
BARCELONA
Wiesbaden
Mainz
Koblenz
Würzburg
Karlsruhe
Heidelberg
Strasbourg
Augsburg
Regensburg
Salzburg
Innsbruck
Graz
Linz
Ostrava
Olomouc
Plzeň
Karlovy Vary
Hradec Králové
Pardubice
České Budějovice
Trnava
Győr
Tatabánya
Veszprém
Székesfehérvár
Kaposvár
Pécs
Sombor
Zalaegerszeg
Eisenstadt
Klagenfurt am Wörthersee
Bolzano
Belluno
Udine
Pordenone
Treviso
Venezia
Verona
Vicenza
Trento
Novara
Vercelli
Cremona
Piacenza
Alessandria
Modena
Ferrara
Ravenna
Forlì
La Spezia
Massa
Prato
Pisa
Livorno
Pesaro
Ancona
Arezzo
Siena
Perugia
Macerata
Ascoli Piceno
Teramo
Terni
L'Aquila
Chieti
Pescara
Viterbo
Grosseto
Ajaccio
Sassari
Nuoro
Latina
Campobasso
Foggia
Barletta
Caserta
Potenza
Taranto
Lecce
Bijeljina
Mostar
Valjevo
Kraljevo
Shkodër
Lezhë
Durrës
Tarragona
Lérida
Barcelona
Perpignan
Toulon
Montpellier
Carcassonne
Avignon
Nîmes
Valence
Grenoble
Gap
Cuneo
Savona
Imperia
Genève
Lausanne
Annecy
Aosta
Varese
Besançon
Dijon
Bourg-en-Bresse
Clermont-Ferrand
Saint-Étienne
Limoges
Angoulême
Bordeaux
Périgueux
Bourges
Nevers
Tours
Orléans
Auxerre
Troyes
Chartres
Melun
Évreux
Rouen
Beauvais
Amiens
Caen
Rennes
Nantes
Le Mans
Angers
Laval
Quimper
Vannes
Saint-Brieuc
St Peter Port
St Helier
Saint-Lô
Mons
Arras
Charleville-Mézières
Châlons-en-Champagne
Metz
Saarbrücken
Kaiserslautern
Worms
Mainz
Gießen
Zwickau
Usti nad Labem
Zlin
Žilina
Salgótarján
Santander
Oviedo
Vitoria
Pamplona
Logroño
Burgos
León
Palencia
Zamora
Soria
Huesca
Zaragoza
Ávila
Madrid
Pau
Tarbes
Foix
Auch
Cahors
Rodez
Agen
Montauban
Albi
Mende
Aurillac
Mont-de-Marsan
Châteauroux
Poitiers
Niort
La Rochelle
La Roche-sur-Yon
Vaduz
Zürich
Basel
Belfort
Colmar
Épinal
Freiburg im Breisgau
Reutlingen
Konstanz
Bregenz
Rostock
Berlin
Prague
Vienna
Budapest
Zagreb
Ljubljana
Sarajevo
Belgrade
Bucharest
Sofia
Skopje
Tirana
Podgorica
Split
Dubrovnik
Bari
Palermo
Catania
Cagliari
Malta
Valletta
Tunis
Algiers
Rabat
Casablanca
Marrakech
Lisbon
Porto
Faro
Seville
Granada
Malaga
Valencia
Alicante
Murcia
Zaragoza
Bilbao
San Sebastián
Pamplona
Toulouse
Marseille
Nice
Cannes
Monaco
Lyon
Saint-Etienne
Clermont-Ferrand
Le Havre
Rouen
Lille
Liège
Cologne
Frankfurt
Hamburg
Munich
Stuttgart
Nuremberg
Leipzig
Dresden
Hannover
Bremen
Amsterdam
Rotterdam
Brussels
Antwerp
Luxembourg
Copenhagen
Malmö
Gothenburg
Stockholm
Oslo
Helsinki
Tallinn
Riga
Vilnius
Minsk
Kyiv
Moscow
Saint Petersburg
Istanbul
Ankara
Athens
Thessaloniki
Reykjavik
Dublin
Cork
Belfast
London
Manchester
Birmingham
Edinburgh
Glasgow
Cardiff
Bristol
Leeds
Liverpool
Newcastle
Sheffield
Nottingham
Leicester
Southampton
Portsmouth
Brighton
Cambridge
Oxford
Norwich
Ipswich
Plymouth
Exeter
Bath
Swansea
Aberdeen
Inverness
Stirling
Perth
Dundee
Belfast
Cork
Galway
Limerick
Waterford
Kilkenny
Wexford
Sligo
Donegal
Letterkenny
Ballyshannon
Ballinrobe
Ballinasloe
Athlone
Mullingar
Navan
Dublin
Belfast
Derry
Lisburn
Newry
Ballymena
Coleraine
Portrush
Ballycastle
Larne
Bangor
Newtownards
Downpatrick
Ballynahinch
Castlewellan
Rostrevor
Kilkeel
Newcastle
Ballycastle
Ballyshannon
Donegal
Letterkenny
Sligo

