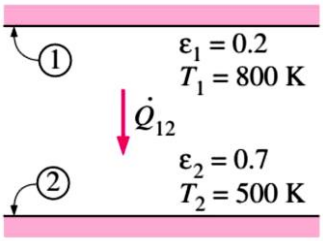
Exercise:

Heat exchange between the two parallel plates:
How many shields with ε=0.1 should we add in order to have the new heat transfer rate to be 1% of the case without shields?



$$\dot{Q}_{12} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

$$\dot{q} = \frac{\dot{Q}}{A}$$

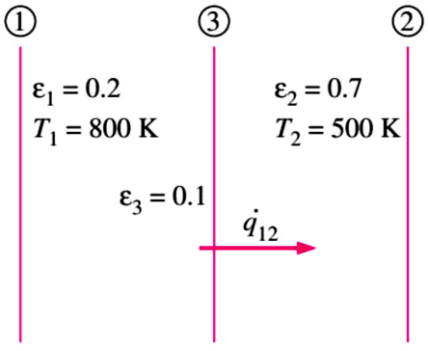
$$\dot{q}_{12} = \frac{5.670 * 10^{-8} * (800^4 - 500^4)}{\frac{1}{0.2} + \frac{1}{0.7} - 1} = \frac{19680{,}57}{5.4286} = 3625{,}35 \quad [W]$$

If the two emissivities of the plates are 0.1:

$$\dot{q}_{12} = \frac{5.670 * 10^{-8} * (800^4 - 500^4)}{\frac{1}{0.1} + \frac{1}{0.1} - 1} = \frac{19680{,}57}{19} = 1035{,}82 \quad [W]$$

With the same area and variation of temperature, if I used a very low emissivity material (ε=0.1) I can reduce the heat transfer of 3 times.

Another solution to reduce the heat transfer is to put a shield between the two parallel plates. (multiple radiation shields)



$$\dot{Q}_{12,\,N\,\text{shields}} = \frac{A\sigma(T_1^4 - T_2^4)}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right) + \cdots + \left(\frac{1}{\varepsilon_{N,1}} + \frac{1}{\varepsilon_{N,2}} - 1\right)}$$

$$\dot{q} = \frac{\dot{Q}}{A}$$

$$\dot{q}_{12,1\text{shield}} = \frac{5.670 * 10^{-8} * (800^4 - 500^4)}{\left(\frac{1}{0.2} + \frac{1}{0.7} - 1\right) + \left(\frac{1}{0.1} + \frac{1}{0.1} - 1\right)} = \frac{19680{,}57}{5.426+19} = \frac{19680{,}57}{24.429} = 805.623 \text{ W}$$ using 1 shield

$\dot{q}_{12,n.\ shields} = \frac{5.670 * 10^{-8} * (800^4 - 500^4)}{\left(\frac{1}{0.2}+\frac{1}{0.7}-1\right)+\left(\frac{1}{0.1}+\frac{1}{0.1}-1\right)+\left(\frac{1}{0.1}+\frac{1}{0.1}-1\right)} = \frac{19680,57}{5.426+19+19} = \frac{19680,57}{43.429} = 453.167$ W using 2 shields

$\dot{q}_{12,n.\ shields} = \frac{5.670 * 10^{-8} * (800^4 - 500^4)}{\left(\frac{1}{0.2}+\frac{1}{0.7}-1\right)+\left(\frac{1}{0.1}+\frac{1}{0.1}-1\right)+\left(\frac{1}{0.1}+\frac{1}{0.1}-1\right)+\left(\frac{1}{0.1}+\frac{1}{0.1}-1\right)} = \frac{19680,57}{5.426+19+19+19} = \frac{19680,57}{62.429} = 315.247$ W using 3 shields. With these 3 shields, I have reduced the heat transfer od 10 times.

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*4)} = \frac{19680,57}{81.429} = 241.690$ W using 4 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*5)} = \frac{19680,57}{100.429} = 195.965$ W using 5 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*6)} = \frac{19680,57}{119.429} = 164.789$ W using 6 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*7)} = \frac{19680,57}{138.429} = 142.171$ W using 7 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*8)} = \frac{19680,57}{157.429} = 125.012$ W using 8 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*9)} = \frac{19680,57}{176.429} = 111.550$ W using 9 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*10)} = \frac{19680,57}{195.429} = 100.704$ W using 10 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*11)} = \frac{19680,57}{214.429} = 91.781$ W using 11 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*12)} = \frac{19680,57}{233.429} = 84.311$ W using 12 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*13)} = \frac{19680,57}{252.429} = 77.965$ W using 13 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*14)} = \frac{19680,57}{271.429} = 72.507$ W using 14 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*15)} = \frac{19680,57}{290.429} = 67.764$ W using 15 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*16)} = \frac{19680,57}{309.429} = 63.603$ W using 16 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*17)} = \frac{19680,57}{328.429} = 59.923$ W using 17 shields

