Energy studies through OpenStudio

Technical Environmental Systems

Politecnico di Milano, December 2018

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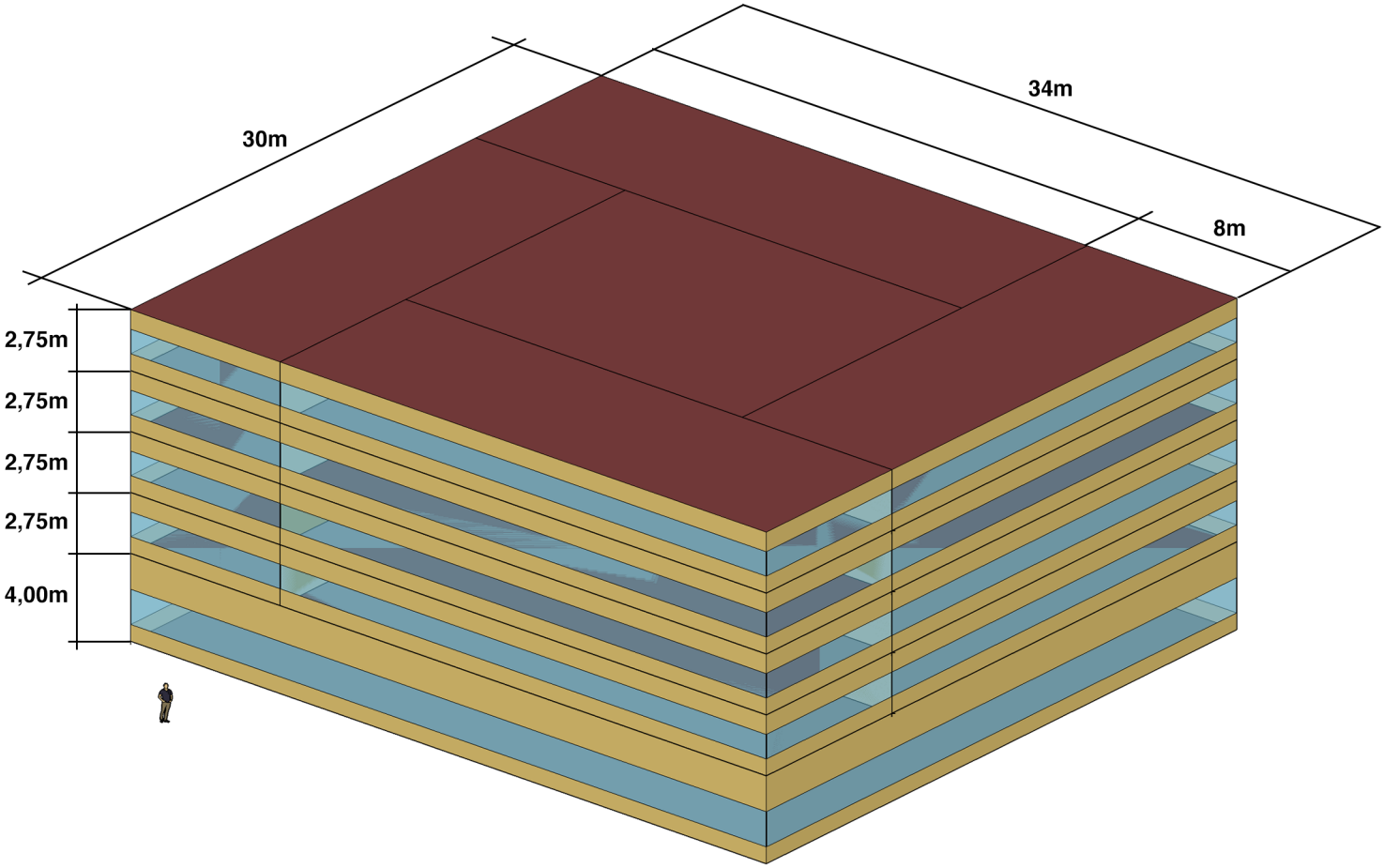
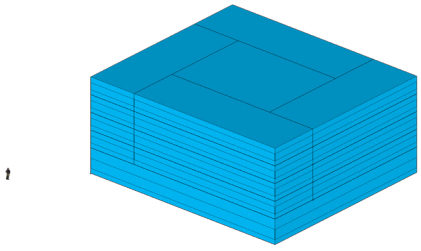
geometry

The chosen geometry for the commercial space is based on an urban shopping mall model, with a large, open first floor and additional floors with a central space for escalators/elevator surrounded by commercial space. This results in the building consisting of only one thermal zone as the escalators penetrates the floor boundaries. Also the interior walls are open to the central core.

