Cost-Benefit Analysis of an Urban Neighbourhood Refurbishment Project

DesignBuilder was used part of a study contracted by the municipality of San Sebastián (Basque Country, Spain) which aimed to extract optimum solutions for building refurbishment in a specific urban context. The analysis was focused on a single representative 9-floor residential block with the objective that the results could be applied to the whole neighbourhood of Amara.

This was part of a wider project (which included energy audit, monitoring, etc) conducted by Aurea Consulting with the support of the municipality of San Sebastián and the users of the building.

Before ***After***

Detailed building model in DesignBuilder merged with before/after refurbishment photos

The Challenges

One of the conditions of the study was that the results could be extrapolated to other buildings in the same zone. Therefore, two simulation models were developed, one collecting all the detail of the particular building and a simplified model that could pick up general assumptions such as different orientations, and glazing fractions. The simplified model helped reduce computing time in the detailed model. Afterwards, general conclusions could be checked against the detailed model to test their validity in a specific building.

Approach and Analysis

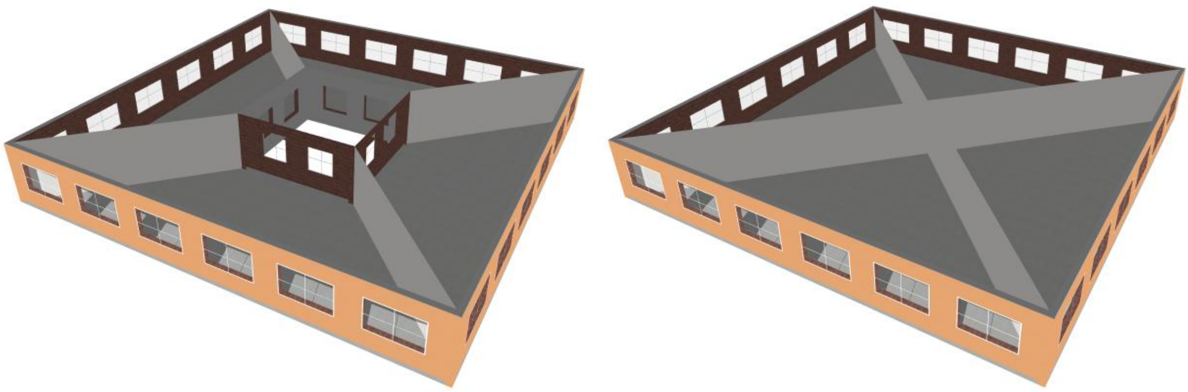
We chose DesignBuilder due to its great flexibility and the capability of its simulation engine EnergyPlus, which allows us to successfully address both small and big projects.

Changes in the model were just a matter of clicks in DesignBuilder so, although not completed as efficiently as it would be with current versions (which now include optimisation and improved parametric modelling) we were able to perform more than a hundred simulations and identify the results with best performance.

Our approach was to develop a simple model to be used as a baseline where we could test the different design alternatives. We focused on solutions that were widely replicable instead of more technically advanced choices, which would not be realistic for many projects.

Simple baseline model description

- ***Site***: after studying the housing development a general arrangement of first commercial plus 8 residential floors was taken, with 28 meters to the nearby buildings.
- ***Shape***: a squared plan model was chosen, divided in 4 dwellings which covered the main orientations N, S, E and W. Both with and without courtyard configurations were analysed. A mean 30% glazing for external walls and 23% for courtyards was taken.