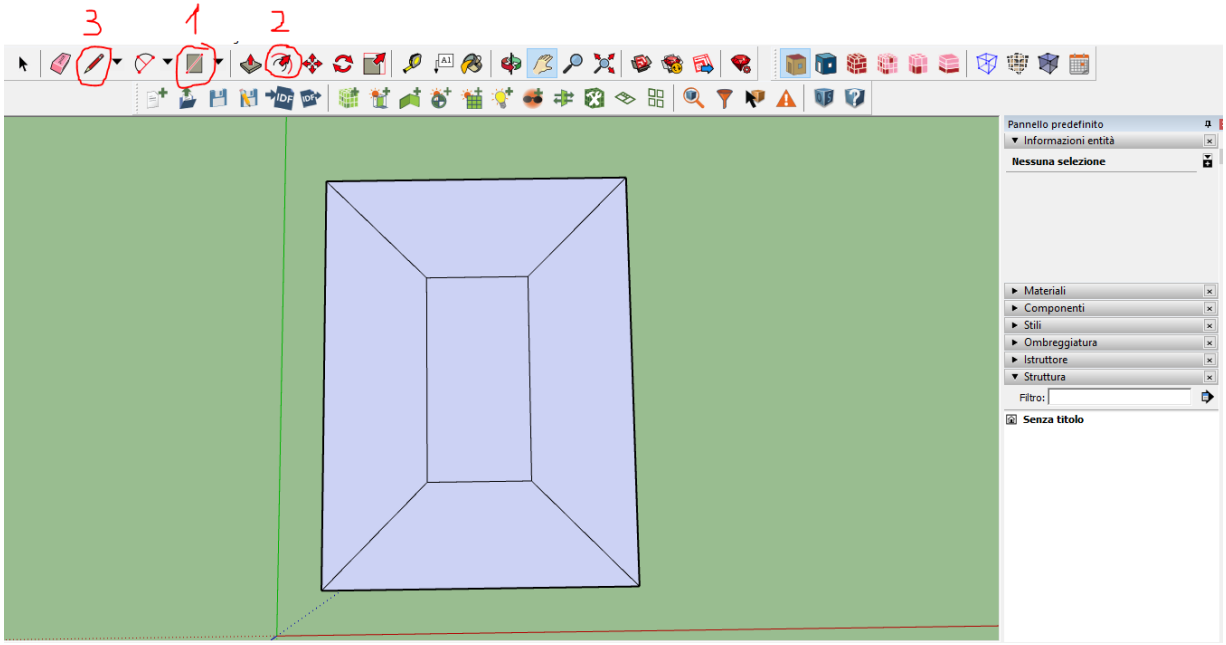
$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*18)} = \frac{19680,57}{347.429} = 56.646$ W using 18 shields

…

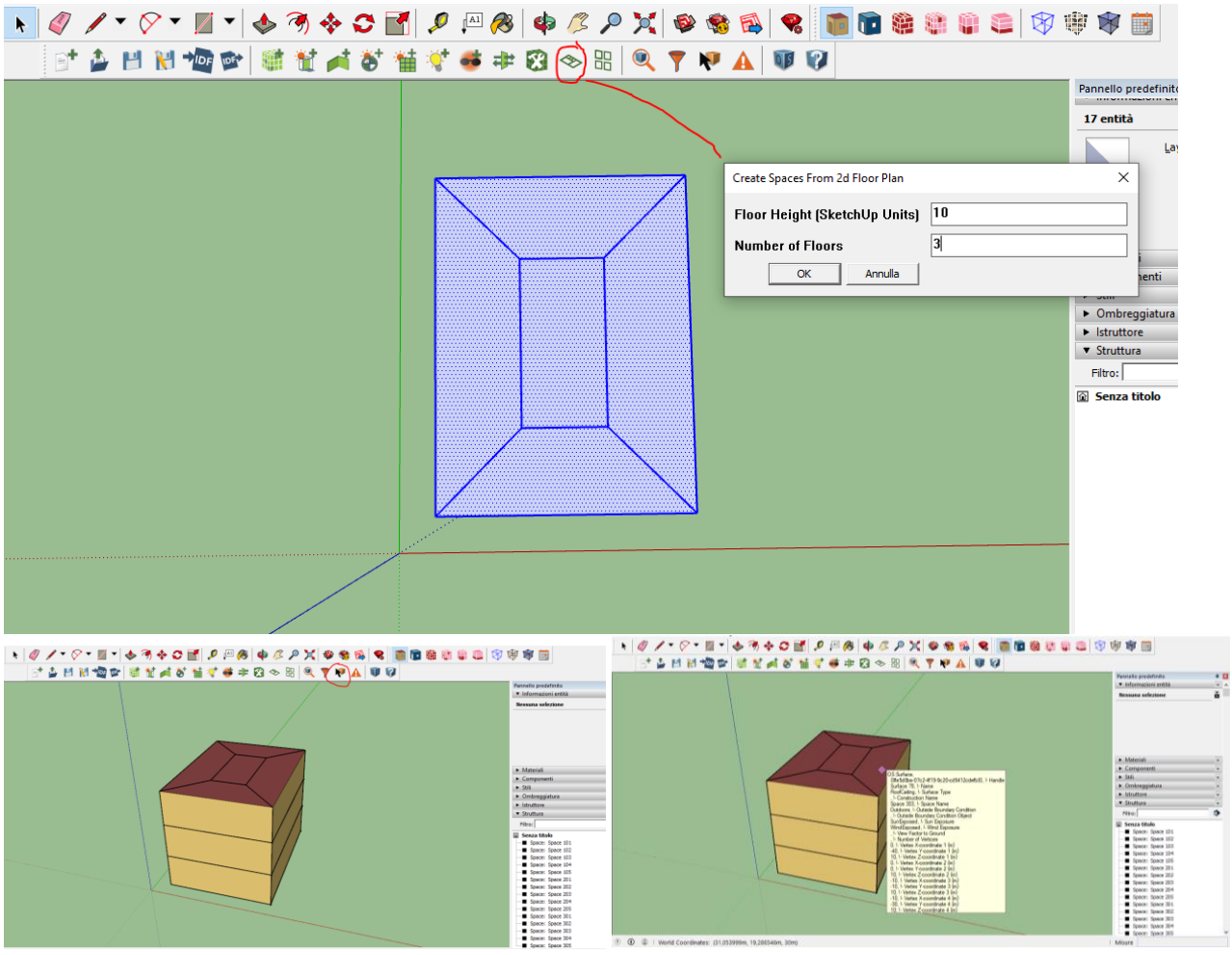
$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*29)} = \frac{19680,57}{537.429} = 36.620\ W$ using 28 shields