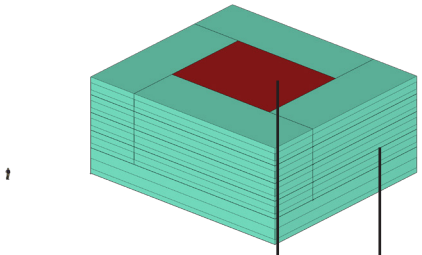


Window to wall ratio: 0.4
Window position: 760mm above floor

Thermal zones



Space types

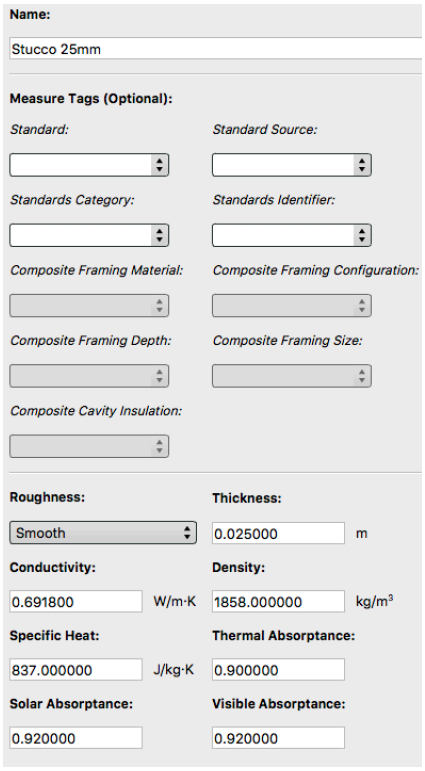


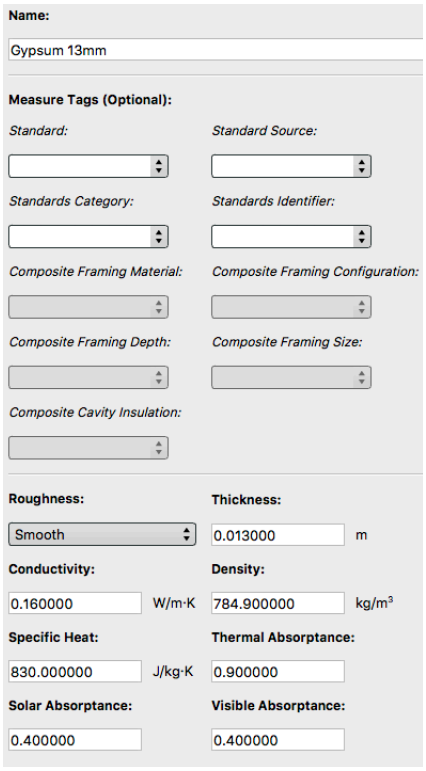
189.1 - 2009 - Office - Corridor CZ1-3

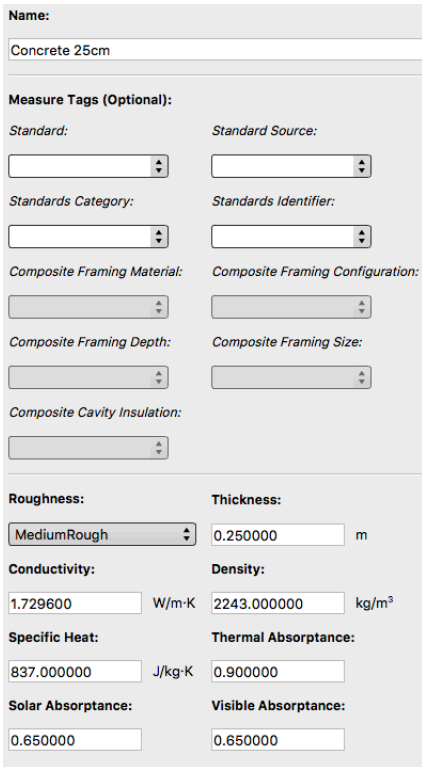
189.1 - 2009 - Office - OpenOffice CZ1-3