DRY BULB WEATHER DATA
(visualized by www.drajmarsh.bitbucket.io)







MILAN	
Summer Design Day	21 Jul
Cooling DB 0.4%	31.9ºC
Winter Design Day	21 Jan
Heating DB 99.6%	-9.1ºC

BARCELONA	
Summer Design Day	21 Aug
Cooling DB 0.4%	30.2ºC
Winter Design Day	21 Jan
Heating DB 99.6%	0.9ºC

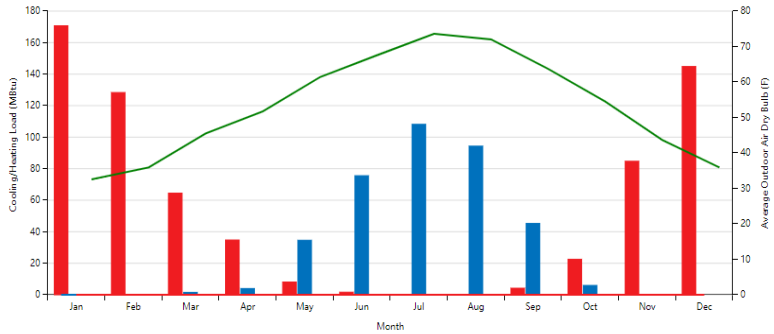
MUNICH	
Summer Design Day	21 Jul
Cooling DB 0.4%	29.4ºC
Winter Design Day	21 Jan
Heating DB 99.6%	-14.2ºC

Yearly Energy Load (EnergyPlus result - SI)

Monthly Energy Load (Open Studio result)

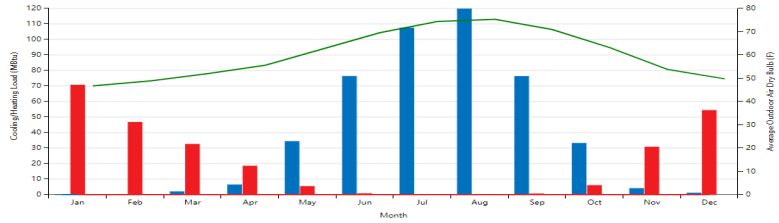
MILAN

	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	701.29 (64%)	389.88 (36%)			1091.17 (100%)	2023.74
			495.39	437.18	932.57	



