TREES **Training for Renovated Energy Efficient Social housing**

Intelligent Energy Europe

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Section 1 Techniques

1.2 Glazing

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Contents

1. Introduction

1.1 Improvement of the performance of glazing

Glazing is an essential component in dwelling, providing light and solar heat but also inducing heat losses and overheating risks. Old buildings were generally equipped with single glazed windows, but the technical performance of glazed components has been dramatically improved these last 30 years : for instance the heat loss factor of advanced glazing is nearly 10 times lower compared to single glazing. Replacing existing windows is therefore one of the most common measure in energy retrofit of buildings.

The technical performance has influenced architectural choices like the window size and glazing ratio in facades. In the 60's, cheap energy lead to increase the glazing ratio, which has then been dramatically reduced in the 80's due to thermal regulation. The improved insulation performance of glazing now gives new possibilities to architects.

The solar and light transmittance have not been improved like the insulation performance. Solar protection may even be more sophisticated in old buildings compared to new constructions. These aspects are also important in a renovation project.

1.2 modification of the glazing area ?

Reducing the glazing area is sometimes proposed when renovating buildings from the 60's if extending an opaque wall is cheaper than replacing the glazing. But this type of modification has some impacts on the tenants' way of life. Therefore their agreement is needed.

Modifying the glazing area has implications on the building energy consumption (for lighting and heating) as well as visual and thermal comfort. Therefore some technical assessment is needed regarding day-lighting, energy performance and thermal comfort.

2. Lighting aspects

2.1 Lighting requirements in dwelling

2.1.1 Quantity of light

Lighting requirements depend on the planned activities in the dwelling : they are higher in a living room or a kitchen than in a corridor or a storage room. The quantity of light is expressed by an indicator called "illuminance", which takes into account the light source (emitted energy quantity), the eye sensitivity (related to the wave length, e.g. the eye is more sensitive to yellow than violet light) and the light distribution (an object receives more light if it is placed near a lamp than if it is far away, light may also be reflected by walls etc.).

The luminous flux is defined in terms of the emitted energy quantity and the wave length of the emitted radiation : it is zero for infra-red and UV, and maximum for yellow and green light. For the same energy flux, the luminous flux is higher using a compact fluorescent lamp compared to an incandescent one. The reason is that an incandescent lamp emits a lot of infra-red radiation that is not visible.

The ratio Luminous flux (expressed in Lm, lumen) / energy flux (in W, Watt) is the efficacy of the lamp. This efficacy is around 15 to 30 Lm/W for incandescent lamps, 60 to 100 Lm/W for compact fluorescent lamps and 100 to 160 Lm/W for daylight. For instance a 100 W incandescent lamp of 20 Lm/W efficacy corresponds to a luminous flux of 2000 Lm.

The luminous flux of a lamp is distributed over an area which increases according to the distance from the lamp. The quantity indicating if a working place receives enough light is the illuminance, expressed in lux = Lm/m2. The quantity of light directly received from the lamp depends on the distance from the lamp, but some light may also be reflected by e.g. walls, ceiling etc.

Recommended illuminance levels are around 300 to 500 lux for reading / writing, 100 to 200 lux for circulating / storing.

2.1.2 Day-lighting

In general, inhabitants prefer clear rooms, and day-lighting contributes to improve visual comfort, but of course there are exceptions. Also, protection against glare may be needed according to the planned activities near a glazed area.

Day-lighting contributes to save energy by reducing the electricity consumption for artificial lighting. In summer, this may reduce the risk of overheating, especially if the efficiency of the artificial light is low (e.g. using incandescent lamps) because in that case a large part of the electricity would be transformed into infra-red radiation, i.e. heat.

The day-light level in a place is indicated by the day-light factor = indoor illuminance / outdoor illuminance by overcast sky (expressed in %). This factor varies a lot in terms of the distance from a window, and a mean value in a room is generally considered as a relevant indicator in dwelling (in working places, lighting is more important and the distribution of light in a room is of course essential).

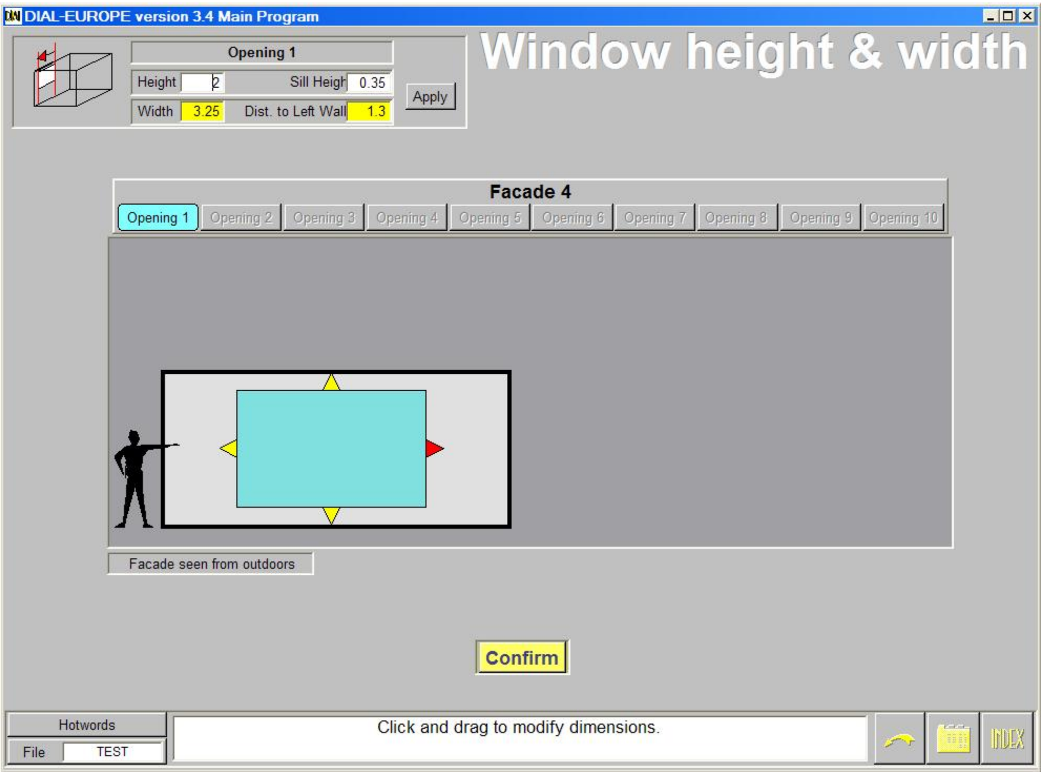
Recommended day-light factors are for example : 1% in a bedroom, 1.5% in a living room, 2% in a kitchen.