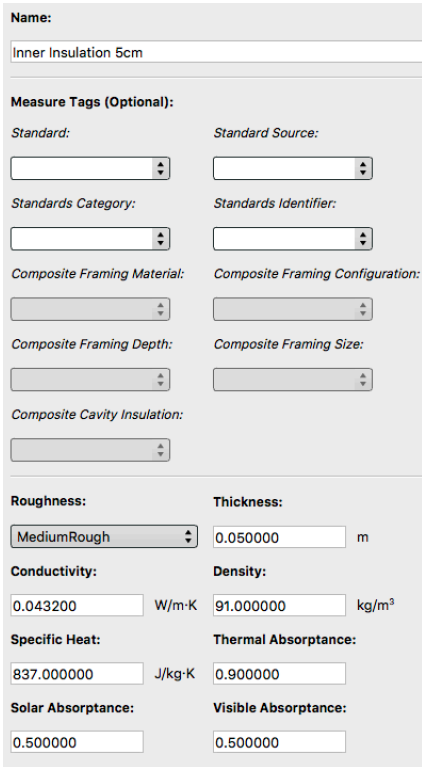
materials

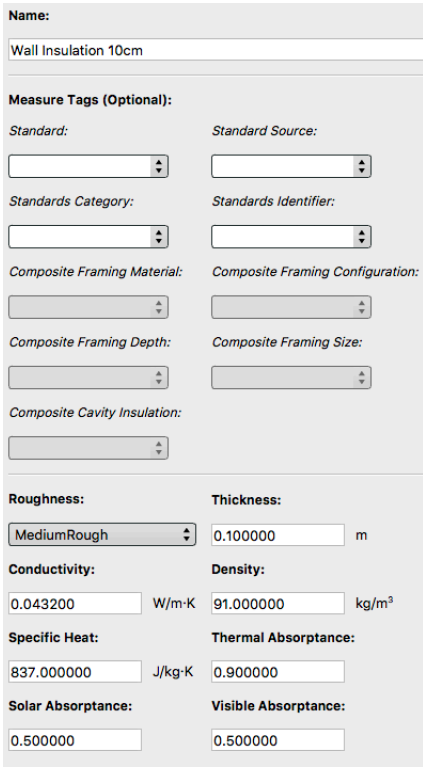
For the materials we have selected three base materials: stucco, concrete and gypsum, appearing in all the wall configurations. These wall configurations are altered with three different insulation thicknesses: 5cm, 10cm and 25cm.

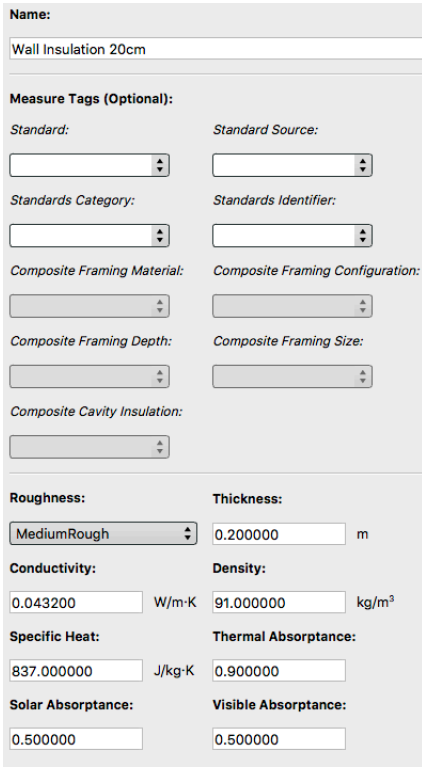












walls

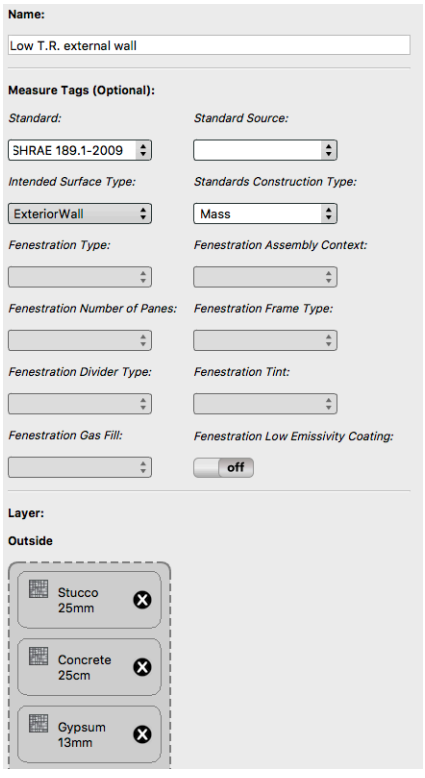
´Our three different walls are composed by the materials seen on the previous page, to achieve walls with low, medium and high thermal resistance.

1. Low thermal resistance external wall
This wall is simply composed by stucco, concrete and gypsum and has no insulation layer,.

2. Medium thermal resistance external wall
Additional to the stucco, concrete and gypsum we have added a 10cm layer of insulation between the concrete and the gypsum.

3. High thermal resistance external wall
In this high thermal resistance wall, we have thickened the insulation layer to 20cm, and also adding an inner insulation layer of 5cm.