Internal zoning of simple model, with and without courtyard

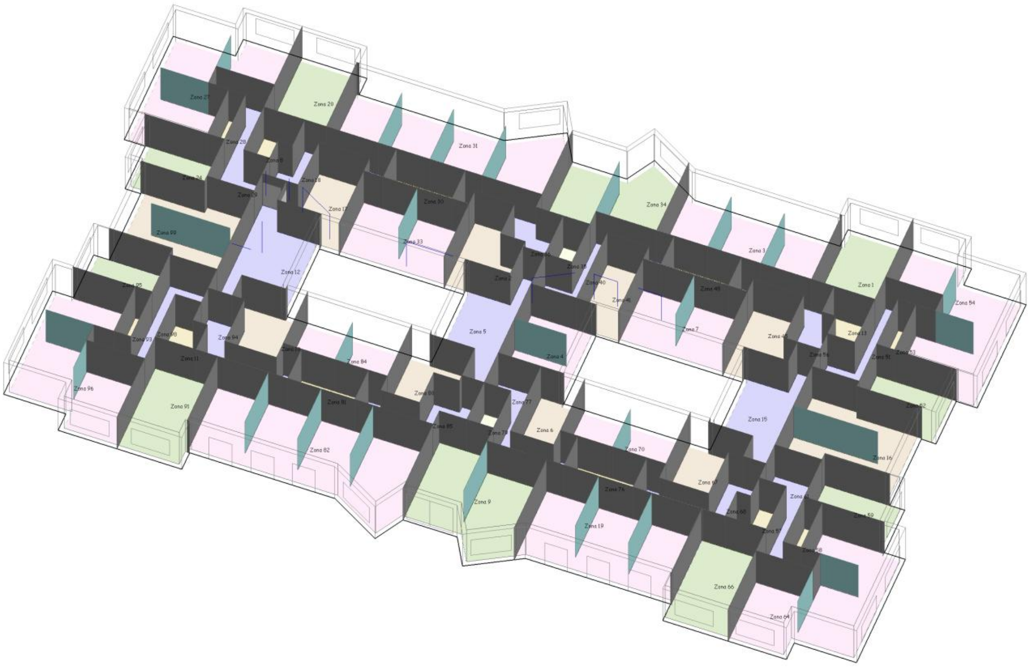
- ***Floors***: only 4 floors were modelled to represent the 9 floor building. A first unconditioned ground floor, a conditioned floor over the ground floor a middle floor with adiabatic floor and ceiling and a top floor with a roof.
- ***Construction***: actual present construction was taken for the baseline case, with uninsulated walls and roof and single glazing.
- ***Activity***: 3 people/100m2, 8,80W/m2 for plug loads + lighting and 1 ACH.
- ***HVAC***: a 65% COP (boiler plus distribution losses) heating with natural gas system was used operating at 20ºC (07:00-23:00) and 17ºC (23.00-07.00) setpoints.

Once the baseline building was ready, 4 combinations of insulation thickness (for walls, roof and exterior/semi-exterior floor) and 2 glazing types were simulated in different combinations in order to determine the most efficient configuration.

As expected for this project and location, the most insulated solution was the one which minimized energy consumption. However, our objective was to find the best alternative taking into account not only energy impact but also economic impact, so that cost would not limit the accessibility to the refurbishment. Municipality interest was to foster refurbishment with an optimum balance between cost and energy savings to reach the maximum number of interested communities.

Therefore, economic analysis had to be part of the study. Each energy demand curve was associated to material and construction cost in order to find out the cost-effectiveness of every measure.