2.2 Evaluation of the visual comfort level in dwelling

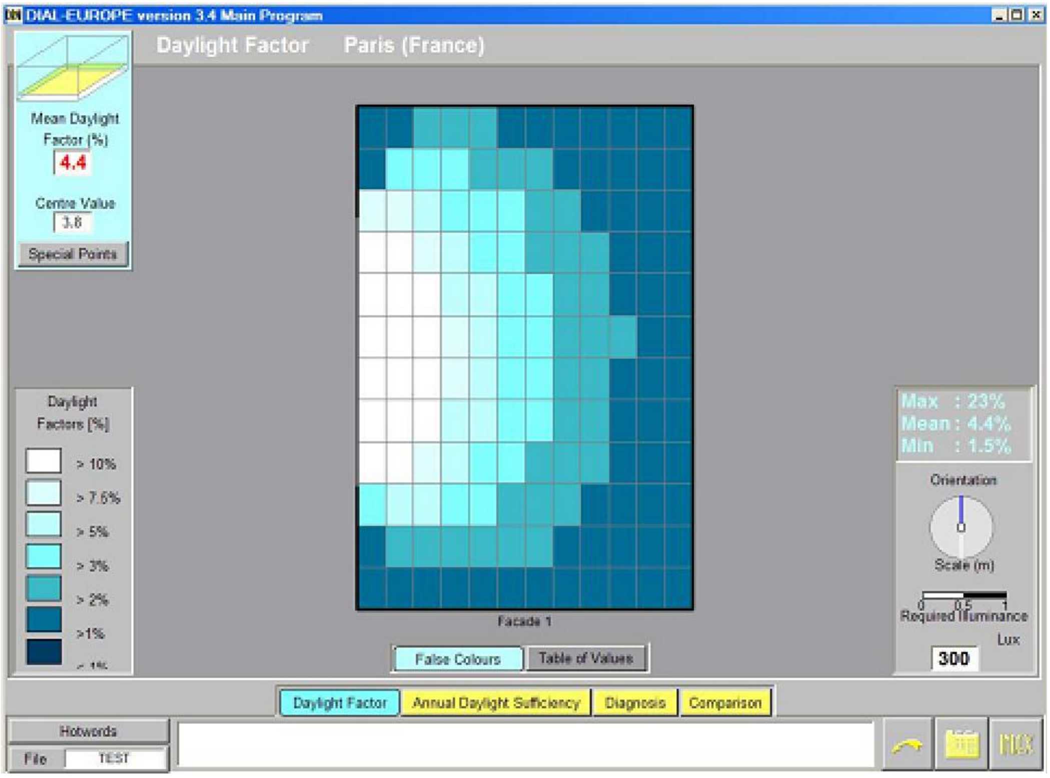
If a modification of the glazing area is studied in a renovation project, it is advised to evaluate its consequence in terms of visual comfort. The requirements in dwelling being limited compared to e.g. offices, schools and museums, simple tools can be used. An example is the Swiss tool DIAL, see : http://www.estia.ch/DIAL-EuropeE.html

The geometry of a room is described, as well as characteristics of walls, possible shading etc. Illuminance levels and daylight factors are calculated and clarification is available (e.g. definitions, comparisons with case studies, advice…).