1



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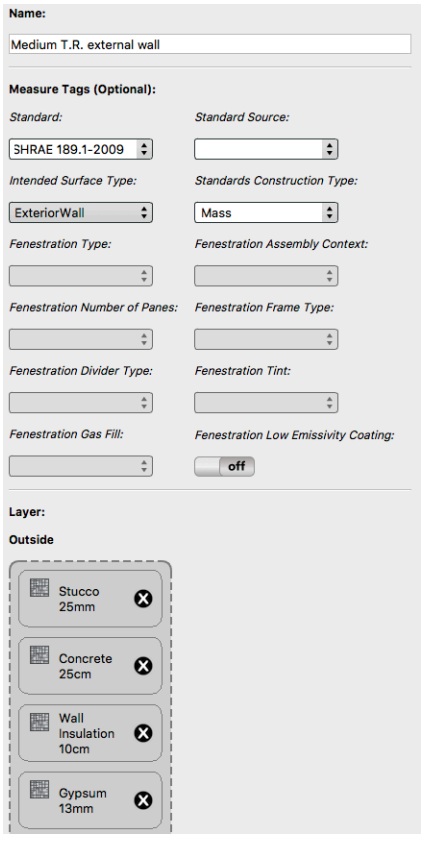
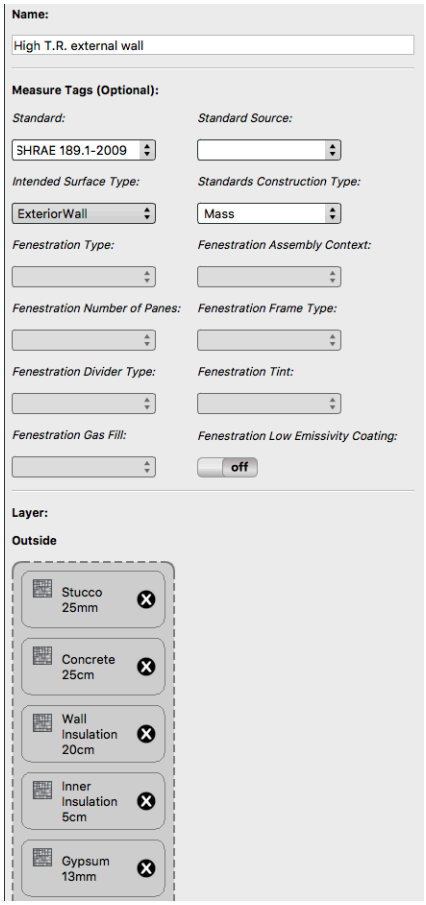


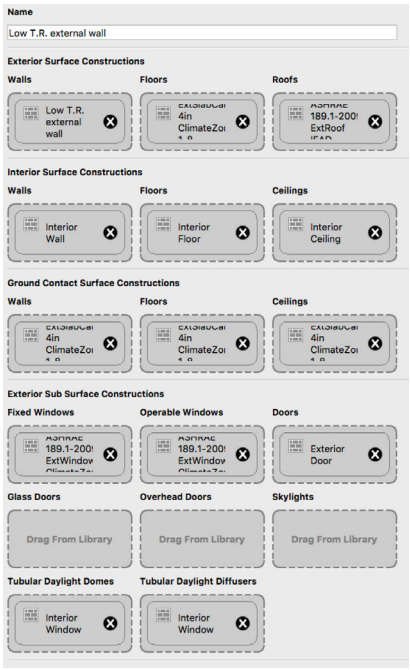
3



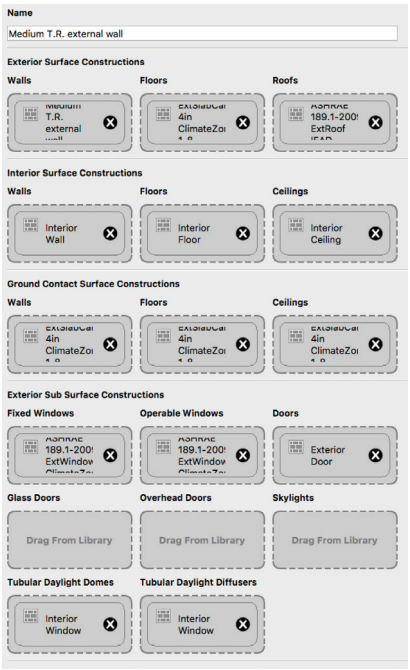
construction sets

For the construction sets, we have used the ’189.1 - 2009 - CZ1 Office’ as the default foundation. Three new construction sets have been created by replacing the default external walls with the three different walls we have presented on the previous page, creating construction sets with three different thermal resistances.

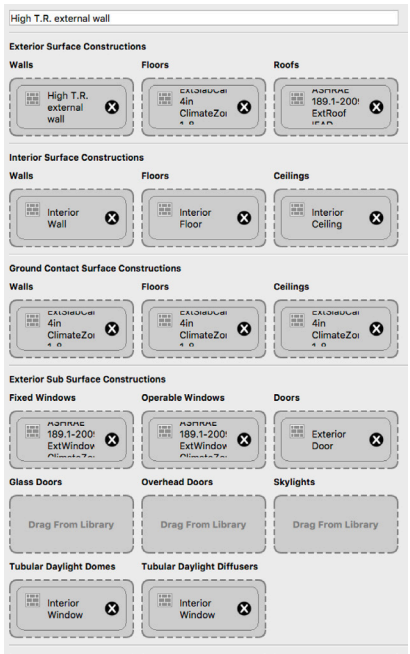
Low T.R.



