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

Intelligent Energy Europe

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Section 3 Case studies

3.4 Montreuil, France

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1. Aim and general description

1.1 Aim of the project

The project, part of the European demonstration project REGEN LINK[1], aims to demonstrate that the fulfilment of Agenda 21 objectives, particularly the reduction of greenhouse gases emissions, is also possible in regeneration, and in the social housing sector. Under strict economical constraint, the concept of " lean regeneration ", i.e. the achievement of high energy performance by improving the building envelope using innovative but not too sophisticated technologies, has been studied and applied in 52 dwellings among a 536 units regeneration project.

The objective of the monitoring phase is to evaluate the performance of the building before renovation, and after implementing various techniques. Compared to a conventional approach, the insulation thickness is increased in order to minimise life cycle cost. Advanced glazing (low emissivity, argon filled in some dwellings) is used instead of standard double glazing. Some glazed balconies allow preheating of ventilation air and reducing thermal bridges. The control of the district heating loop is improved by creating a specific loop for the studied building. Additional equipment like water saving and moisture controlled ventilation is tested in some dwellings. Integration of solar domestic water heating is studied. Advantages of these techniques are energy saving and improvement of comfort. Disadvantage is a higher investment cost and, concerning glazed balconies, the need to check the residents' acceptance.

The overcost of advanced glazing is considered too large and the present project should demonstrate that low cost implementation can be achieved and that this technique could become the new standard in a next future, as it is already in some other E.U. countries. Argon filled glazing is considered at risk (durability, maintenance) by a technical advisor of the municipality and it is hoped that the demonstration project proposed here will show the relevance of this technique.

Humidity-controlled ventilation is still controversial among social housing technical experts, and is therefore rarely implemented. Implementation and monitoring of this technique improves the knowledge of its performance and of possible constraints (maintenance, cleaning,...).

Integration of renewable energy components is extremely rare in France, particularly in the social housing sector. The very good solar exposure of the selected building is well adapted to the demonstration of solar balconies as energy collectors. Preheating of ventilation air in such spaces is efficient and is not common in Greater Paris area. Also, the implementation of solar water heaters in a building where domestic hot water is prepared by a collective system is innovative and worth studying, though the pay back time might be high.

The objective is to reduce the heating load by 50%, i.e. by 25% compared to a standard renovation. The dwelling blocks are heated by a district heating using mainly coal fuel (70%), and it is hoped to reduce a large amount of CO_2 emissions. This regeneration project is part of a more global urban project according to an environmental agenda defined by the municipality. The results of this project concerning the reduction of operation cost and the environmental benefit of innovative techniques like advanced glazing will hopefully influence other decision makers in the social housing sector. Some of the techniques may not be economical, but at least partial replication of the project is targeted.

[1] Bruno Peuportier, Assessment and design of a renovation project using life cycle analysis and Green Building Tool, Sustainable Building 2002 Conference, Oslo, September 2002

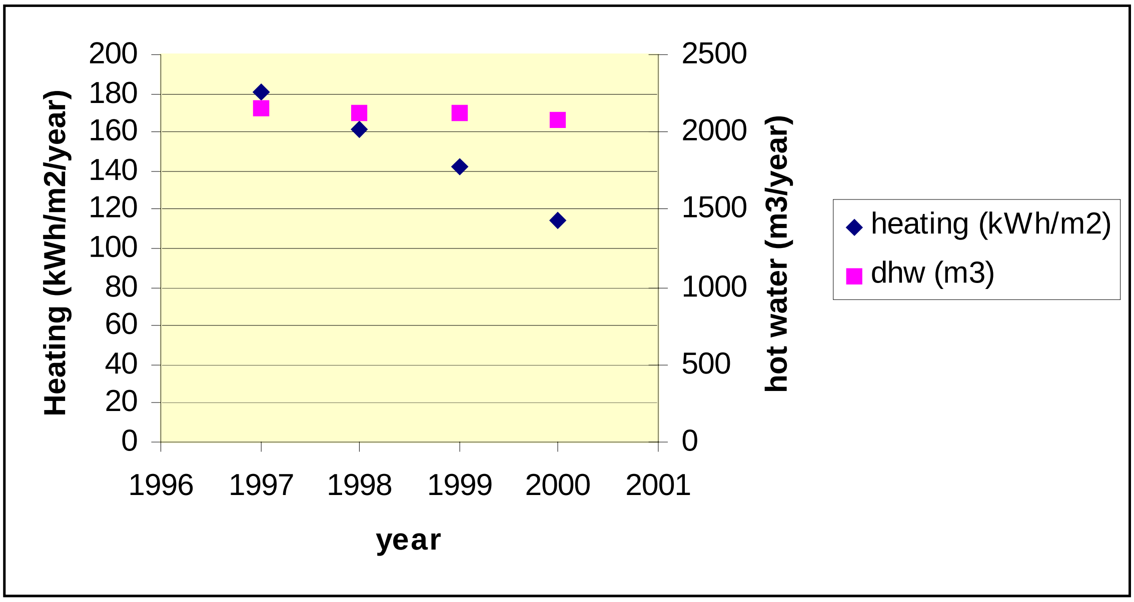
1.2 Description of the site

Montreuil is a city of around 96.000 inhabitants in the Greater Paris area. A neighbourhood, rather isolated from the rest of the city, has been selected by the municipal environment service to conduct a pilot social and environmental action plan. This neighbourhood includes around 1.500 dwelling units, among which 536 are owned by the public social housing association OPHLM de Montreuil. The whole renovation project is concerned with these 536 dwellings. The corresponding buildings are either blocks of 4 to 8 storeys or high-rise buildings of 18 storeys. The building considered in the REGEN LINK project is a 4 storeys block including 52 dwelling units. The buildings have been built in the sixties, without any insulation and with a large percentage (around 50%) of single glazed windows.

1.3 State of the building before renovation

The studied apartment block has been built 1969, before any thermal regulation. The walls are not insulated, and the windows are equipped with single glazing. The following picture shows the south facade of the building. The facades are not flat, which has consequences on the choice of an insulation material : mineral woll is more adapted than boards (e.g. polystyrene or polyurethane) because it can be placed more easily on an uneven surface.