Example

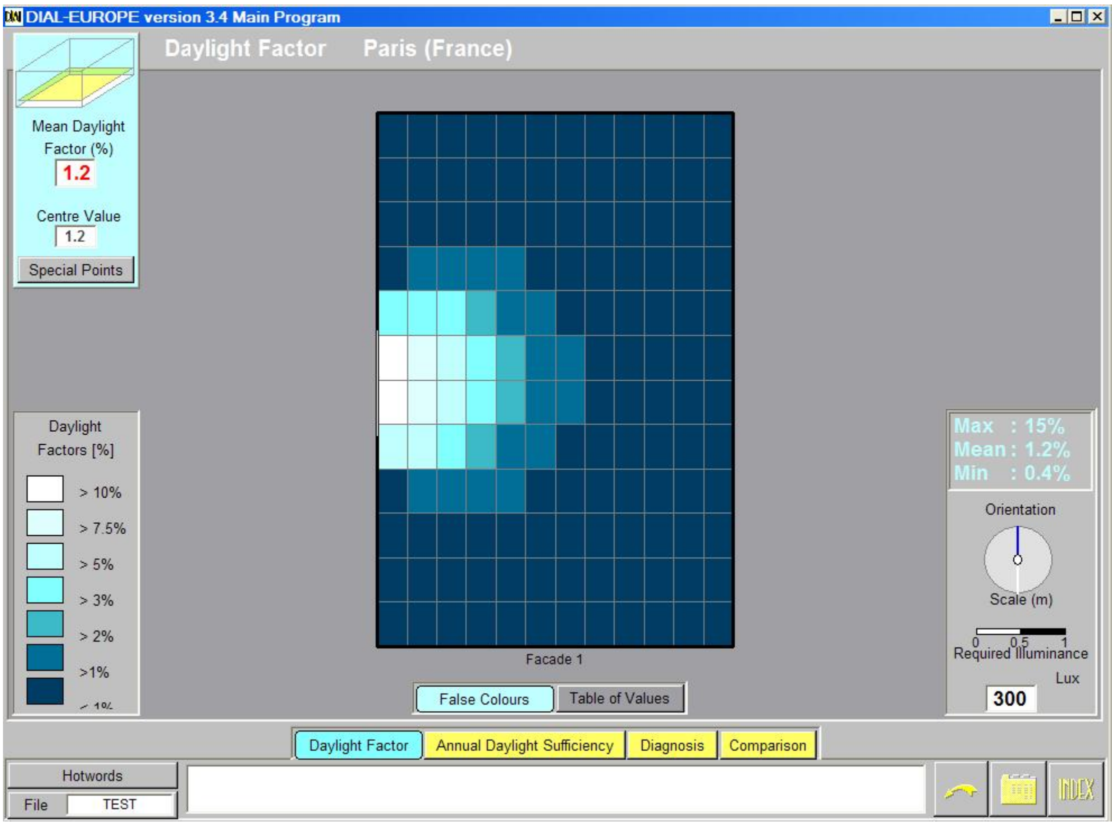


Example input window in DIAL, window size



Example output window in DIAL, daylight factor

If a reduction of the window size is studied, the daylight factors after renovation would become the following in this example.



Example output window in DIAL, daylight factor, case of reduced window area

Such an important reduction of the window size would lead to an insufficient daylight factor in a living room but it may be acceptable in a bedroom (the mean daylight factor being 1.2%).

3. Glazing and heating load

The influence of glazing on the heating load of a building results from a heat balance including thermal losses and solar gains. These two elements depend on the climate (temperature, solar radiation), the solar exposure of the façade (orientation, shading), the characteristics of the glazing (heat loss and solar transmittance factors), the characteristics of the building (e.g. glazing area, thermal mass), the equipment (and its control) and the indoor conditions (temperature, internal heat gains).

Decisions like the modification of the glazing area and the choice of a glazing type have to integrate these aspects in order to design an energy efficient retrofit project.

3.1 Solar exposure of a facade

The solar exposure of a façade influences the choice of a window size and glazing type. For instance in a north oriented façade, the solar gain is limited so that heat losses are more important. In such a case, small windows are preferred as long as the day-lighting requirements are fulfilled. For the same reason, the glazing type is chosen with the lowest heat loss factor even if its solar transmittance is low.

The following table summarizes the different cases. The definition of a “well exposed façade” and of the glazing properties will be precised further.

Orientation and exposure	Glazing area	Glazing type
Well exposed (little shading), between south-east and south-west	As large as possible	Double glazing, as transparent as possible except in Nordic climates where insulation is more important
Other cases	According to day-lighting requirements	Lowest heat loss factor

The following picture shows an example of a south facing façade.


Example of a south facing facade

On this photograph, around half of the façade is shaded, but of course this may change according to the time. This façade includes a large glazing area (around 50% of the façade is glazed).Is this façade well exposed, in other words does it receive enough solar radiation to justify keeping this large glazing area ?

Answering this question requires a site analysis. The neighbouring buildings are shown on the next photographs.

Studied building (left)

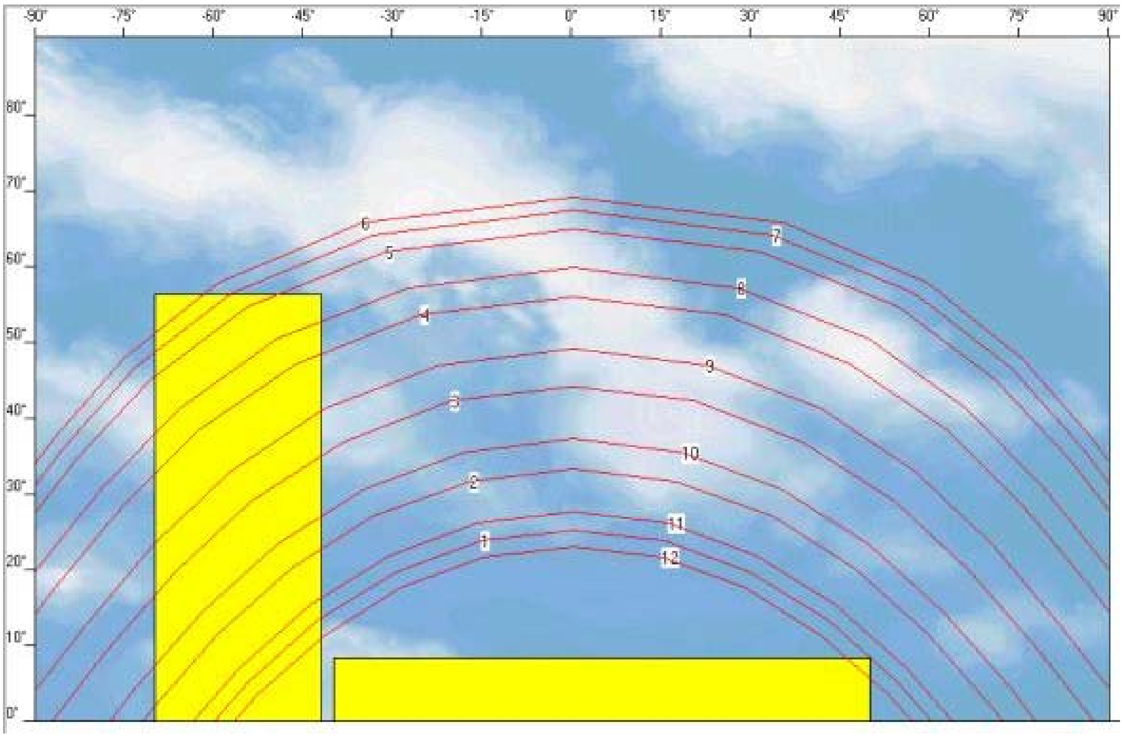
Neighbouring buildings (east and south)