Medium T.R.



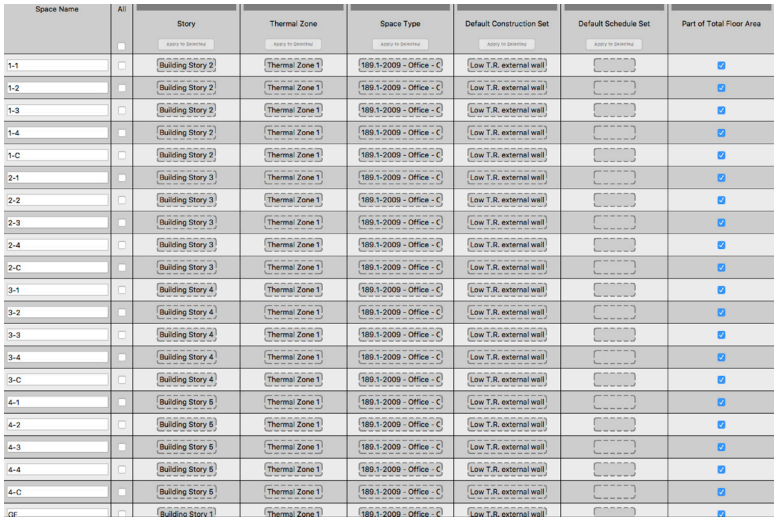
High T.R.



space configurations

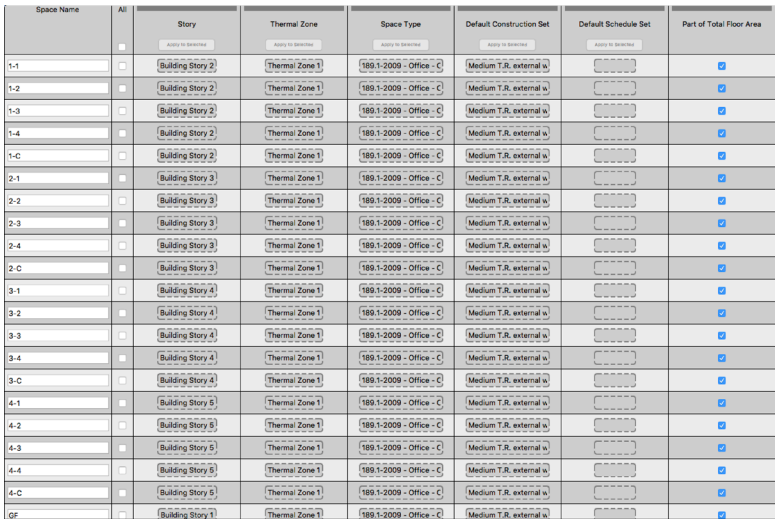
Further, we have applied the different construction sets to create three buildings with different thermal qualities. There is one open ground floor, and four commercial spaces in each of the additional floors. For these, we have used the default space type ’189.1 - 2009 - Office - OpenOffice CZ1-3’. For the escalator area in floors 1-4 we have used the default space type ”189.1 - 2009 - Office - Corridor CZ1 - 3’. The different spaces all belong to the same thermal zones, as mentioned.

Low T.R.



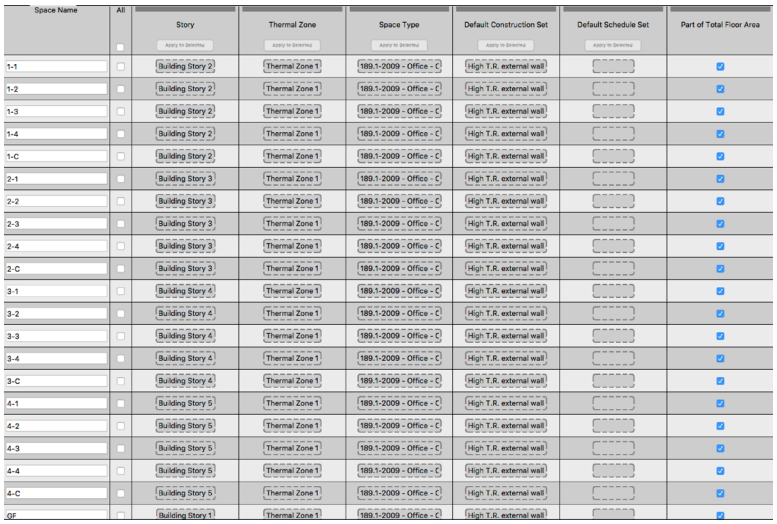
Space Name	All	Story	Thermal Zone	Space Type	Default Construction Set	Default Schedule Set	Part of Total Floor Area
1-1	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
1-2	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
1-3	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
1-4	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
1-C	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
2-1	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
2-2	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
2-3	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
2-4	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
2-C	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
3-1	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
3-2	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
3-3	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
3-4	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
3-C	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
4-1	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
4-2	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
4-3	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
4-4	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
4-C	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑
GF	☐	Building Story 1	Thermal Zone 1	189.1-2009 - Office - C	Low T.R. external wall		☑

Medium T.R.