The heating load before renovation has been estimated based upon the accounting of the district heating company. Because there is a single heating loop for two buildings, the portion of the total consumption corresponding to the studied building has been estimated proportionnally to the heated area.
The ground floor is sometimes used for recreational activities (e.g. dance course), but these activities are occanionnal. This implies a high variation in the measured energy consumption for heating (see next figure), which also depends on clmiatic variations.



Heat consumption for space heating and domestic hot water before renovation

An average value has been considered to compare the performance after and before renovation.

2. Design of the renovation project

2.1 Decision process

2.1.1 Energy retrofit is part of a global strategy

A renovation project is not only motivated by energy saving. In the case presented here, the municipality and the social housing organisation wanted to improve the image of the building and its neighbourhood, to reduce operation costs for low income families while improving the comfort in the dwelling and reducing environmental impacts.

Energy performance is the result of combined efforts by several actors : the owner, architect, consultant and contractors in charge of the works and of the maintenance. But the users also play an important role : achieving the planned performance depends a lot on their behaviour. Complementing the energy efficiency concept (efficient systems, well insulated building envelope etc.), the energy moderation concept regards the users behaviour, for instance : setting a thermostat at 20°C and not 23°, using a shower rather than a bath, etc. A participatory approach involving the residents is essential to achieve a high energy performance.

The design of the renovation project presented here was an iterative process. For instance the glazing area is the result of a compromise between cost aspects (opaque wall is cheaper than glazed components), energy efficiency (south oriented glazing reduces the energy consumption for space heating), and some residents' wish to keep large windows.

2.1.2 First steps

Knowing the budget for the renovation works according to the affordability of the residents is of course a major issue that will direct the technical choices. Financial issues related to loan and rent levels, possible European, national or regional subsidies for energy efficient technologies have lead to fix a budget limit in the project presented here.

An enquiry is essential to identify the needs and wishes of the residents, particularly if some of the planned technologies have an important influence on their way of life : for instance closing a balcony using glazed elements may change the way of using this space. It is therefore needed to ask the opinion of all concerned persons about this proposal. In Montreuil, each family has been visited and asked if they would accept a glazed balcony. The area of glazing on the building facades has also been a discussion topic. At the same time, energy efficient domestic appliances and lighting have been presented in the frame of a demand side management approach.

The municipality has also organised neighbourhood meetings during which sustainability issues were presented regarding energy, water, green spaces, waste management and transport. The presentations were followed by a discussion. This has resulted in proposals regarding waste sorting (location of sorted waste storages), and public transport (location of bus stops).

A first step in the design of a renovation project is to analyse the existing building, the main criteria being : wall, roof and floor insulation, glazing type, ventilation, heating equipment and control. Analysing the site is also very important : passive or active solar components are useful if they can benefit from a sufficient solar exposure, according to the orientation of facades and roof, accounting for possible shading (trees, other buildings etc.).

The maintenance ability of the building manager may also limit the choice of equipment, e.g. too complex systems may have to be avoided.

Technical choices have of course to be discussed with the architect in charge of the project. Some systems require a proper integration of components in the building (e.g. solar collectors), and this architectural integration may impose some limitations regarding for instance the size of such systems (e.g. available area to install collectors).

2.1.3 Choosing the main design options

Accounting for the prerequisites listed above, the main technical design options have been chosen by answering the following questions :

- is the solar exposure high enough to integrate passive and active components ?
- how thick should be the insulation ?
- how to reduce ventilation heat losses ?
- which is the most appropriate glazing type ?
- what are the priorities according to the budget ?
- are the proposed technical solutions acceptable for the tenants ?

Answering these questions implied an iterative process involving architecture, techniques,costs and users' acceptance.

2.1.4 Participation of the residents

In the frame of the pilot social and environmental action plan conducted by the municipality, several meetings are organised with the residents of the neighbourhood to discuss various aspects like the open and green spaces, waste management, public transportation, energy and water saving.

A meeting has been organised by the municipality with the inhabitants to inform them about the REGEN LINK project, aiming at sensibilisation on environmental issues. Energy and water saving are related to operation costs of the buildings, and this aspect is important for the low income families concerned by this project.

In general, a renovation project begins with an audit phase during which the residents are contacted to evaluate their needs and wishes. This phase allows a first sketch of the renovation project to be presented and feedback to be collected. In coordination with the architect, the social housing company has chosen an external insulation and cladding system having a better appearance than cheaper products, with the objective to improve the image of this neighbourhood.

Unlike technical solutions like the increase of insulation and the modification of the glazing type, transforming a balcony into a sunspace has important implications on the residents life. Their agreement is therefore needed for such a transformation. Each apartment of the longer aisle of the building (dwelling units including a south facing facade) have been visited in order to know if the occupants would accept a glazed balcony,.

Most of the inhabitants are in favour of glazed balconies because these improve the winter comfort by preheating the ventilation air and they constitute a nice space, which can be used e.g. as a play space for children. Less favourable reactions were emanating from some elderly persons, who want to avoid works in their dwelling and fear that an opaque window basement would block the view to the outdoor spaces. One person prefers to be in the open air on her balcony.

According to the architect, all apartments situated on the same vertical line must be equipped with a glazed balcony in order to be water-tight. The only column of 4 apartments where all inhabitants would accept glazed balconies is situated in the middle of the south facade.

Techniques for the reduction of electricity demand were also proposed by the local energy management agency. The demand side management campaign concerned 10 dwelling units (low consumption lighting, avoiding stand by in domestic appliances) among which 5 dwellings are equipped with A class refrigerators. This should reduce the electricity bill in these apartments. The measurements made before the renovation show that electricity consumption varies between 1400 and 5300 kWh/year per apartment according to the equipment in the dwellings and the number of inhabitants. The mean value is 3050 kWh/year, i.e. 33 kWh/year/m2 and 730 kWh/year/person. After an analysis of the different contributions (refrigeration, lighting, washing, etc.), the possible reduction is estimated to be around 1000 kWh/year per apartment as an average value.