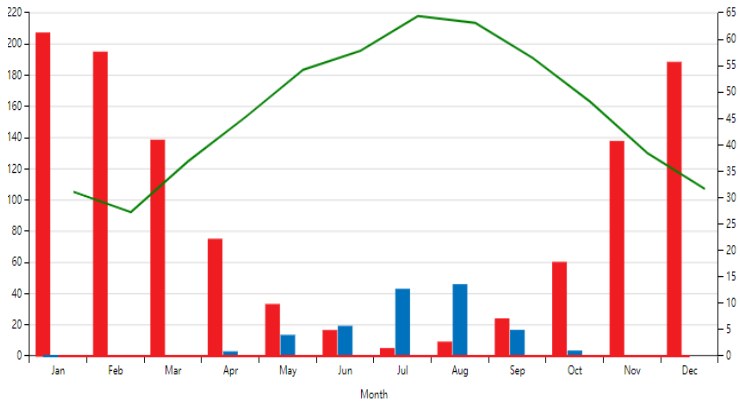
BARCELONA

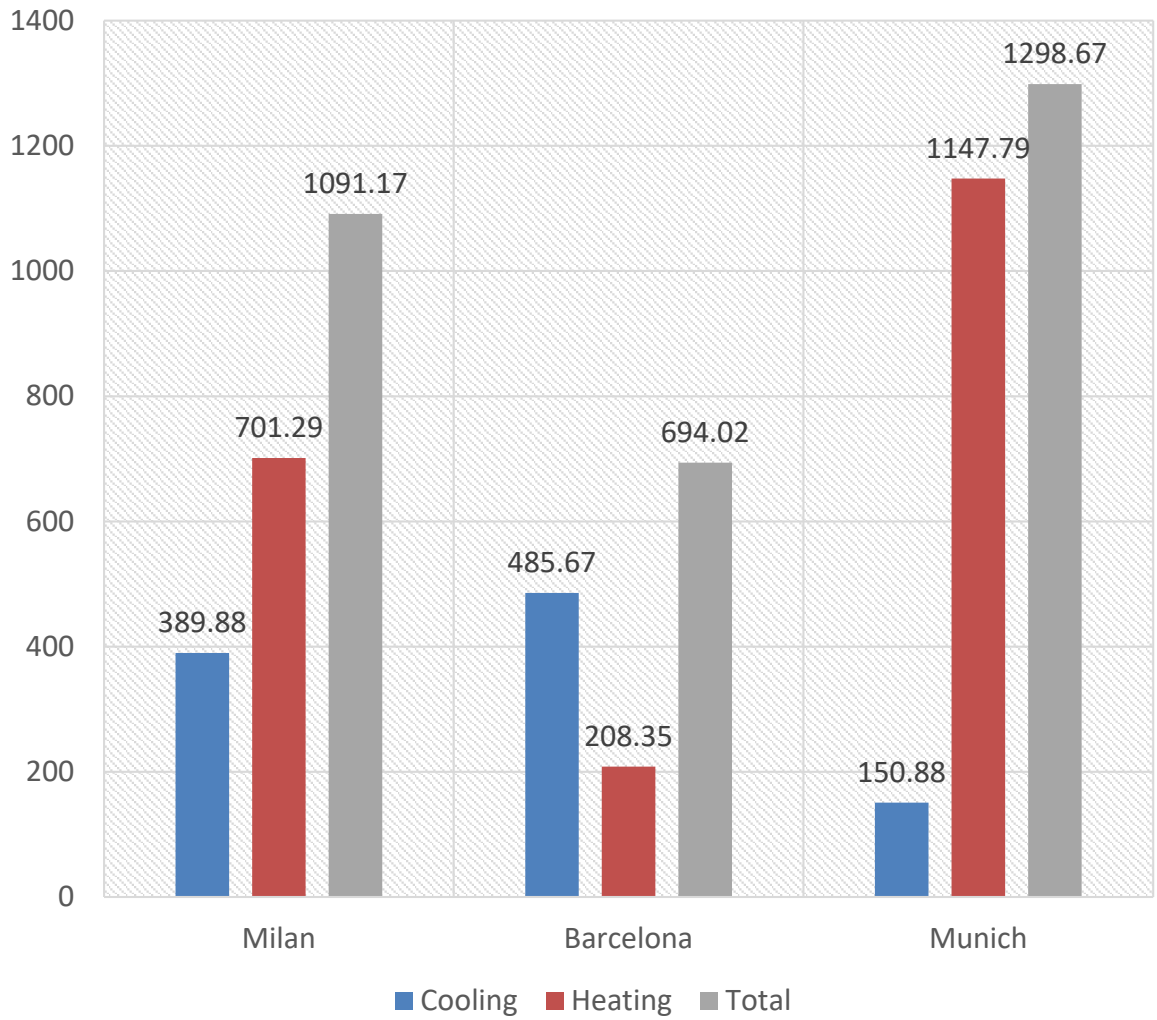
	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	208.35 (30%)	485.67 (70%)			694.02 (100%)	1626.59
			495.39	437.18	932.57	