Space Name	All	Story	Thermal Zone	Space Type	Default Construction Set	Default Schedule Set	Part of Total Floor Area
1-1	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
1-2	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
1-3	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
1-4	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
1-C	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
2-1	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
2-2	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
2-3	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
2-4	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
2-C	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
3-1	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
3-2	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
3-3	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
3-4	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
3-C	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
4-1	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
4-2	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
4-3	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
4-4	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
4-C	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑
GF	☐	Building Story 1	Thermal Zone 1	189.1-2009 - Office - C	Medium T.R. external w		☑

High T.R.



Space Name	All	Story	Thermal Zone	Space Type	Default Construction Set	Default Schedule Set	Part of Total Floor Area
1-1	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
1-2	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
1-3	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
1-4	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
1-C	☐	Building Story 2	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
2-1	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
2-2	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
2-3	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
2-4	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
2-C	☐	Building Story 3	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
3-1	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
3-2	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
3-3	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
3-4	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
3-C	☐	Building Story 4	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
4-1	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
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4-3	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
4-4	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
4-C	☐	Building Story 5	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑
GF	☐	Building Story 1	Thermal Zone 1	189.1-2009 - Office - C	High T.R. external wall		☑

results: end uses

We then ran the simulation, calculating annual energy need for heating and cooling the three different external wall configurations. We used the weather data for Piacenza, for this comparison.

Low T.R.

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	790.37	0.00
Cooling	0.00	0.00	0.00	416.84	0.00	0.00
Interior Lighting	562.98	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	562.85	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	1125.84	0.00	0.00	416.84	790.37	0.00

Note: District heat appears to be the principal heating source based on energy usage.

Medium T.R.

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	603.47	0.00
Cooling	0.00	0.00	0.00	385.09	0.00	0.00
Interior Lighting	562.98	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	562.85	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	1125.84	0.00	0.00	385.09	603.47	0.00

Note: District heat appears to be the principal heating source based on energy usage.

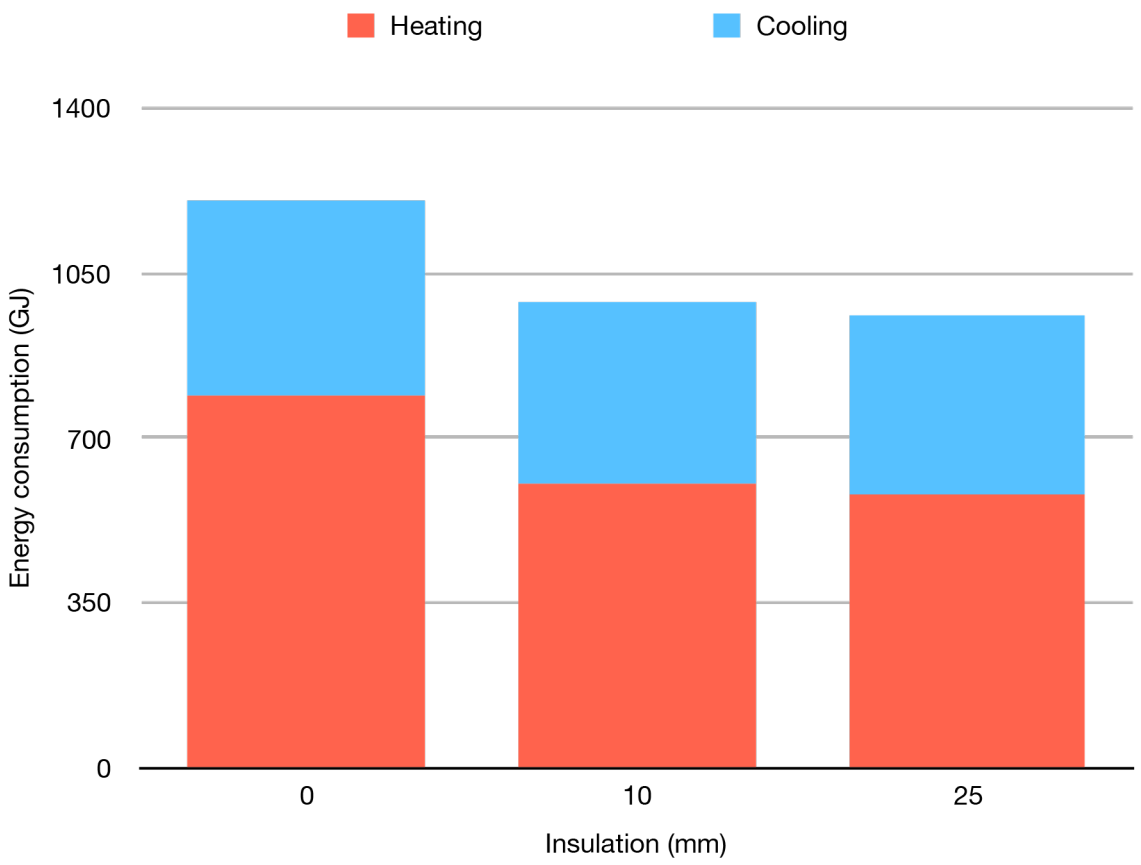
High T.R.