According to thermal and economic evaluations, a reduction of the glazing area in the facades was proposed. The inhabitants have been contacted by OPHLM and they are not in favour of such a reduction. A compromise has been found : the glazing area should be reduced by 50% in the north and east facades, adjacent to the bedrooms, and by 20% in the south and west facades, adjacent to living rooms and kitchens.

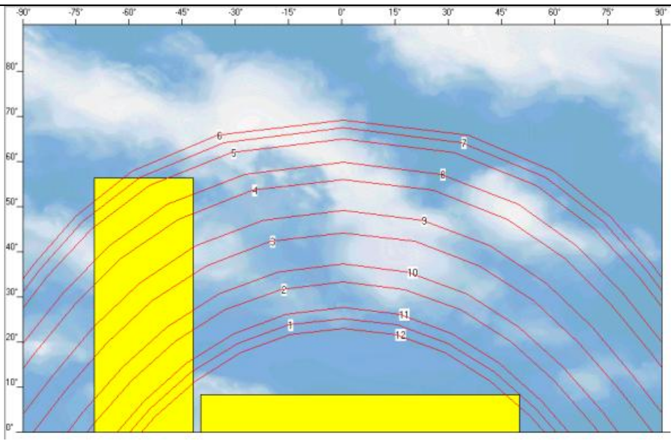
Taking the tenants opinions, technical, environmental and financial aspects into account makes this design activity more complex, but a more satisfactory result is achieved.

2.2 Design study

2.2.1 Site analysis

The studied building is situated on the northern side of an open space, which allows a high level of solar exposure of the south façade (see the following pictures).

The solar path diagram (see right figure) shows the position of the sun in the sky in terms of its azimuth (horizontal axis) and height angle (vertical axis). The neighbouring buildings are drawn on the diagram, their azimuth being obtained using a compass and the height angle using a clinometer or evaluating the height in terms of the number of storeys (see section 1.2 for more details).

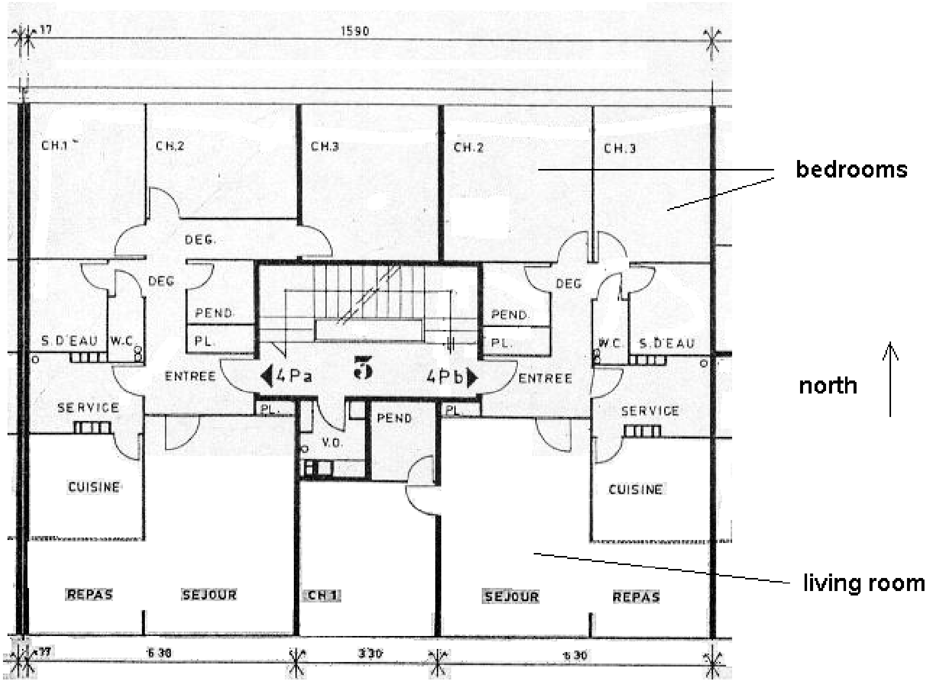


The neighbouring buildings obstruct solar radiation during only limited time, the shading being more important at the ground level compared to the roof level.

REGEN LINK building before renovation (left)

Neighbouring buildings (east and south)

The organisation of the dwellings is also adapted to the use of passive solar gains : the living rooms are facing south and the bedrooms, heated at a lower temperature, are on the northern side (see next figure).



Plan of 2 typical dwelling units

2.2.2 Choice of technical measures

Energy efficient renovation combines energy efficiency and integration of renewable energy systems, regarding both the envelope and equipment, see next table.

	Energy efficiency	Renewable energy systems
envelope	Thermal insulation (walls, floor, roof, glazing) Reducing thermal bridges (foundations, slab perimeter, partition walls, roof perimeter, window frames…)	Integration of solar collectors Sunspaces, glazed balconies Double skin facades
equipment	Ventilation (heat recovery, moisture control) Lighting (low consumption) Heating and domestic hot water (condensing boiler, district heating…) Low flow rate sanitary equipment	Solar domestic hot water Photovoltaic systems Biomass Wind energy

Renewable energies were not supported by the Greater Paris Area Region when the project has been designed. Therefore it was difficult to integrate these technologies in social housing, for economic reasons. The heating equipment (district heating) is considered well suited for energy efficiency, and it is hoped that the heat production will be improved in the future (e.g. replacing fuel and coal by biomass).

The lighting equipment is chosen by the residents. Sensibilisation activities have been performed by the local energy agency (MVE) to promote low consumption lamps and domestic appliances.

The following technical measures have been chosen :

- Improved insulation
- advanced glazing
- humidity-controlled ventilation
- air preheating in glazed balconies
- Solar water heaters
- low flow rate sanitary equipment

An alternative to the preheating of ventilation air in glazed balconies would have been heat recovery on exhaust air. This would have required a lot of air pipes in the dwelling and at this solution has been rejected at that time (1998). This solution would have been further studied at the present time (2006).