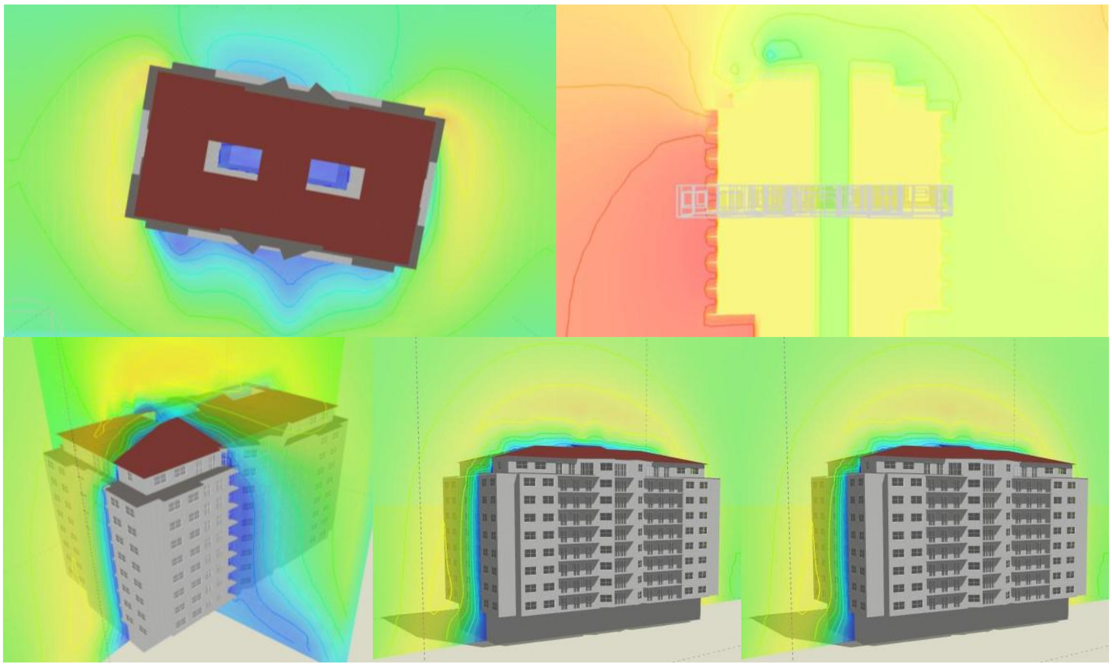
Detailed model



Detailed model zoning

The detailed model was initially built to calibrate model assumptions to real consumption data to verify their validity for the parametric study with the simple model. Additionally, it served to validate the conclusions extracted from the simple model in a restricted sample of cases whilst also allowing us to obtain more precise numbers for the specific representative building chosen for the study.

The detailed model was also used for some extra analyses, such as determining the wind pressures around the building and air movement in the courtyard. For those studies, DesignBuilder CFD was used, taking advantage of the already available geometry and the great ease of use of DesignBuilder's fully-integrated CFD module.



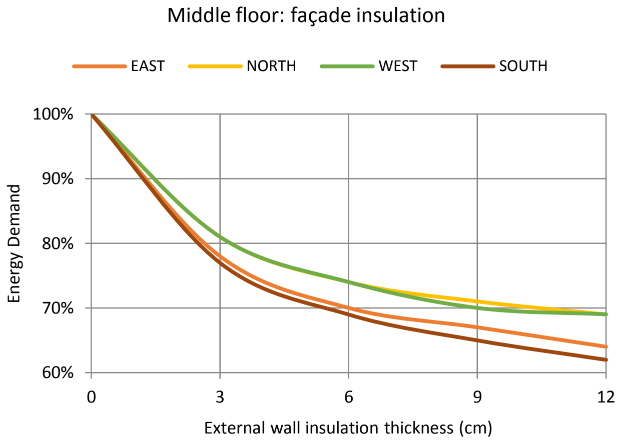
Additional studies carried out with DesignBuilder's CFD module

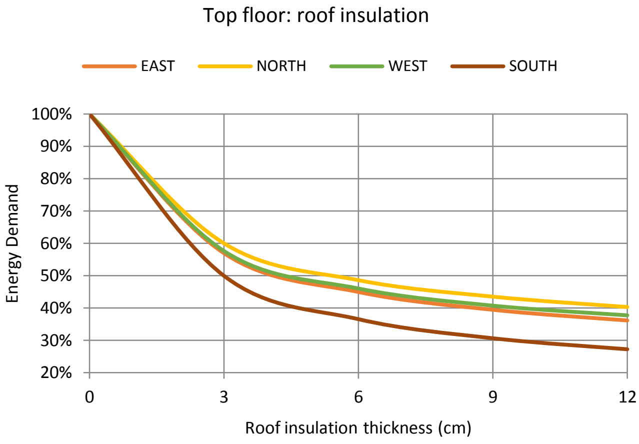
Results

The results from the simulations could be summarised as follows:

Improving the insulation levels in roofs and floors significantly reduces whole building demand and at the same time improves comfort.