The neighbouring buildings and other possible shading can be drawn on a solar path diagram as shown in the next graph. The horizontal axis corresponds to the azimuth (which can be obtained using a compass). On this scale, O° corresponds to due south, -90° to the East and +90° to the West. The vertical axis corresponds to the angular height : 90° corresponds to Zenith, 0° to the horizon.

The solar path depends on the latitude of the site, and on the season, the next graph corresponding to a location near Paris (49° North latitude).

The angular height of a shading object can be measured using a clinometer, or estimated by counting the number of storeys of a building (the average height of one storey being e.g. 3 m), and the distance to the studied façade. For instance the angular height h of a 18 storeys building, if the distance between this building and the façade is 100 m, is given by :
tg (h) = 18 x 3 / 100
i.e. h = 28°

The next graph shows the solar path diagram corresponding to the example shown on the previous photographs.



Example solar path diagram, 49° North latitude

In this example, the neighbouring building in the south direction is far and low enough so that its corresponding shading effect on the façade is very limited. The East oriented building is higher and nearer, but it is rather thin so that the shading effect is limited to 1 or 2 hours in the morning. Globally, the diagram shows that the direct solar radiation is not much blocked, therefore the façade can be considered as well exposed.

3.2 Thermal properties of a glazing

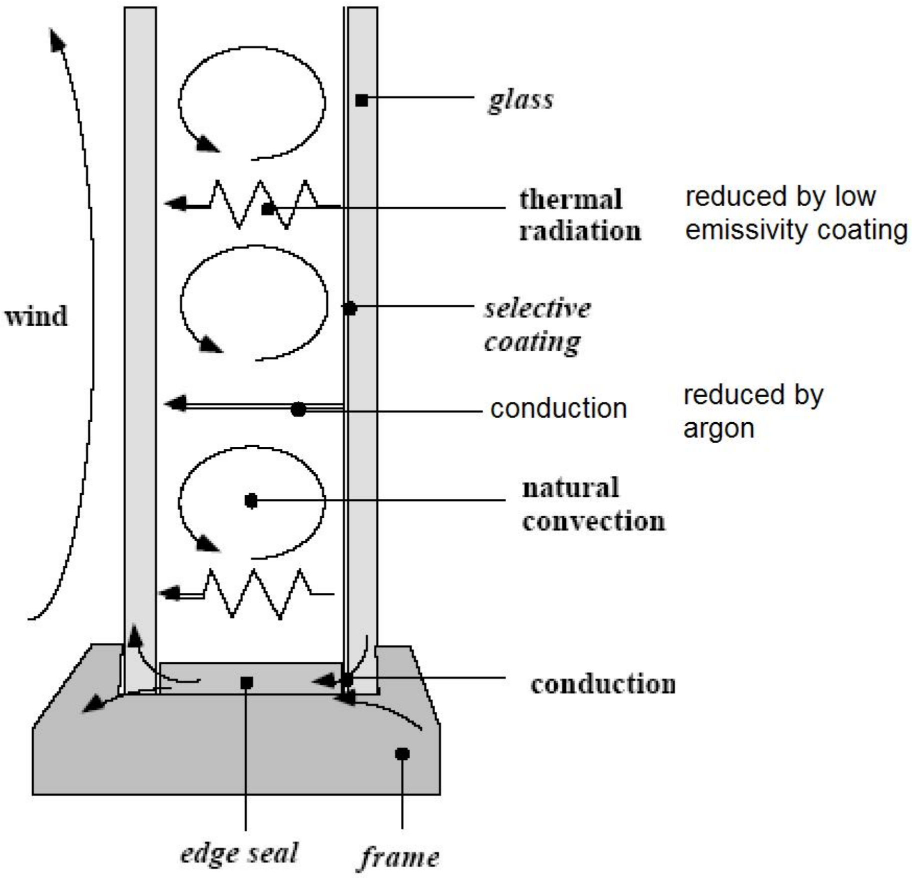
3.2.1 Heat transfer in a glazing

In a double glazing, heat is transferred from the hot side to the cold side by 3 modes (cf. next figure) :

- conduction in the glass, the frame, the edge seal and in the gas between the two panes,
- convection in the gas between the two panes (i.e. the gaseous molecules move and transfer heat), this transfer is limited because the thickness of the gap is small,
- radiation is emitted by the hot pane to the cold one.

The following techniques can be used to reduce this heat transfer :

- replacing air by less conductive gases (e.g. argon, xenon, krypton),
- coating the side of the internal pane situated between the two panes with a selective surface (i.e. which reduces the emission of heat but let the light through),
- adding a third pane.

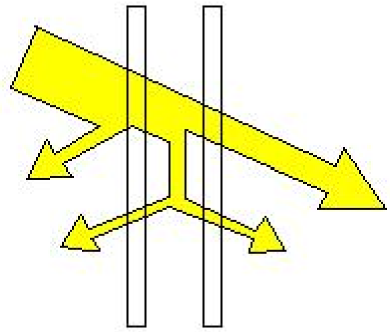


Heat transfer in a double glazing

3.2.2 *Thermal properties of a glazing*

Two main characteristics influence the heat balance of a glazing : the heat loss coefficient (U-value), expressed in W / m2 / K. This is the energy flux in W lost through 1m2 glazing area if the temperature difference between the two sides is 1K (or 1 °C).