2.2.3 Thermal simulation study

A thermal study has been performed in order to :

- evaluate the thermal performance before and after renovation,
- design an improved renovation plan with the objective to reduce the heating load by 25% compared to the standard renovation initially planned,
- select appropriate techniques (e.g. insulation, glazing) to minimise the heating load,
- evaluate the comfort level in glazed balconies and in the dwellings.

The thermal simulation tool COMFIE has been used. The building has been modelled in 9 zones, in order to account for different thermal behaviours in the ground floor, 4 orientations with a distinction between the upper level apartments, in which supplementary losses occur through the roof, and other storeys.

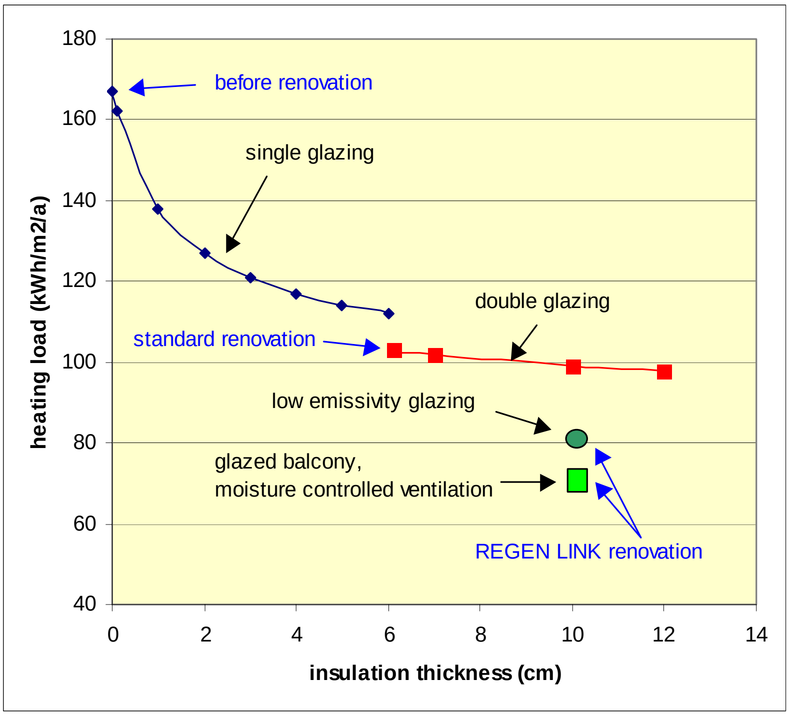
Data on the performance of innovative glazing has been collected from 3 different manufacturers in order to compare various products.

The glazing types have been chosen in order to find the best compromise between thermal insulation and solar gains, within the cost limit of the project. Low emissivity double glazing has been chosen, with a hard coating layer for the south facade in order to keep a high solar transmittance and a soft coating on the other facades in order to lower the U-value. In fact, the contractor in charge of replacing windows is a subsidiary of Saint Gobain, and this manufacturer has stopped the production of hard coating type low emissivity glazing. Soft coating has therefore been implemented on all facades, except in the glazed balconies which are built by another contractor. Argon filled glazing is tested in the north oriented windows of 4 apartments.

According to thermal and economic evaluations, a reduction of the glazing area in the facades was proposed, but the residents were not satisfied with this proposal because they like clearness in the apartments. As compromise it has been proposed to reduce the glazing area by 50% in the north and east facades, adjacent to the bedrooms, and by 30% in the south and west facades, adjacent to living rooms and kitchens.

Thermal calculations have been performed in order to evaluate the variation of heating load in terms of the glazing area. The heating load is reduced by 5% if the glazing area is reduced by 50% in the north façade and by 30% in the west façade, but it is increased by 2.5% if the south oriented glazing area is reduced by 30%. After a second negotiation with the inhabitants, the glazing area in the south and west facades is reduced by 20% instead of 30%. This should lead globally to a minor decrease of the heating load.

The heating load of the project has been evaluated before renovation, after a standard renovation, and considering various alternatives (increased insulation thickness, innovative glazing, preheating of ventilation air in glazed balconies, moisture controlled ventilation). The results are presented in the graph below. The heating load is expressed in kWh per square meter, in terms of the insulation thickness and other characteristics.



Space heating load in terms of renovation measures

The heating load before renovation is estimated about 170 kWh/m2/a. The measured energy consumption varies between 120 and 180 kWh/m2/a in terms of the year. Measured yearly degree days allow to correct the evaluation in terms of the real climatic data. In the calculations, a typical meteorological year (test reference Year) is used. The temperature in the dwellings is assumed 21°C, but in fact it is lower in the north oriented bedrooms, and this could explain part of the discrepancy between calculated and measured heating loads. Also, the ground floor may be heated for cultural activities during some periods.

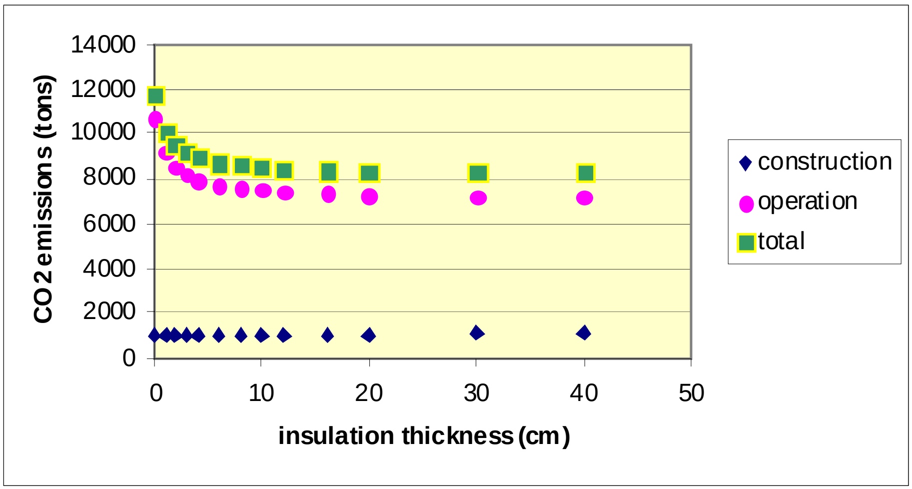
The standard renovation consists in applying an external insulation layer (6 cm thick) and replacing the single glazed windows by double glazing. The curve above shows the very important reduction of the heating load from 0 to 6 cm insulation thickness. Including the replacement of single glazing by double glazed windows, the resulting heating load is around 100 kWh/m2/a. When increasing the insulation thickness from 6 to 12 cm, the variation is less important. Increasing the insulation thickness above 10 cm would require a different structure, e.g. using larger aluminum fixing. This would lead to a much higher cost with a low reduction of the heating load, and it would be counterproductive as a demonstration project. Therefore a 10 cm thickness has been adopted. Various types of insulation have been compared. Panels have not been chosen because they are more difficult to install and, particularly for polyurethane, a special flammability test is required.