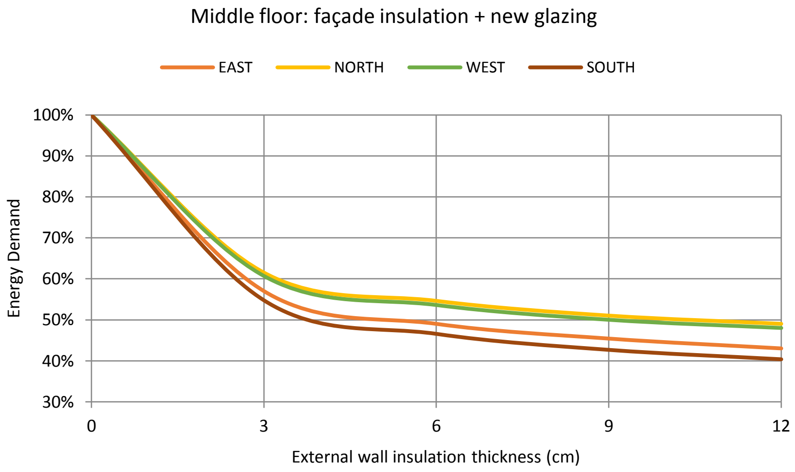
Results suggest 6-8 cm for wall insulation thickness and 9-12 for floor and roof:





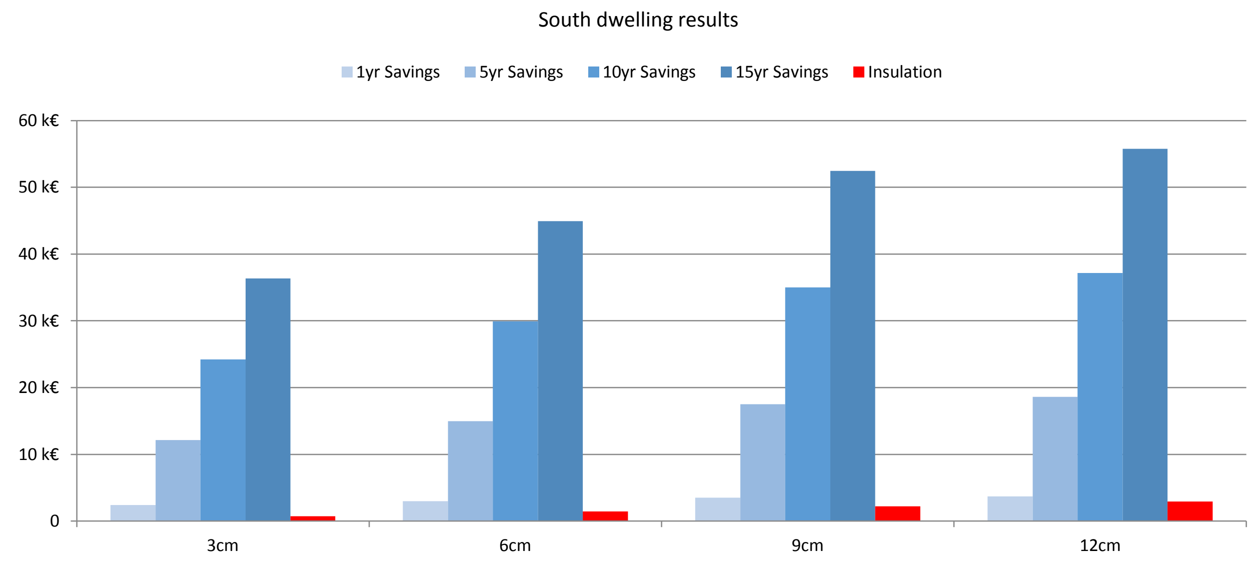
Different orientations and heights should be approached in a different way. South dwellings, even without insulation could be less demanding than an insulated North dwelling. However, in practice, often a common solution is taken.