$\dot{q}_{12,n.\ shields} = \frac{19680,57}{5.426+(19*29)} = \frac{19680,57}{556.429} = 35.369\ W$ using 29 shields

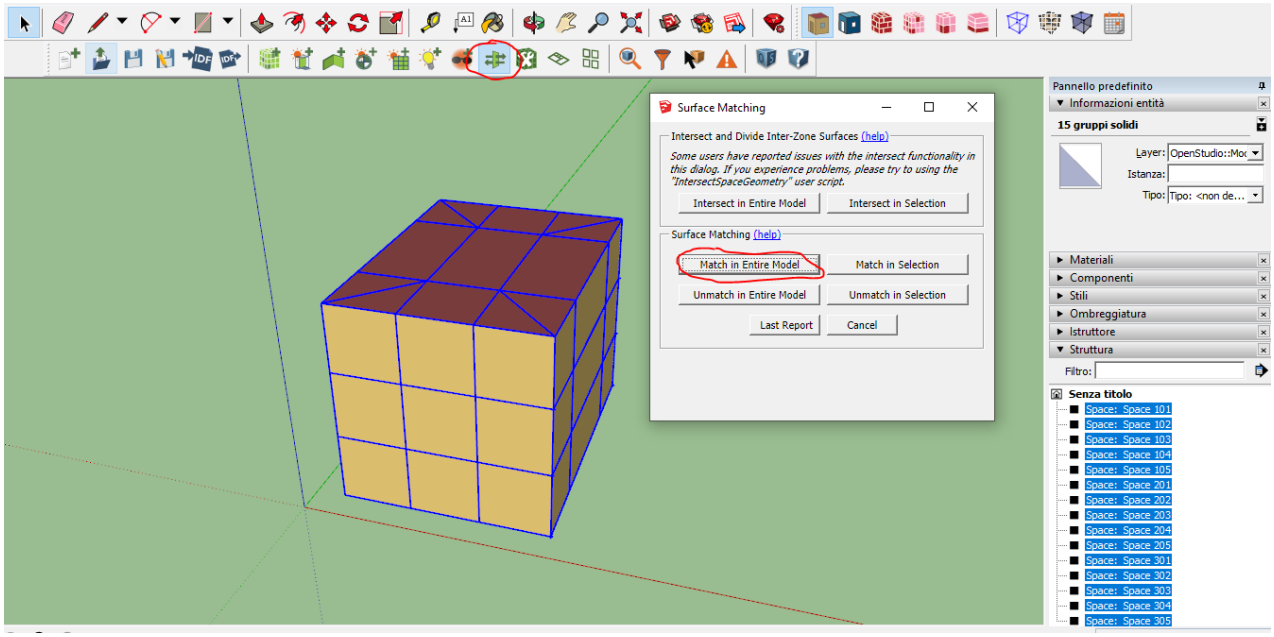
Using 28/29 shields with ε=0.1, I have reduced the initial heat transfer of 100 times.



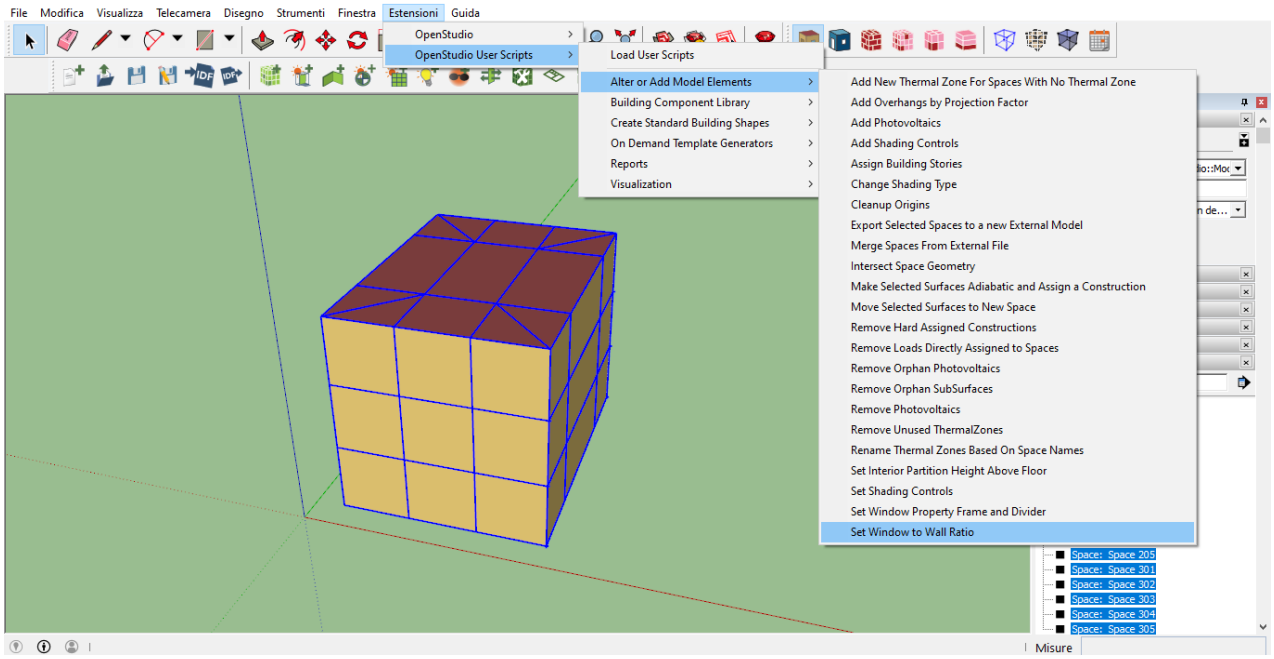
I have created a rectangular with dimension 30x40 cm using as a tool the rectangular size, offset (of 10m through the center) and the pen.