The second parameter is the solar factor g, i.e. the % of solar radiation transmitted towards the inside. This factor includes the solar transmittance, but also the part of the radiation absorbed in the glass and emitted towards the inside (cf. next graph). It is in general different from the light transmittance, because it concerns also the infra-red part of the solar radiation (around 50%). Lowering the iron content in glass increases the solar factor, but such glass is more expensive.



Transmission, reflection, absorption and re-emission of radiation in a double glazing

The following table provides typical values of U and g for different types of glazing. More precise figures can be obtained from the manufacturers.

Glazing type	U value in W/m2/K	Solar factor g in %
double glazing	3	78
Hard coating low e with 12 mm air gap	1,9	72
Hard coating low e with 16 mm argon gap	1,5	72
soft coating low e with 12 mm air gap	1,7	58
soft coating low e with 16 mm argon gap	1,1	58
Low iron + soft coating + 16 mm argon gap	1,1	75
3-pane window with low-e coating and argon filling	0.9	42
3-pane window with low-e coating and krypton filling	0.6	42
3-pane window with low iron glass, low-e coating and krypton filling	0.6	62

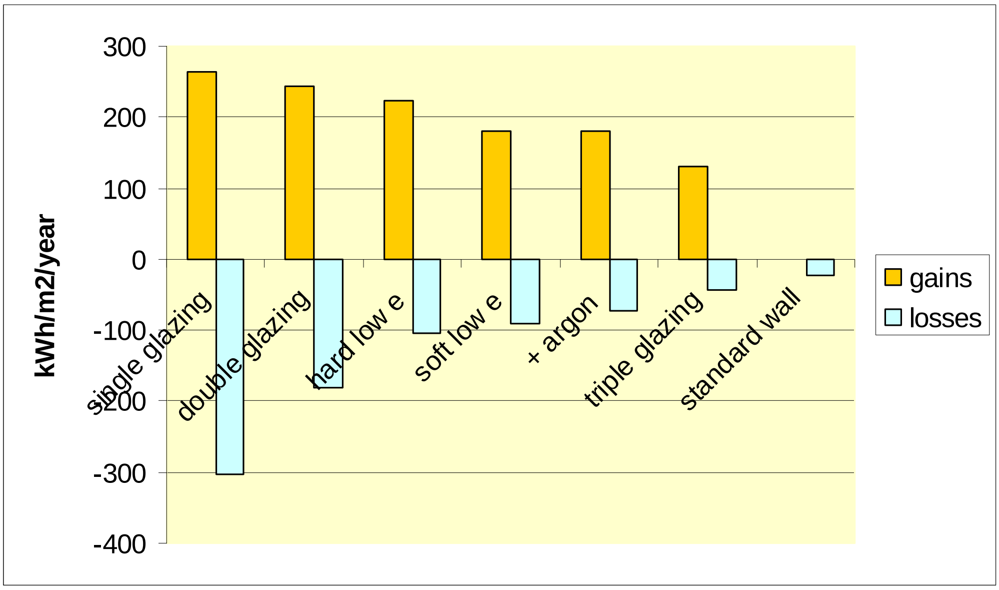
In a window, glazing corresponds to 60 to 90% of the area, therefore the frame is also important. Some materials like metals have a high conductivity compared to plastics and timber, therefore some insulation is incorporated to avoid thermal bridges. The typical U-value of a well insulated frame is around 1.3 W/m2/K.

3.3 balancing heat losses and heat gains

3.3.1 Heat balance of 1m2 south oriented glazing

The decision to modify the glazing area and the choice of the glazing type should account for the heat balance of the glazing, according to the climate, the solar exposure of the façade, the characteristics of the building (particularly thermal mass), and its use (and particularly the indoor temperature level). Using a calculation tool (see section 2.1) is preferable for this type of study.

In the following example result, we assume that the typical indoor temperature in social housing is 20°C. The thermal mass of the building is medium, which corresponds for instance to heavy floors (20 cm concrete) and light facades. The solar gains would be less useful with a very light building (e.g. wooden structure and floor), and more useful in a very heavy structure (e.g. 20 cm concrete in floors and walls, with external insulation). In a heavy structure, the solar gains can be stored from day-time until evening and the reduction of the energy consumption is therefore higher. The first m2 of glazing are more efficient than adding one supplementary m2 to an already very glazed space : the supplementary solar radiation would mainly contribute to overheating. The following graph corresponds to 1 m2 south facing glazing in the Paris climate.



Example heat balance of 1 m2 south facing glazing in the Paris climate

In this example, heat losses are higher than solar gains in the case of a single glazing, but the global balance (gains – losses) is positive for all other glazing types, which means that reducing the south facing glazing area would increase the energy consumption of this type of building in this type of climate. Except single glazing, the net energy balance (gains – losses) is positive compared to a standard wall (insulation level corresponding to the thermal regulation).