MUNICH

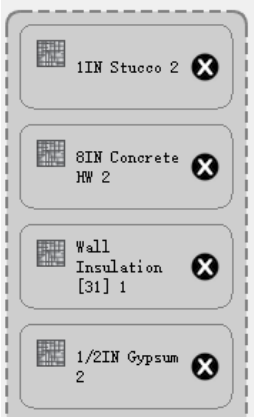
	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	1147.79 (88%)	150.88 (12%)			1298.67 (100%)	2231.24
			495.39	437.18	932.57	





Between the 3 cities, Munich is the most energy-intensive to design a building. Next is Milan and the least is Barcelona.

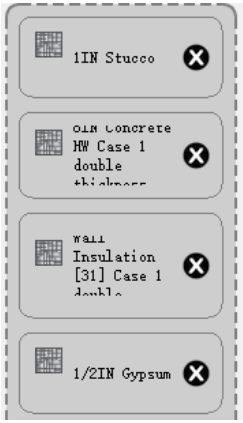
In Munich, heating load is the majority (88%). In Milan, heating load is also higher than cooling but the different is not so significant (64%-36%). In the contrary, in Barcelona the cooling load is the majority (70%).



BASE CASE
189.1-2009-CZ1-Office

Layer	Thickness /(m)	Conductivity λ (W/m.ºC)
1IN Stucco	0.0253	0.6918
8IN Concrete HW	0.2033	1.7296
Wall Insulation 31	0.0337	0.0432
1/2IN Gypsum	0.0127	0.16

$R_{1IN\ Stucco}$ = 0.0253/ 0.6918 = 0.0366 m²° C/W
$R_{8IN\ Concrete\ HW}$ = 0.2033/ 1.7296 = 0.1175 m²° C/W
$R_{Wall\ Insulation\ 31}$ = 0.0337/ 0.0432 = 0.78 m²° C/W
$R_{1/2IN\ Gypsum}$ = 0.0127/ 0.16 = 0.0794 m²° C/W
R_{TOTAL} = 0.0366+0.1175+0.78+0.0794
= 1.0135 m²° C/W
U = 1/ R_{TOTAL} = 1/1.0135 = 0.9867 W/m²° C

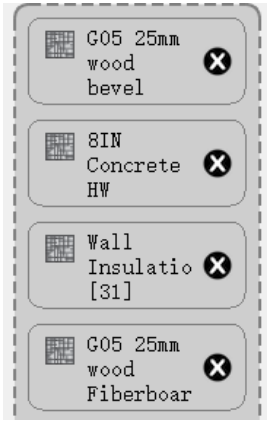


COMPARISON CASE 1
Custom – 16IN Concrete & 2 Insulation Layers

Layer	Thickness /(m)	Conductivity λ (W/m.ºC)
1IN Stucco	0.0253	0.6918
16IN Concrete HW	0.4066	1.7296
2xWall Insulation 31	0.0674	0.0432
1/2IN Gypsum	0.0127	0.16