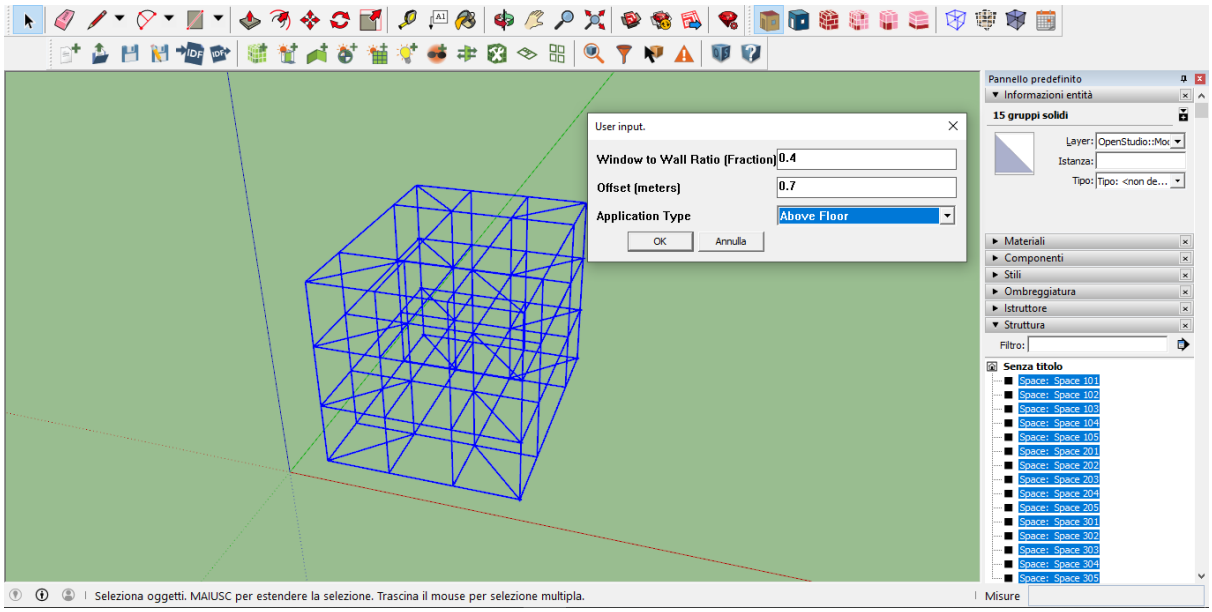


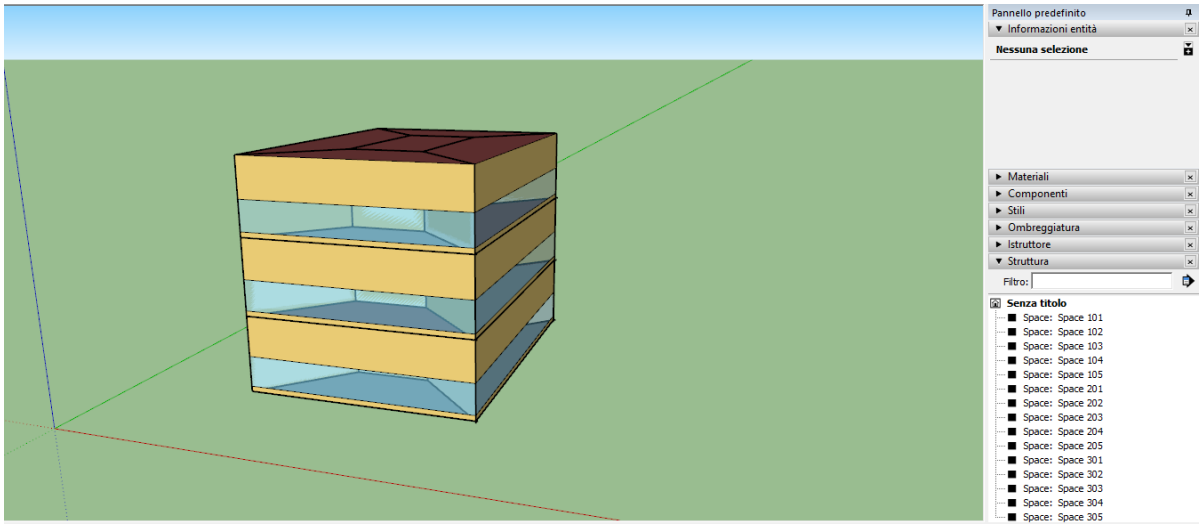
By using the tool Create Spaces From 2nd Floor Plan I have created a building of 3-floor height 10m. Selecting all the buildings and using Info Tool, I can see all the properties of each element that compose it.