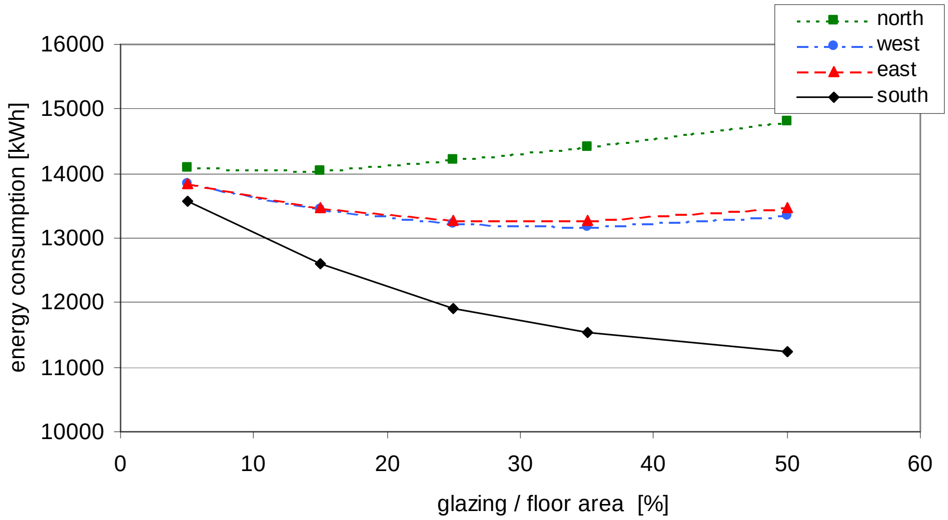
Of course solar gains would be lower and heat losses would be larger in a nordic climate. Solar gains depend also from the orientation and solar exposure of the facade. But this example shows the type of analysis that can be performed.

Another conclusion is that a soft low emissivity coating reduces the heat losses compared to a hard coating, but also the solar gains. Globally, a hard coating is preferable in this climate (of course another conclusion may be drawn in another climate). Replacing air with argon reduces the heat losses with no reduction of the solar gains.

3.3.2 Heat balance of a building

Varying the glazing area influences the heating load and energy consumption of a building, according to the orientation of the considered façade. Again, thiis can be studied using a calculation tool and the results depend on the climate. The following example has been obtained considering the Paris climate, typical indoor conditions in a residential building, and a medium thermal mass building.

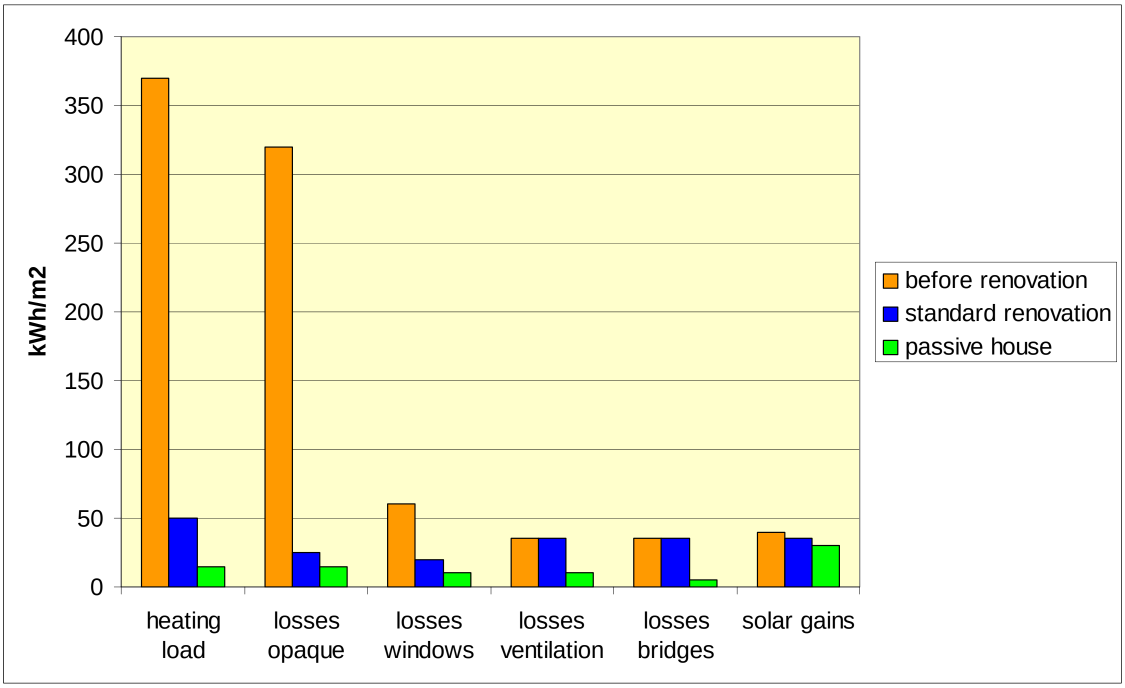
The horizontal axis corresponds to a glazing ratio, i.e. the glazing area divided by the floor area, and the vertical axis represents the energy consumption in kWh (including heating and hot water).



Example calculation results, energy consumption in terms of glazing area for different facade orientations

In this example, increasing the glazing area reduces the energy consumption of a building if the façade is south oriented, but the reverse is true for a north oriented façade. The glazing ratio has a limited influence on the energy performance for east and west orientations.

Calculation tools also allow the performance of a building before and after renovation to be compared. The following graph corresponds to the same climate. The heating load, heat losses (opaque walls+roof+floor, windows, ventilation and thermal bridges) and solar gains are compared before and after renovation, providing also the best practice level ("passive house" standard). All figures are expressed in kWh/m2 of living area.



Example calculation results : heat balance of a building before and after renovation, and comparison with best practice (”passive house”)

The graph shows the large influence of opaque insulation (reduced heat losses and heating load). But replacing the glazing (from single to low emissivity double glazing in this example) is also efficient. In the passive house standard, triple glazing is used, and complenentary measures are implemented : heat recovery on ventilation air, and reducing thermal bridges.