2.2.4 Influence of the insulation thickness on life cycle performance

The previous graph shows that the influence of the insulation thickness on the heating load is small beyond 10 cm, which constitutes an economic optimum because a more expensive structure would be needed for a higher thickness.

But does the economic optimum also correspond to an environmental optimum ? To answer this question, the life cycle assessment tool EQUER has been used (see section 2.3). The next graph shows the influence of the insulation thickness on greenhouse gases emissions (GHG).

The variation of the heating load induces a variation of CO_2 emissions corresponding to the operation of the building, accounting for the district heating system. The energy mix for the district heating is 70% coal, 12% fuel, 5% gas and electricity in summer (78% nuclear, 14% hrydro-electricity and 8% coal and gas thermal plants). This mix leads to a GHG emission factor of 343 g CO_2 per kWh.



LCA results using EQUER : greenhouse gases emissions in terms of wall insulation thickness

Because operation related emissions become rather steady beyond 10 cm but the emissions corresponding to the fabrication of the material are proportional to its thickness, there is an optimum like for costs. The optimum thickness corresponding to this environmental criteria is higher than the economic optimum, but the curve is very flat between 10 and 40 cm.

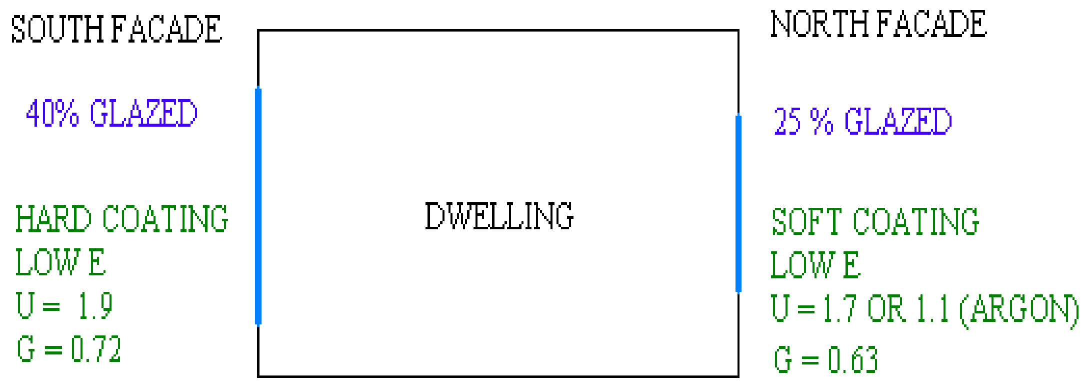
View of the building site, implementing the external insulation

2.2.5 Study of the glazing area and type

It is proposed to replace the planned standard double glazing by low emissivity glazing, using different types according to the orientation of the facades. The performance of these glazing types, provided by the manufacturer (Saint Gobain Vitrages) are indicated in the table below.

Facade	Type of glazing	U value (W/m2/K)	Solar factor
South facade	EKO PLUS	1.9	0.72
Other facades	PLANITHERM FUTUR	1.7	0.58

The EKO PLUS glazing includes a hard low emissivity coating. Its U-value (i.e. the thermal losses) is a little higher compared to a soft coating low emissivity glazing, but its solar factor is higher. The use of this type of glazing in the south facade leads to a higher net energy gain. On the other facades, the incident solar radiation is lower and the priority should be given to the thermal insulation (lower U-value) even if the solar factor is lower.

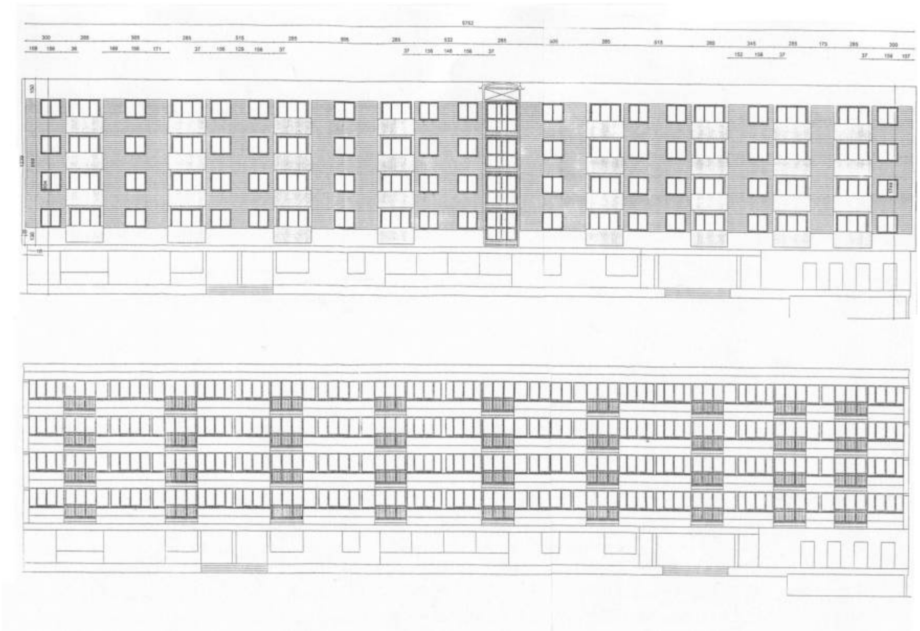


Actually, Saint Gobain Vitrages had just stopped the production of hard coated glazing, so that Pilkington glazing has been used in the glazed balconies.