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Additional Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]
Heating	0.00	0.00	0.00	0.00	581.43	0.00
Cooling	0.00	0.00	0.00	379.49	0.00	0.00
Interior Lighting	562.98	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	562.85	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	1125.84	0.00	0.00	379.49	581.43	0.00

Note: District heat appears to be the principal heating source based on energy usage.

results: comparison of wall configurations in Piacenza



	Heating (GJ)	Cooling (GJ)	Total (GJ)
Piacenza Low	790	416	1206
Piacenza Med	603	385	988
Piacenza High	581	379	960

From the results, we definately see a difference in the energy consumption. The difference is greater from the configuration with no insulation, to the one with 10 cm insulation. What is interesting to observe in this case, is that, adding 15cm makes little difference, when you already have 10cm of insulation.

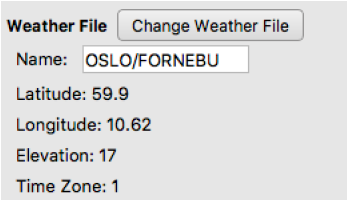
Adding 10 cm of insulation to the concrete wall saves a substantial 22% of the energy consumption for heating/cooling.

But, adding an additional 15 cm on top of that saves you less than 3% of the energy consumption.

climate comparisons

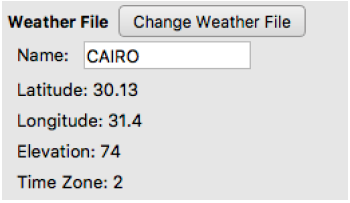
After comparing the wall configurations, we used the 'Medium T.R.' configuration as the base to compare annual energy consuption for heating/cooling in three different climates with regards to temperature. We downloaded the data from EnergyPlus, using the .epw- and .ddy-files.

Oslo, Norway (cold)



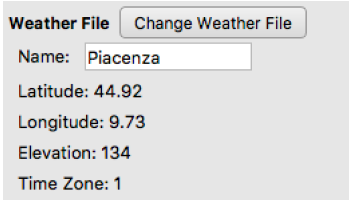
NOR_Oslo.Fornebu.014880_IWEC

Piacenza, Italy (mild)



ITA_Piacenza.160840_IGDG

Cairo, Egypt(hot)

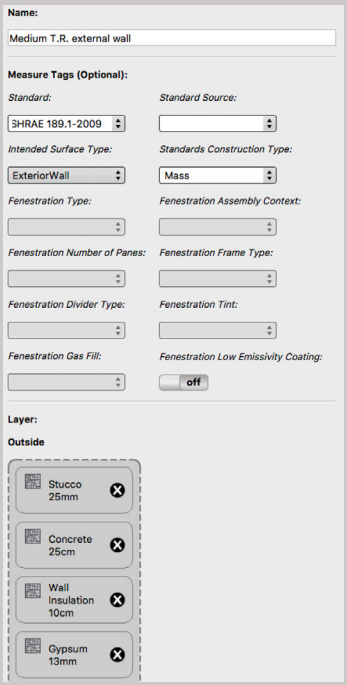


EGY_Cairo.623660_IWEC

Wall Configuration Base used for climate comparison

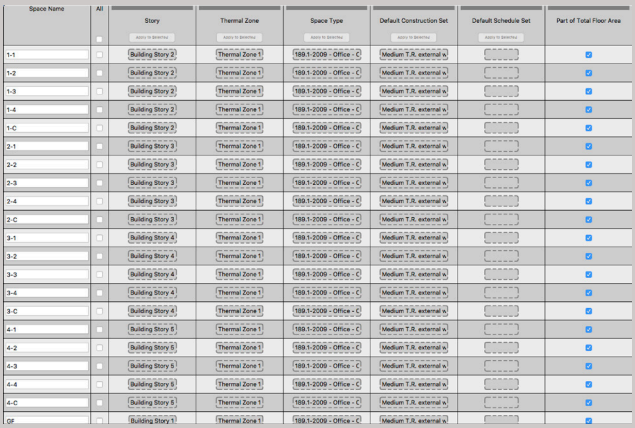
The wall configurations of the climate comparison are the 'Medium T.R.' for all three cases.