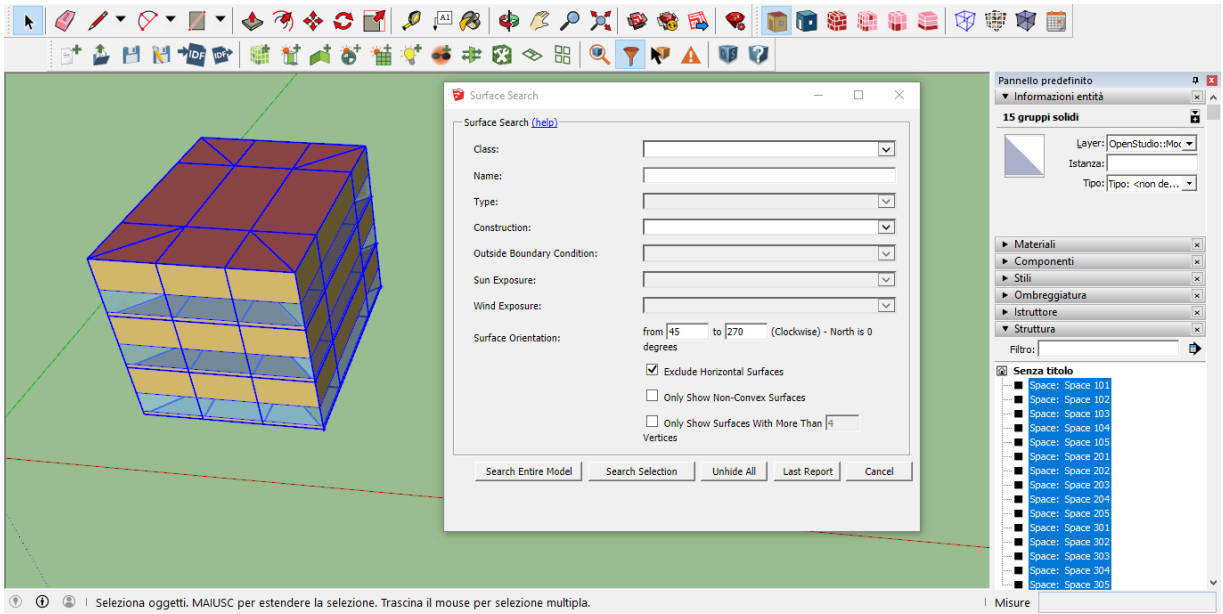
Selecting all the building >> Surface Matching >>Match the Entire Model.
Doing these passages, in the following passages I won't create windows inside my building.



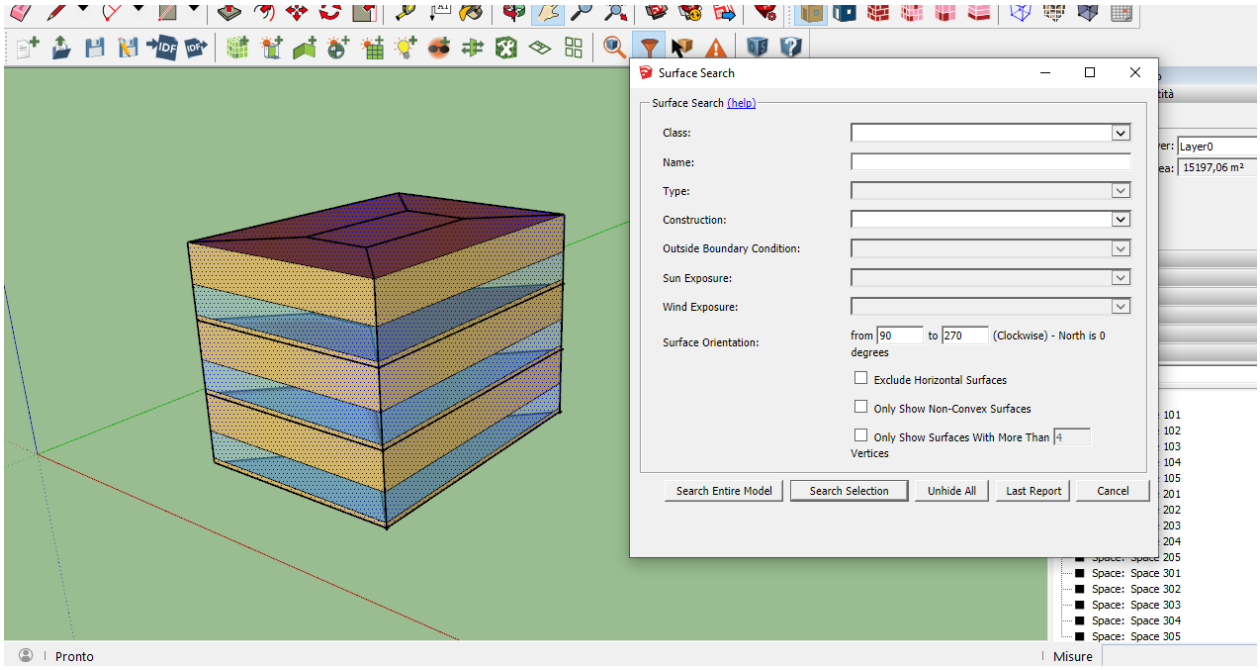




Doing these passages, I have created the windows on each surface of the building.