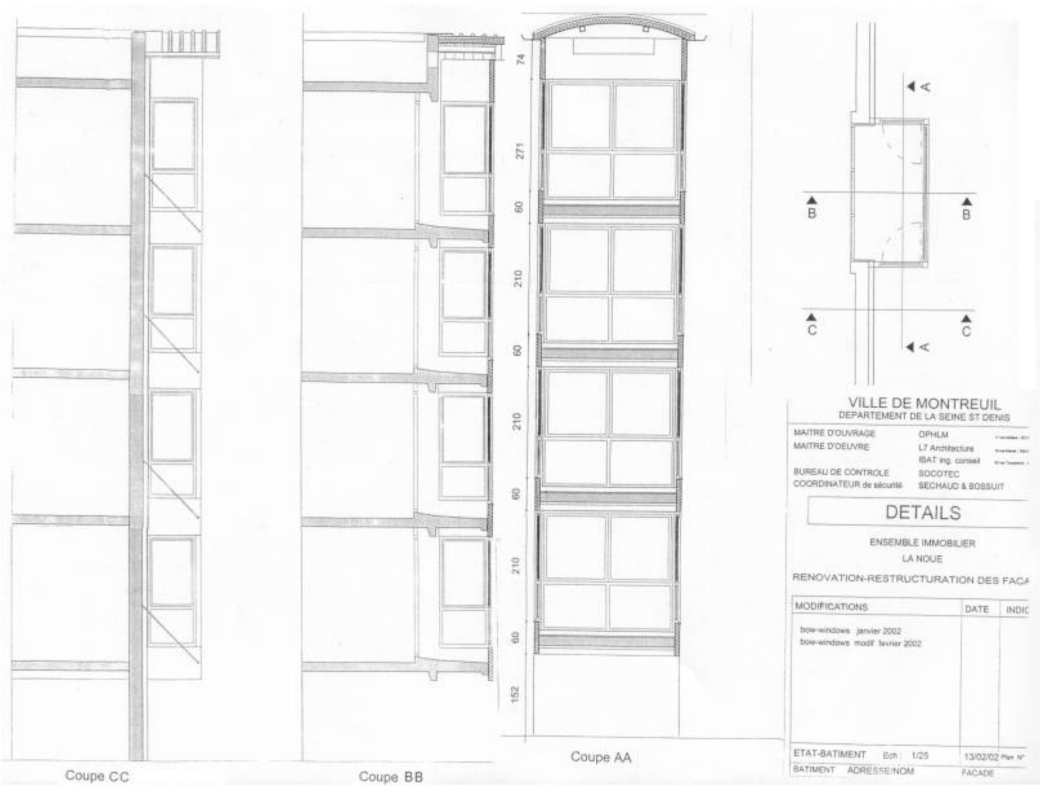
2.2.6Solar preheating and ventilation control

In some of the dwellings, preheating of ventilation air in glazed balconies has been implemented. After the tenants survey presented above, a set of 4 apartments has been selected where these balconies can be constructed. These glazed balconies have been designed by the architect in charge of the project, Mr. Serge Constantinoff (Ligne 7 Architecture).

The architect’s sketch is shown below.



façade of the building (above), and glazed balconies (below) Architect : Serge Constantinoff (Ligne 7 Architecture).



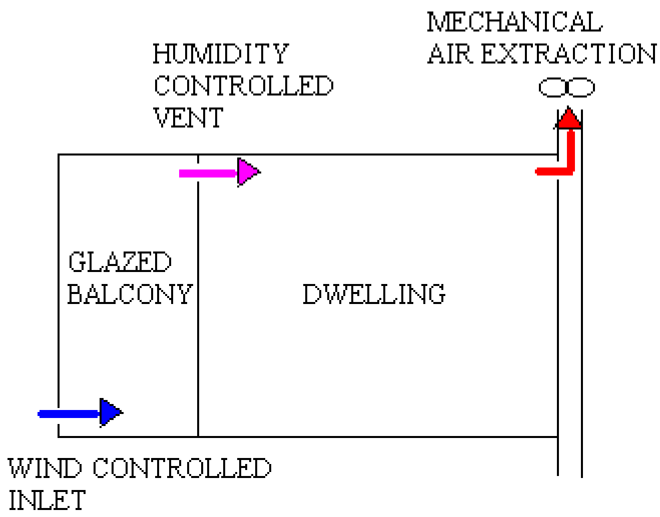
A planning permission has been obtained for the standard renovation project. An extension had to be asked for glazed balconies.

The type of glazing in the glazed balconies has been selected after a sensitivity study using multizone simulation. A thermal zone corresponds to the glazed balconies, another one represents the south facing living rooms and a third zone the north facing bedrooms. Three types have been compared : a standard double glazing, a low emissivity glazing with soft coating and with hard coating. The U-value of the hard coating low emissivity glazing is a little higher compared to soft coating, but the g value (total solar transmittance) is higher, leading to a slightly better performance. This type of coating was thus chosen.

One advantage of glazed balconies is to reduce the thermal bridges through the concrete floor slab : this slab transmits the heat from the dwelling to the outside, and this heat is trapped if the balcony is glazed.

The glazed balconies include air inlets in order to preheat ventilation air before it flows into the dwelling.

A moisture controlled ventilation has been installed between the glazed balconies and the living room (see next figure). In each dwelling, there are two moisture controlled air inlets from the balcony to the dwelling, and 3 moisture controlled outlets (kitchen, bathroom, WC).