$R_{1IN\ Stucco}$ = 0.0253/ 0.6918 = 0.0366 m²° C/W
$R_{16IN\ Concrete\ HW}$ = 0.4066/ 1.7296 = 0.2351 m²° C/W
$R_{2xWall\ Insulation\ 31}$ = 0.0674/ 0.0432 = **1.56 m²° C/W**
$R_{1/2IN\ Gypsum}$ = 0.0127/ 0.16 = 0.0794 m²° C/W
R_{TOTAL1} = 0.0366+0.2351+1.56+0.0794
= 1.9111 m²° C/W
U_1 = 1/ R_{TOTAL1} = 1/1.0135 = 0.5233 W/m²° C

**The main difference is due to the increment of insulation layer*



COMPARISON CASE 2
Custom – Ext. Wood Bevel Boards and Int. Wood Fiberboard

Layer	Thickness /(m)	Conductivity λ (W/m.ºC)
Wood Bevel Boards	0.2540	0.1814
8IN Concrete HW	0.2033	1.7296
Wall Insulation 31	0.0337	0.0432
Wood Fiberboard	0.2540	0.1104

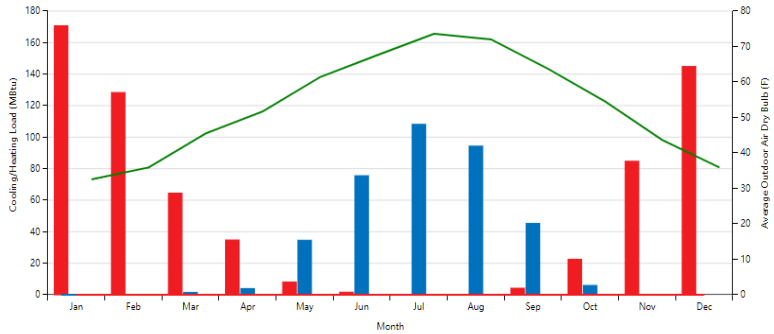
$R_{WoodBevel}$ = 0.2540/ 0.1814 = 0.14 m²° C/W
$R_{8IN\ Concrete\ HW}$ = 0.2033/ 1.7296 = 0.1175 m²° C/W
$R_{Wall\ Insulation\ 31}$ = 0.0337/ 0.0432 = 0.78 m²° C/W
$R_{WoodFiberboard}$ = 0.2540/ 0.1104 = 0.23 m²° C/W
R_{TOTAL2} = 0.14+0.1175+0.78+0.23
= 1.2675 m²° C/W
U_2 = 1/ R_{TOTAL2} = 0.7889 W/ m²° C

Yearly Energy Load (EnergyPlus result - SI)

Monthly Energy Load (Open Studio result)

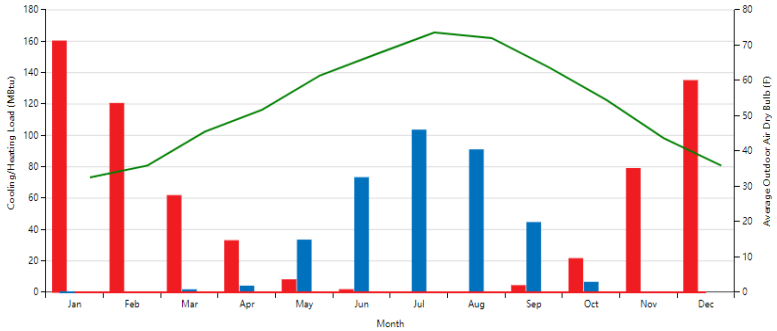
BASE CASE 189.1-2009-CZ1-Office

	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	701.29	389.88			1091.17	2023.74
			495.39	437.18	932.57	