The energy impact caused by glazing is important, reducing consumption between 10 and 20%. Installing double glazing, even without low-e coating, is enough to significantly improve performance. This would also help to improve comfort by reducing radiant asymmetry.

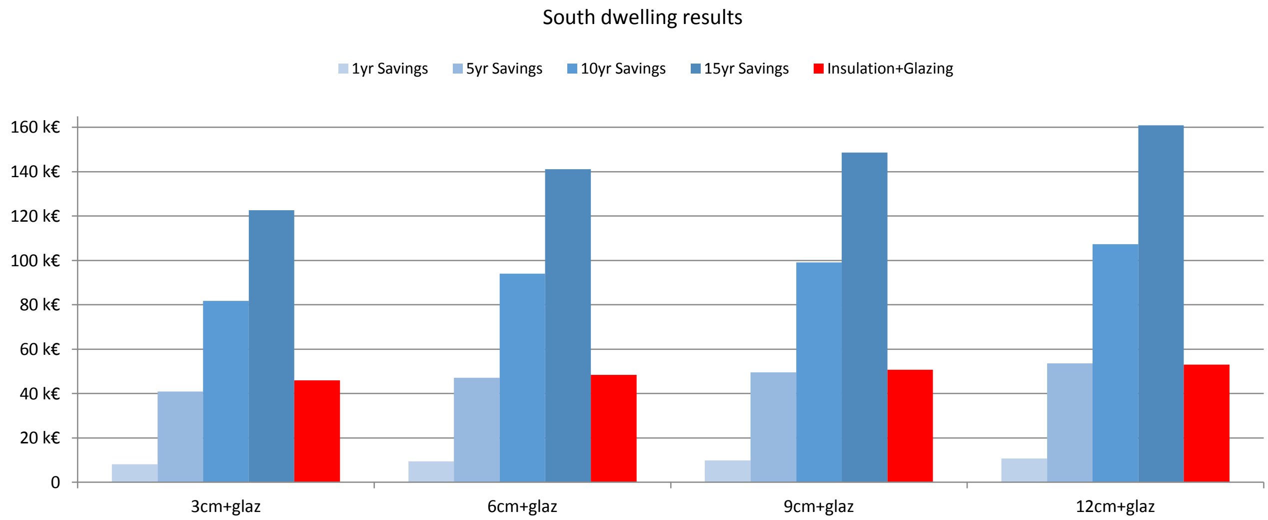


As the building was to be refurbished anyway, the economic analysis only included the addition of insulation and improved glazing but did not include the whole shared construction work.

Taking this into account, the analysis showed that investment in increasing insulation is recovered in the first year.



Economic saving during 1, 5, 10 and 15 years by insulating the façades (3-12cm). In red, the cost of the insulation.



Economic saving during 1, 5, 10 and 15 years by insulating the façades, ground floor and roof (3-12cm) and changing the glazing. In red, the cost of insulation and glazing.

However, the change of the glazing is not recovered until the 5th year, which, although longer, completely justifies the change.

The aim of this study was to prove that although energy saving measures were an obligatory part of the refurbishment, their cost-effectiveness will depend on correct analysis to identify the optimum cost-benefit for appropriate measures. Additionally, the often missed side effect of increasing the sale value of the building can easily compensate the whole work cost.

Finally, an interesting conclusion to consider is the fact that most energy savings are provided by the first few centimetres of insulation. Although you don't need detailed analysis to know that the insulation cost would be recovered through energy savings, the analysis did help to establish the insulation thickness for optimum cost-benefit.

Aurea Consulting Sustainable Architecture and Engineering SL (**www.ecoeficiente.es**) is a firm based in San Sebastián, Spain. The company specialises in consultancy services on energy efficiency and sustainability of buildings.

Aurea's goal is to reduce building environmental impact by providing consultancy and advice through the different stages of building process, from early design stage to building occupation and operation. To achieve this aim, Aurea's services include the development, distribution and use of building simulation tools, building energy performance and monitoring, and training activities.