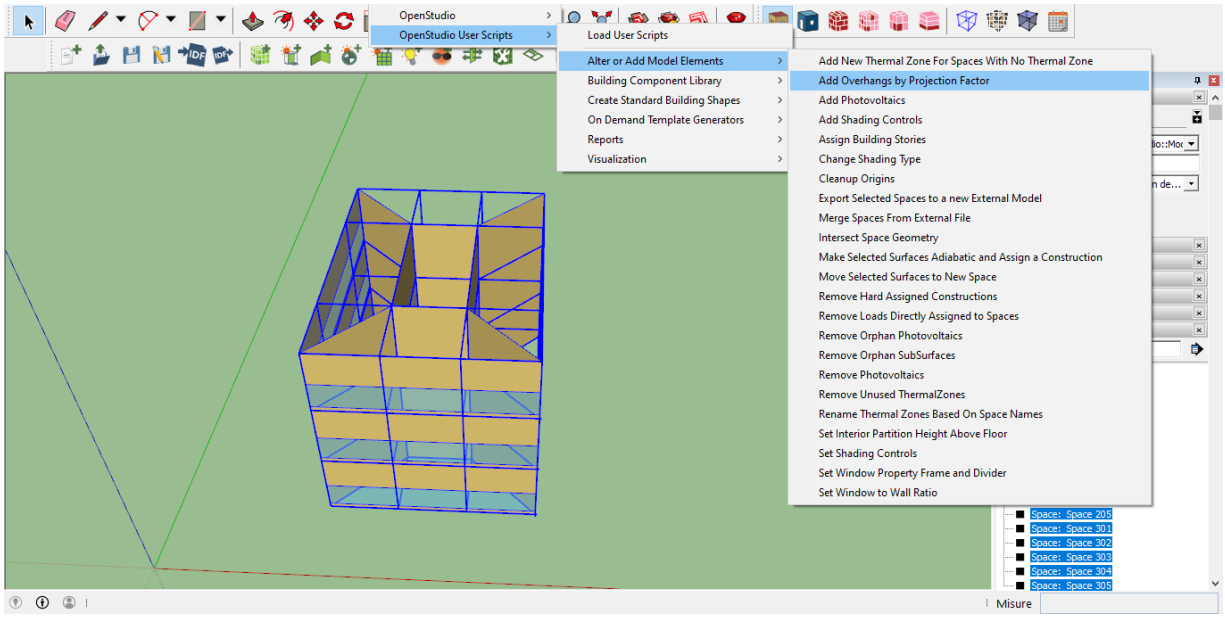


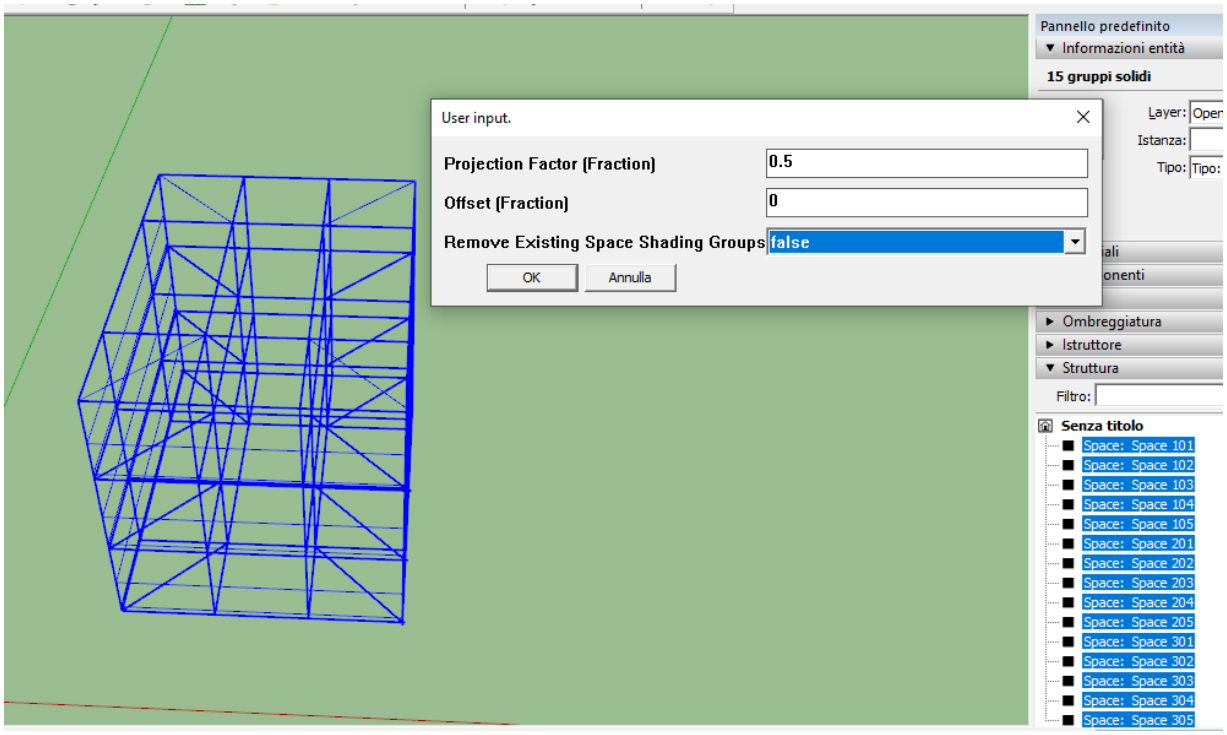
Doing so, and repeating this passage, I can exclude the north facade.