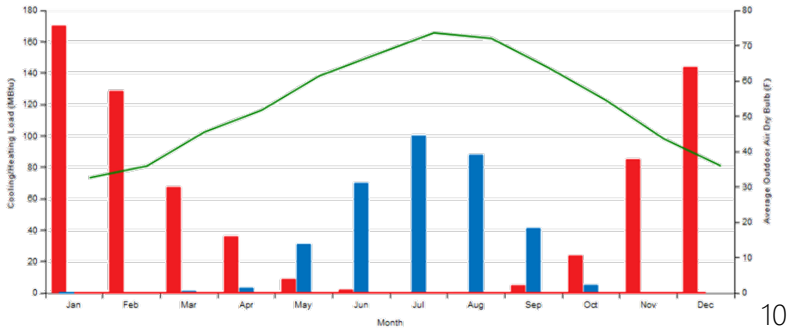
COMPARISON CASE 1 Custom – 16IN Concrete & 2 Insulation Layers

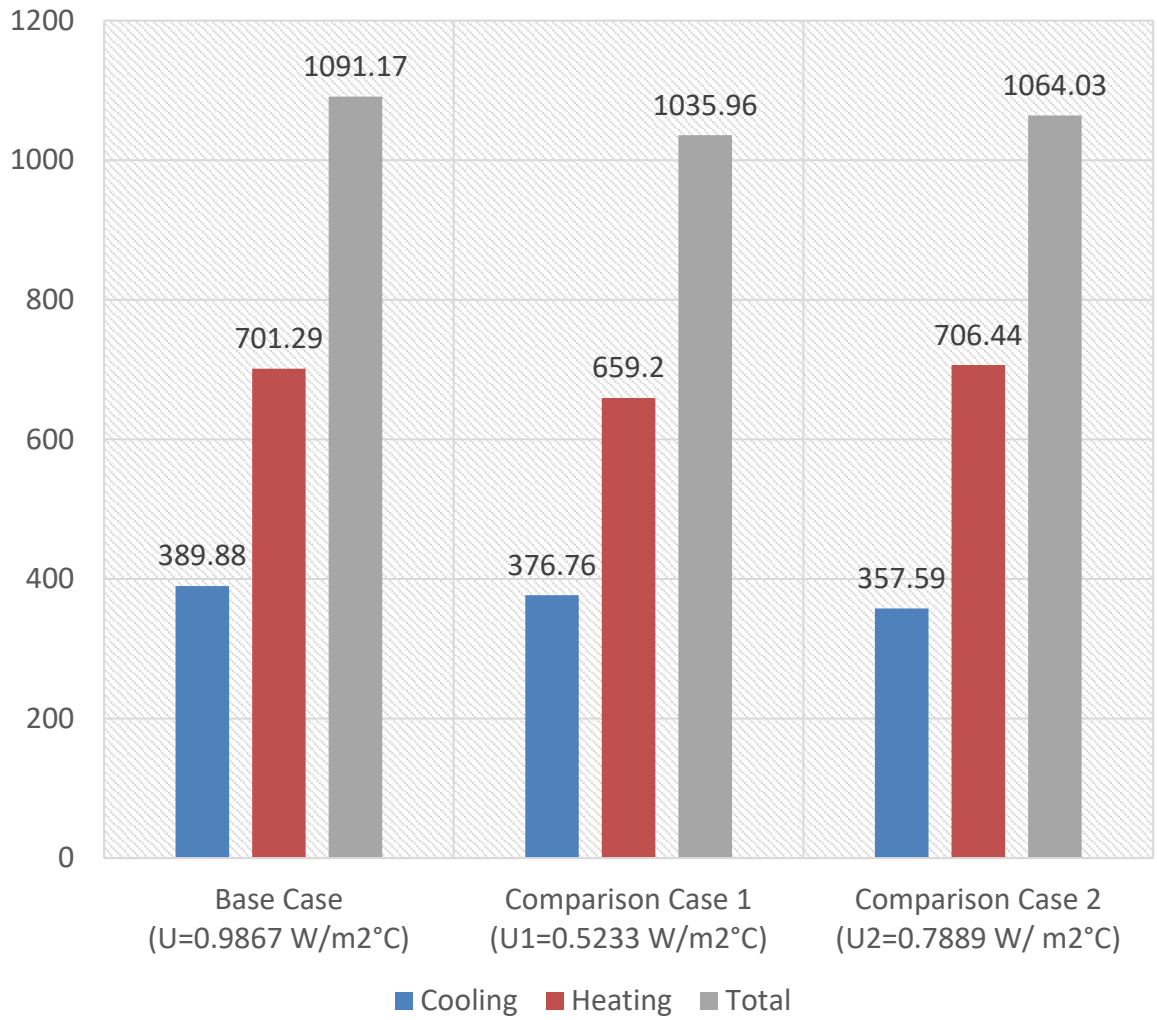
	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	659.20 (-6%)	376.76 (-3%)			1035.96 (-5%)	1626.59
			495.39	437.18	932.57	