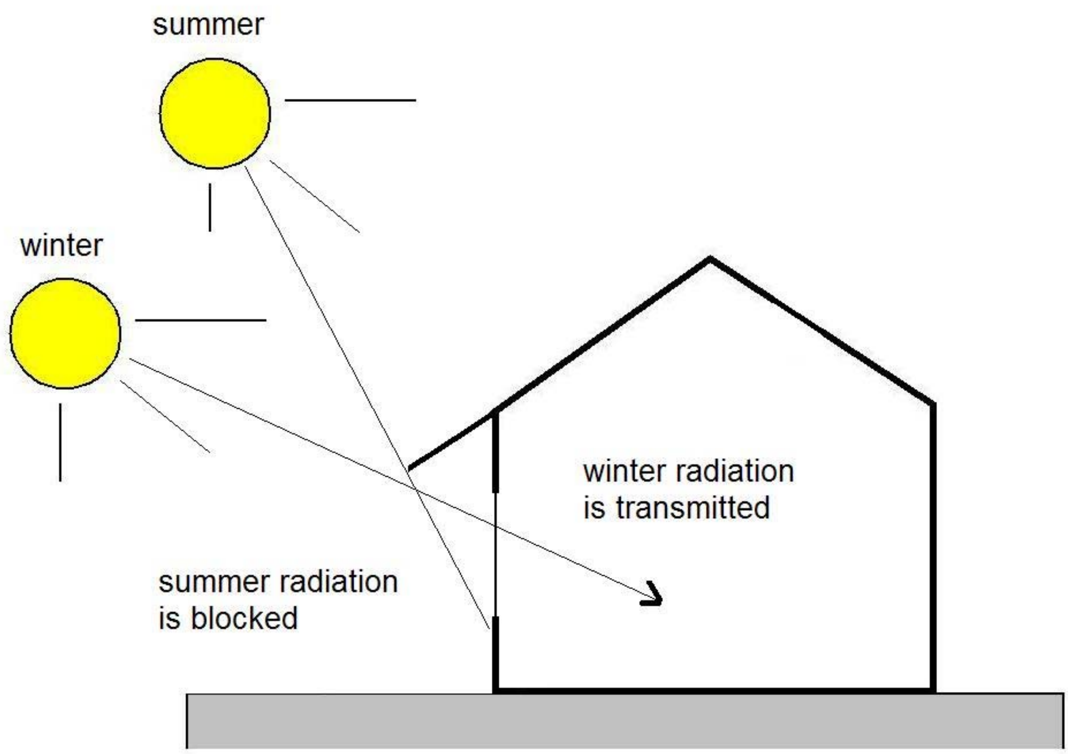
4. Glazing and thermal comfort

Global warming increases the risk of more frequent hot summer periods, therefore glazed components have to be complemented with appropriate solar protection. Two main types are movable shading devices (roller and venetian blinds, shutters…), and architectural shading (balconies, overhangs, fins…). Some of these devices are also suitable for ventilation purposes. Night ventilation is an efficient way to cool a building when the surroundings are not too noisy.

4.1 Solar protection by architectural shading

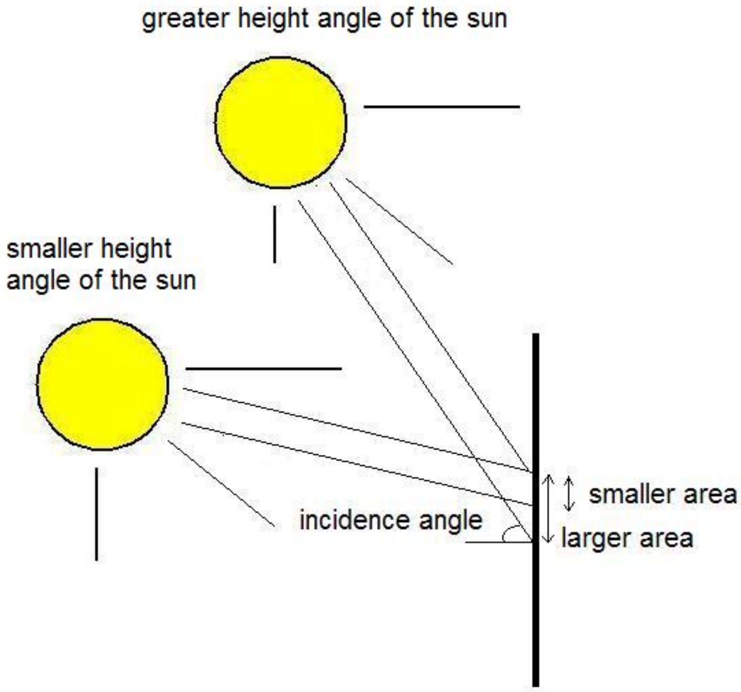
4.1.1 Solar height angle

As we have seen on the solar path graph, the sun is higher in the sky in summer than in winter. This gives the possibility to use architectural shading like overhangs in order to block solar radiation in summer while using solar gains in winter, see next graph.