Preheating of ventilation air in a glazed balcony

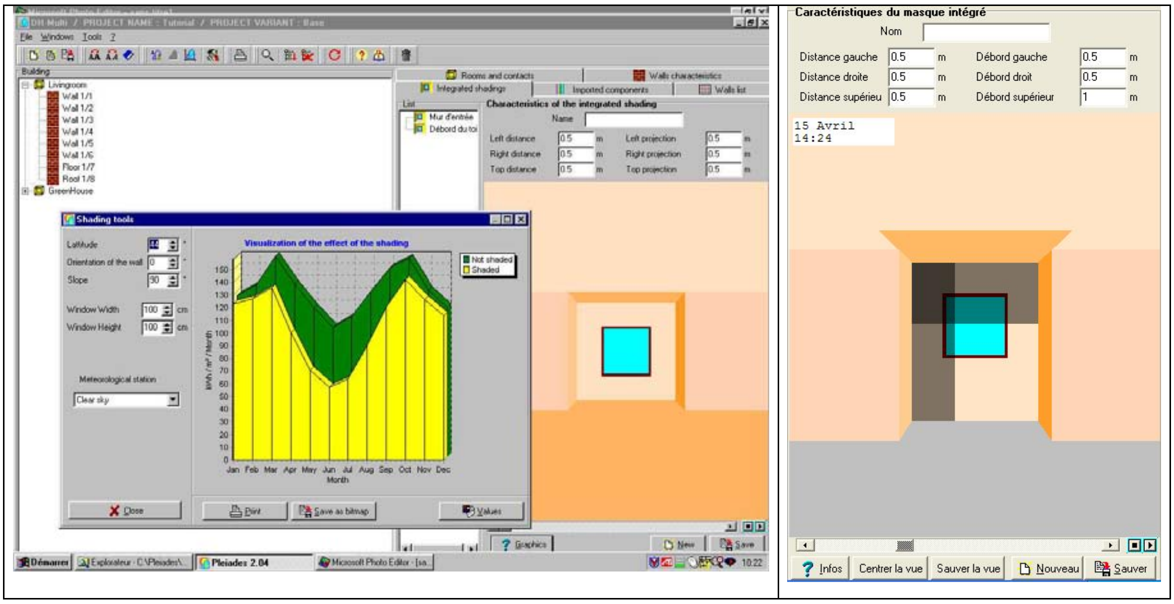
Moisture controlled air vents have been proposed so that the air ventilation is lowered if the inhabitants are not present, thus reducing the heat losses. We assumed in the calculation that the flow rate is reduced by 60% when inhabitants are absent (this corresponds to an information from a manufacturer, ALDES). We consider that inhabitants are absent during 8 hours (which might be different in the reality, because some inhabitants are retired or unemployed). In this case, the mean ventilation air exchange rate considered is 0.48 ach instead of 0.60 for a standard mechanical ventilation.

In the apartments, the fresh air inlet aperture is controlled according to the wind speed : a high wind speed induces a high pressure on the opening, which pushes a plate that reduces the flow section, keeping the flow at a constant rate.

In the case of glazed balconies, the flow rate of preheated air is estimated by the following method. 9 living rooms and 3 bedrooms are facing south for each storey. The air flows into the living rooms through the balconies, whereas the air entering the bedrooms flows directly from the outside. The health regulation imposes certain flow rates in terms of the number of rooms and sanitary rooms in each dwelling. According to these regulations, we consider a flow rate of 600 m^3/h through the balconies to the south zones, 180 m^3/h from the outside to the south zones (south oriented bedrooms) and 750 m^3/h from the outside to the north zones (north oriented bedrooms) for each storey. The air renewal rate is thus 0.52 ach by mechanical ventilation, and the total air renewal, including infiltration, is estimated 0.6 ach, of which 0.2 ach is preheated through the balconies.

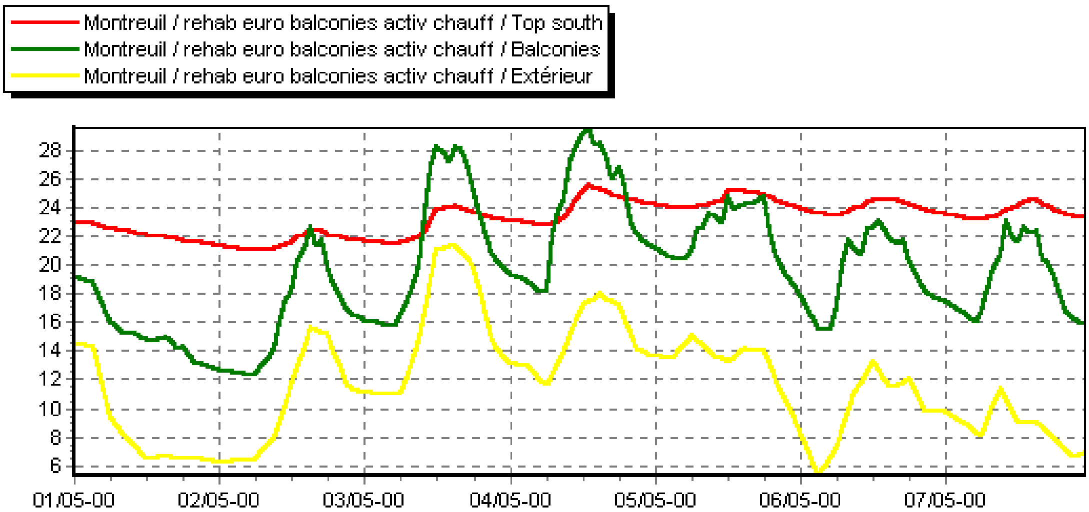
In these apartments, the north facing windows are equipped with low emissivity argon filled glazing (with a 16 mm air gap between the glass panes instead of 12 in the other apartments). The thermal properties of such glazing, according to the manufacturer (SAINT GOBAIN), are the following : U = 1.1 W/(m2.K), solar factor = 0.58.

The corresponding heating load is estimated 71 kWh/m²/year (for the same window area as before renovation). In such glazed spaces, it is essential to assess the comfort level in summer and mid-season. Shading created by overhangs formed by the balconies over the living room windows, and shading devices have been modelled.