COMPARISON CASE 2 Custom – Ext. Wood Bevel Boards and Int. Wood Fiberboard

	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	706.44 (+1%)	357.59 (-8%)			1064.03 (-2%)	2231.24
			495.39	437.18	932.57	





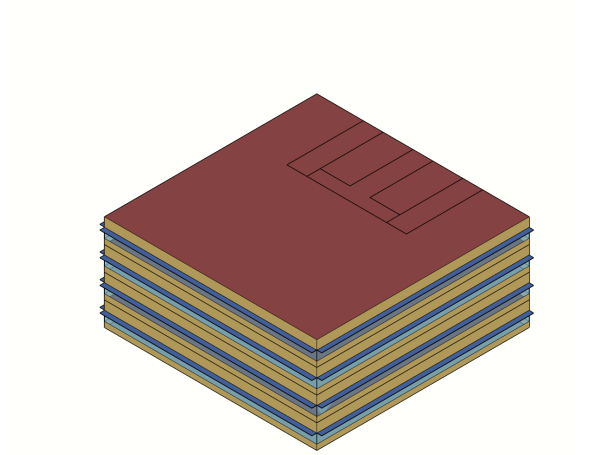
Increasing the U-value of the wall can help reduce the energy load but only to some extend.
The reason is that heating and cooling load is also affected by other facade components (in this case - the window). In a low-rise building, roof material is also another factor that have high impact on HVAC load.

In this extra part, we tested how the layout of functional space can have effect on energy consumption. This may help architect's design decision since conceptual design to deliver a more sustainable building?

Yearly Energy Load (EnergyPlus result - SI)

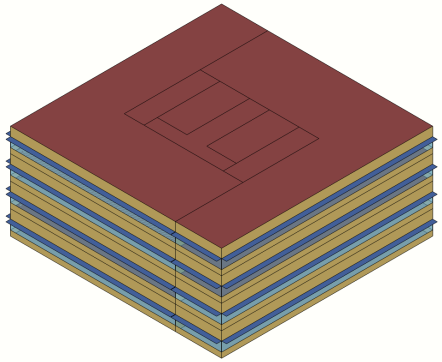
BASE CASE Core at North Side

	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	701.29	389.88			1091.17	2023.74
			495.39	437.18	932.57	



COMPARISON CASE 1 Central Core

	Heating	Cooling	Interior Lighting	Interior Equipment	Total	
GJ	720.98 (+2%)	380.98 (-2%)			1101.96 (+1%)	2034.53
			495.39	437.18	932.57	



The simulation result showed that the core at center can lead to a minor energy increase (1%) when more conditioned spaces are exposed. The difference may be amplified if the building have more levels – more exposed facade (in the case of an office tower).

However, central core is better for open offices in term of natural lighting. Because Open Studio does not take into account natural lighting in calculation interior lighting (it's always the same in any case regardless building material, location, etc.), we can not come to a clear conclusion.

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