Wall

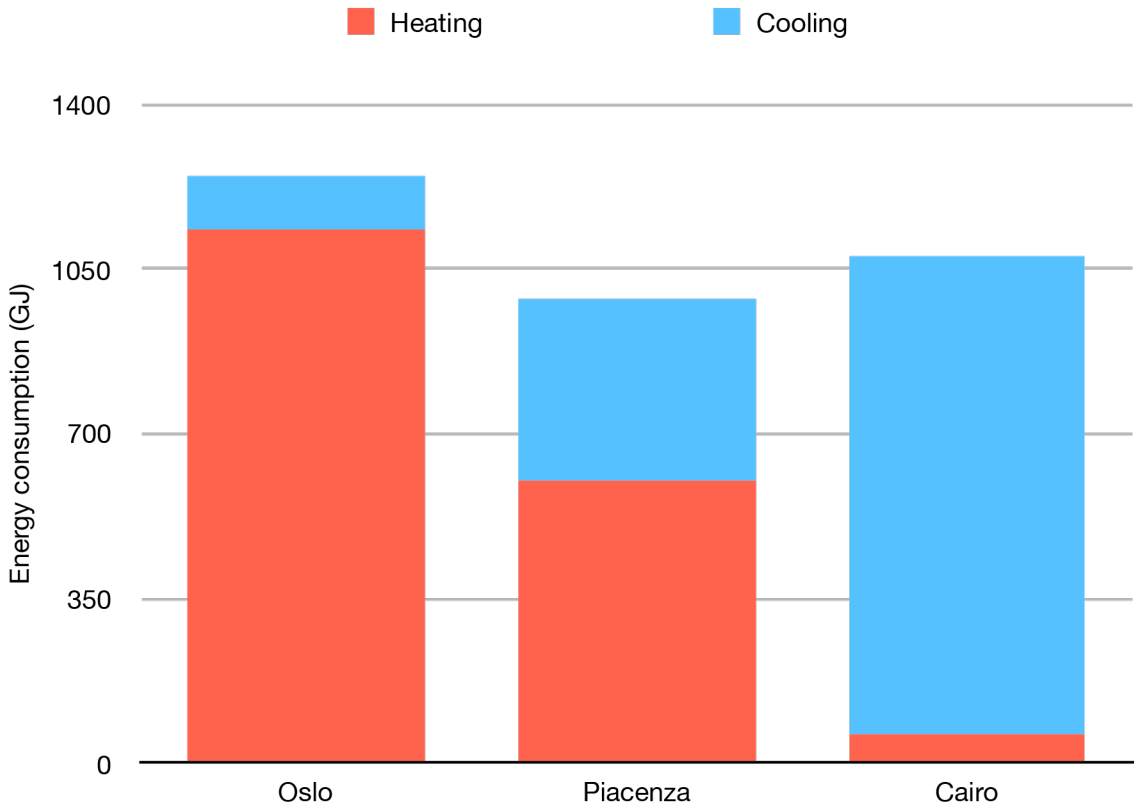


Construction set

Space configurations



results: comparison of climates



	Heating (GJ)	Cooling (GJ)	Total (GJ)
Oslo	1134	113	1247
Piacenza	603	385	988
Cairo	62	1017	1079

As expected, we see huge differences in how the energy consuption is distributed for heating and cooling, in the different climates. But it is interesting to see how the overall consumption for heating/ cooling makes a relatively small difference.

The need for cooling in Cairo, actually produces a energy consuption, almost 9% higher than that of Piacenza. And the energy consuption in Oslo is more than 20% than that of Piacenza.

conclusion

In the wall configurations comparison, we see that the relative effect of the insulation decreases the more insulation you insert. Seeing that the window surface makes 40% of the exterior wall surface, this means that the thermal resistance of the wall will only account for 60% of the exterior boundary's thermal resistance. And, the other way around, even with optimal exterior walls, 40% of window surface will induce a substantial heat loss

Furthermore, we see in the comparison of climates, that Cairo need a substantial amount of energy for cooling and that the total energy consumption regarding heating/cooling is actually lower in colder Piacenza. This, could be due to the large window area.

note:
As mentioned during our conversation with Prof. Najafi, the 20th of December, we would like to remind that the reason we have only one thermal zone, is due to the considerations of the model as an urban mall with continuous escalators (connecting all the rooms). We concluded, during the conversation, that, even though it would be optimal to do the assignment with several thermal zones, we would leave it like this, due to the fact that the assignment was already finished, and that time was an issue regarding the option of doing it again.