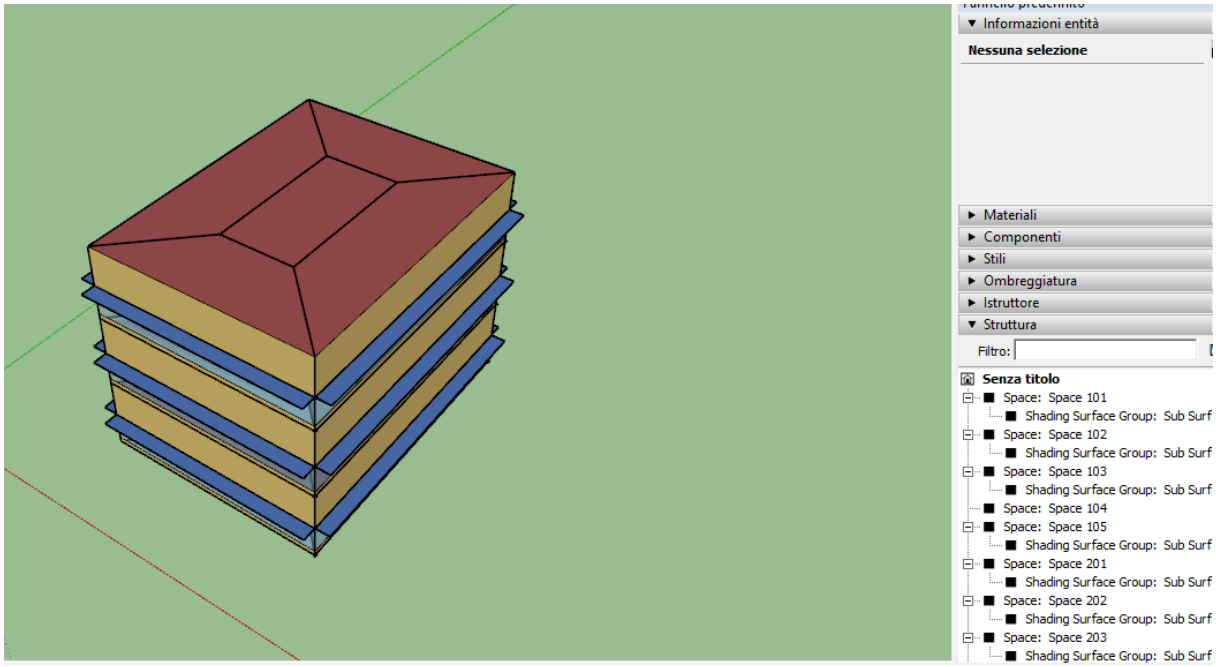


With the tool Search Surface, and pressed Search Selection, I should add external shading on the three surfaces (no on the north because I have excluded it.

In my project, I could have missed and get wrong some passage, because I have an overhang on every façade, but during the next lessons I will correct it).

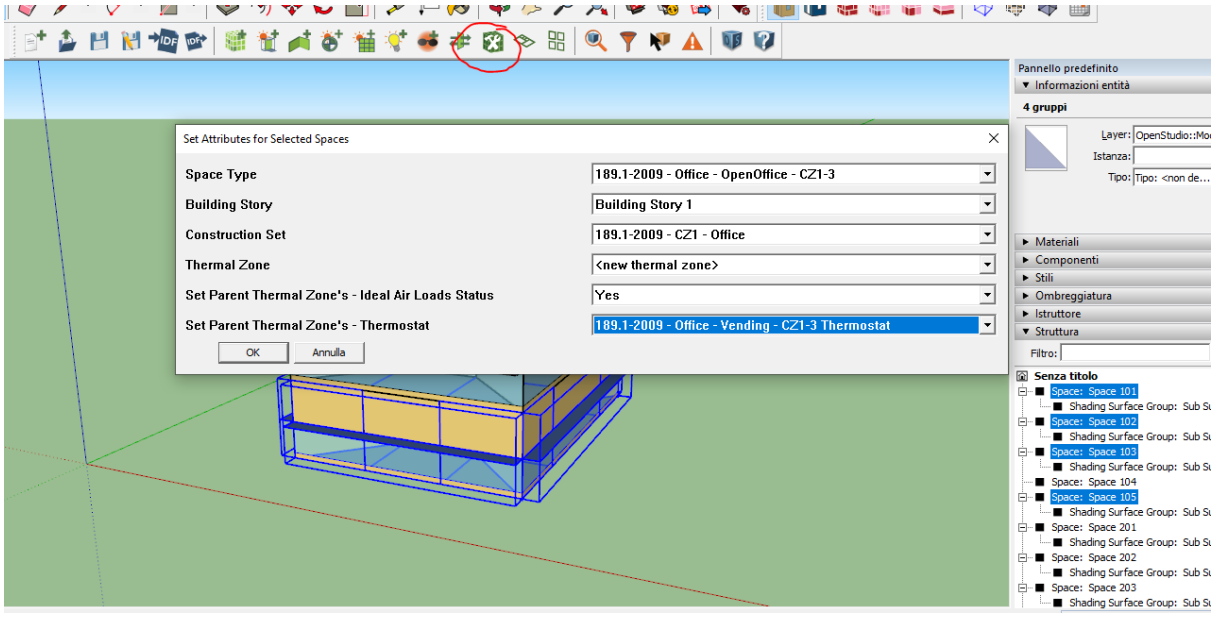


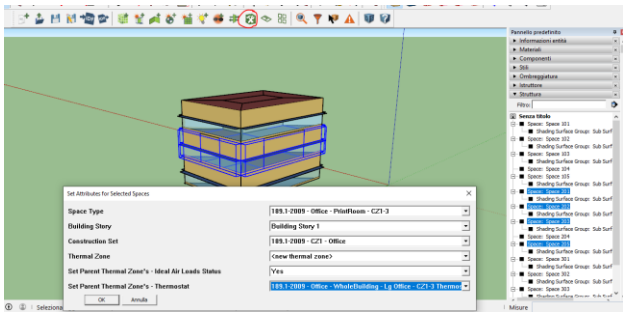


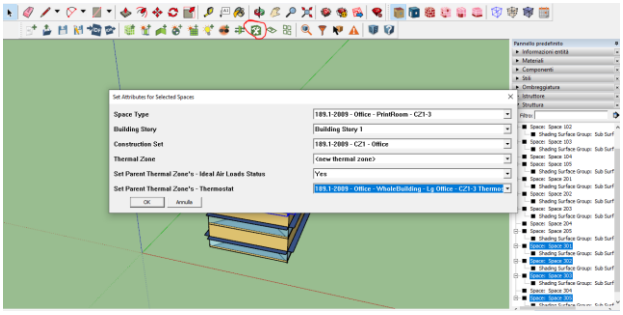


I put now the overhang that should go only on the three facades. (but it goes also on the north facade)

Now I start to select each thermal zone adding the specification: I start from the ground floor (Space 101,102,103,105)