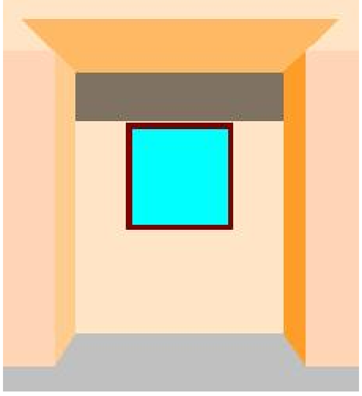
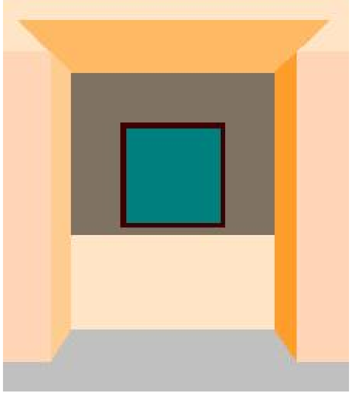
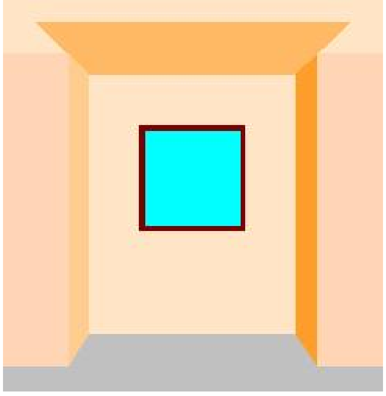
Position of the sun, effect of an overhang in summer and winter on a south oriented facade

Because of this greater height angle in summer, the incidence angle of the sun is higher on a vertical south façade compared to west and east oriented facades for which the incidence angle is low, the sun being near the horizon in the morning and evening. As a consequence, the solar radiation per m2 of south façade is lower compared to 1 m2 of east or west façade, the same amount of radiation being distributed over a larger area (cf. next graph).



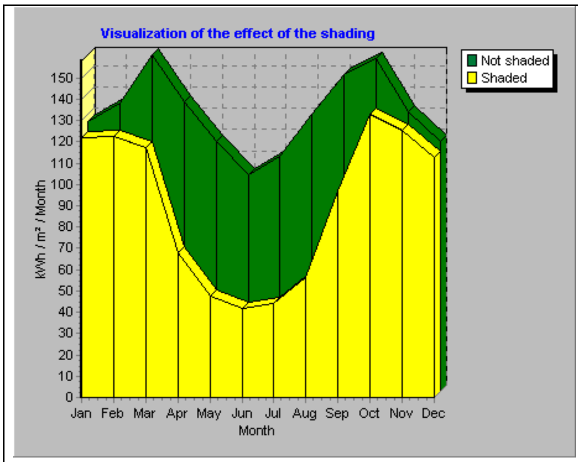
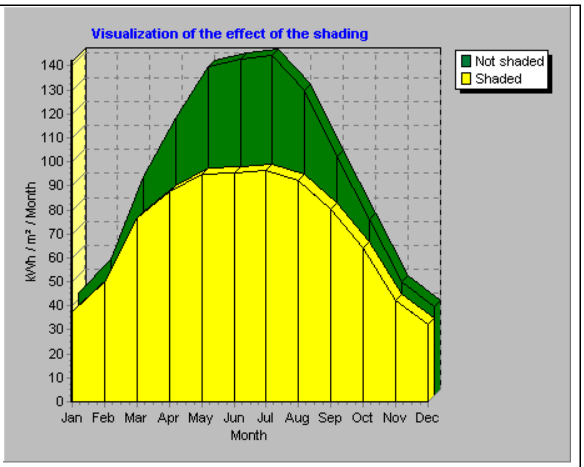
Solar radiation on a vertical façade in terms of the height angle of the sun

If the height angle is larger, it is easier to protect the façade using an overhang. This is why solar protection is easier on a south façade compared to east and west facades. The next graphs show example shading effects for different orientations and seasons.

 South orientation, winter, little effect of an overhang	 South orientation, summer, important effect of an overhang	 West orientation, little effect of an overhang

4.1.2 Monthly solar radiation values

The next graph shows the incident and transmitted solar radiation on South and West façades, accounting for a 1m wide overhang, for the different months of a year (location near Paris).

 Incident (green) and transmitted (yellow) solar radiation on a South façade with 1 m wide overhang, example in Paris	 Incident (green) and transmitted (yellow) solar radiation on a West façade with 1 m wide overhang, example in Paris

In the case of a south oriented façade, the maximum radiation is received in march and October : it is lower in winter, but also in summer due to a higher incidence angle as previously explained. On the other hand, the maximum solar radiation is received in summer on a West façade, and the effect of the overhang is lower compared to a south façade.

A recommendation could be to keep a large south facing glazing area, but to reduce the area of west facing glazing. Radiation curves for East oriented facades are similar to the previous one for West facades, but the maximum radiation on an East oriented façade is received in the morning, when the outdoor temperature is still low. Therefore the most problematic glazing orientation is West. Of course horizontal glazing would lead to a still higher overheating risk, but such glazing integration is not common in social housing.

4.1.3 Horizontal and vertical solar protection

In the case of East and West facades, vertical fins constitute a more efficient solar protection than an overhang, which is more adapted to South oriented facades.

Examples are shown in the table below.

 Overhang, example : Zephyr system www.zefyrgroup.com	 Vertical fins AWAX building in Athens, Architect : Alexandros Tombazis

4.2 Movable shading device

Movable shading devices complement architectural shading. These solar protections are more efficient if they are implemented on the outer side of a glazing, otherwise they absorb a part of the solar radiation, which is transformed into heat and is blocked by the glazing (greenhouse effect).

The next graph provides some indication of the solar factor of different types of movable shading device. Like for glazing, the solar factor includes the transmitted % of solar radiation and the part of the absorbed radiation which is re-emitted towards the inside.

For instance, external wooden shutters transmit only 9 to 10% of the incident radiation, whereas internal venetian blinds transmit 45 to 65% of the radiation (a poor solar protection).

5. Conclusions

The main recommendations derived from the analysis presented above are the following :

►Keep large glazing area in living rooms (daylighting)
►Keep large glazing % in south facade and integrate solar protection (overhangs)
►Reduce glazing area in north facades
►Choose low-e (but high g-value in south facades), argon filled glazing, well insulated window frames, possibly triple glazing according to the climate
►Integrate adapted solar protection (external roller blind, horizontal or vertical shading…)