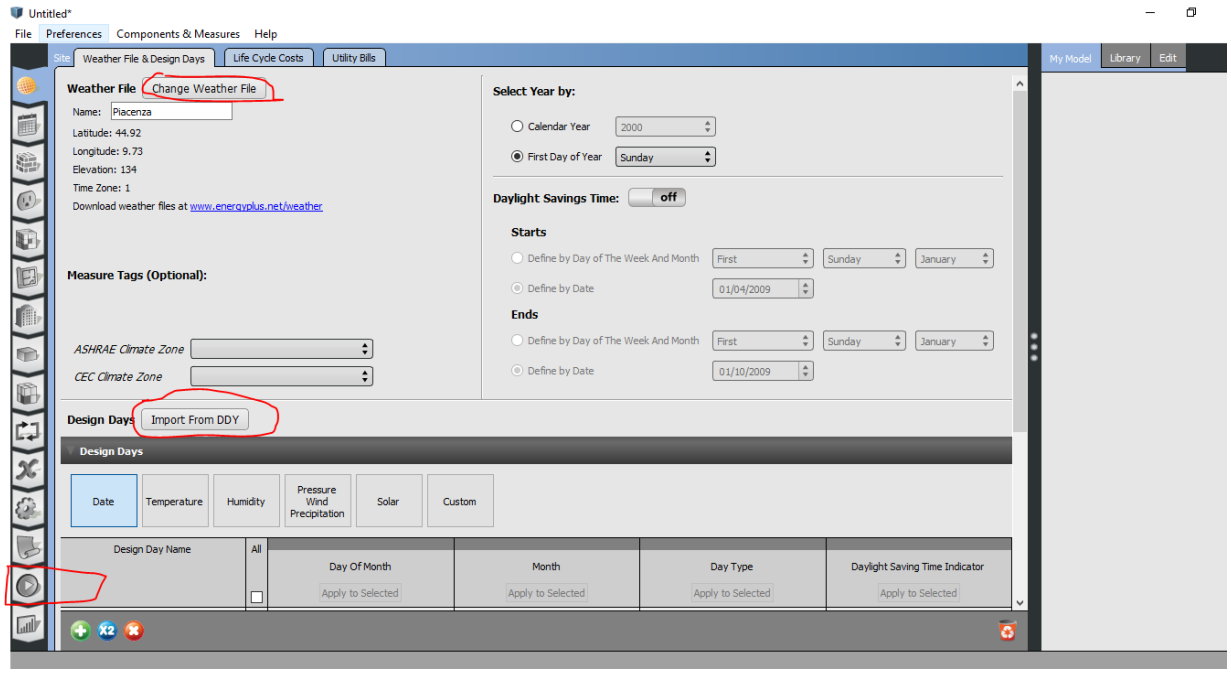


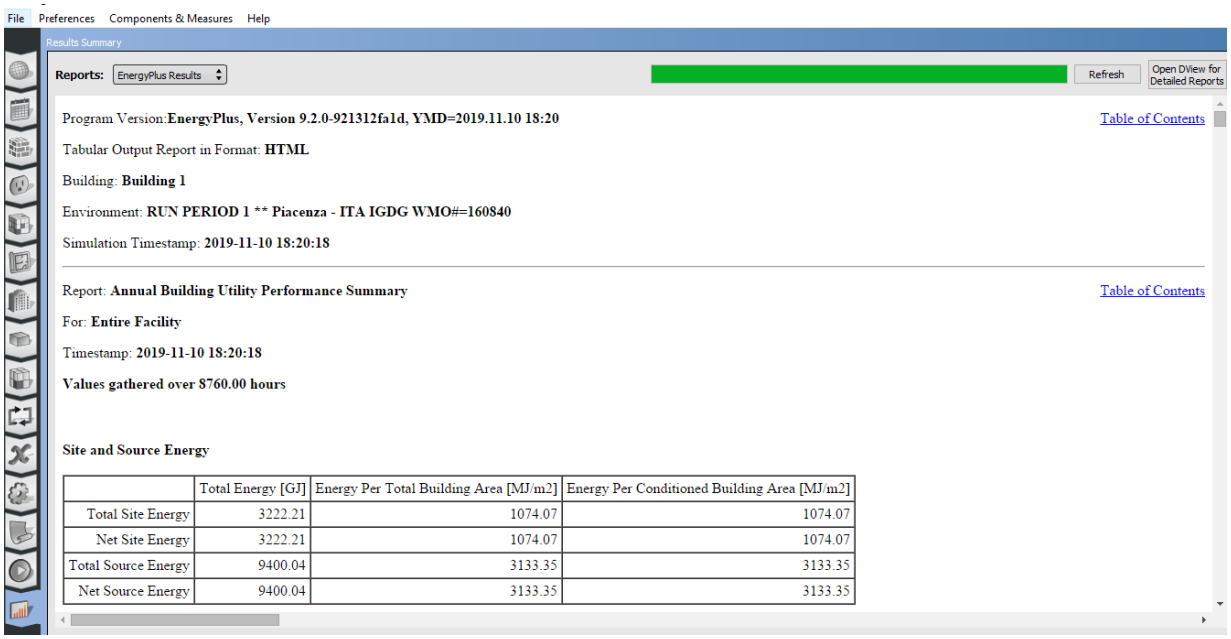




In base of the function I want to put in the building, I can guess the number of people that will be into.

Now I can open Open Studio, insert the Weather File and the Design Days.
Doing this, I have put the coordination of Piacenza.
Then, I press Run.





	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	3222.21	1074.07	1074.07
Net Site Energy	3222.21	1074.07	1074.07
Total Source Energy	9400.04	3133.35	3133.35
Net Source Energy	9400.04	3133.35	3133.35

Here I can see the Results Summary of my building.