Effect of shading on incoming solar radiation through a window, monthly values of incident and transmitted radiation (software PLEIADES).

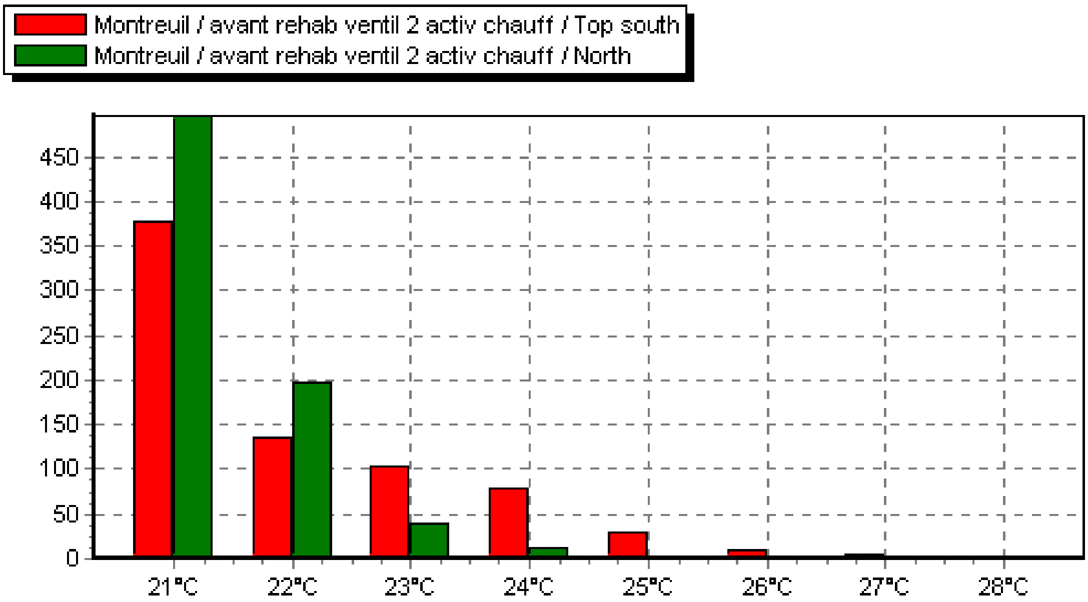
The estimated temperature profile at the beginning of May (typical year) is the following.



Temperature profile (outdoor, balcony and living room) during a typical week in May

The estimated overheating shows the necessity, during some sunny periods in mid season, either to close the air vent between the balcony and the living room and to open another one directly from the outside, or (which is simpler) to ventilate the balcony. In this configuration, the temperature profile is nearly identical to the profile obtained without glazed balcony, with a maximum temperature of 25°C.

Temperature histograms present a good picture of the thermal comfort, by indicating (vertical axis) the number of hours during which the temperature corresponds to the values of the horizontal axis.



Temperature histogram for a typical summer

In this example, assuming that solar protection (external roller blind) is properly used and that windows are open at night, the temperature in the north oriented rooms remain under 25°C and in the south rooms temperature is below 28°C.

The following picture shows the construction of the glazed balconies.

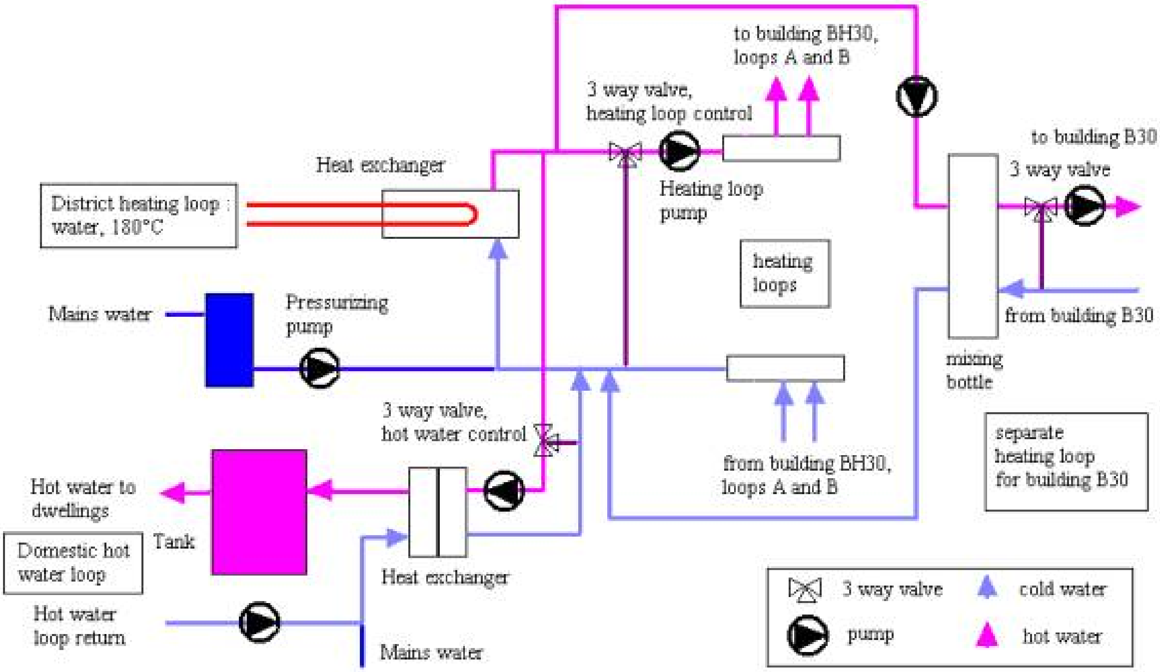
Glazed balconies

The cost of one unit is 9,000 €. Possible industrialisation of the process is studied further to reduce this cost.

2.2.7 *Modification of the heating loop*

Before renovation, the considered building was grouped with another building in a single heating loop. A specific loop has been created in order to allow a more precise control of the temperature (see next figure).

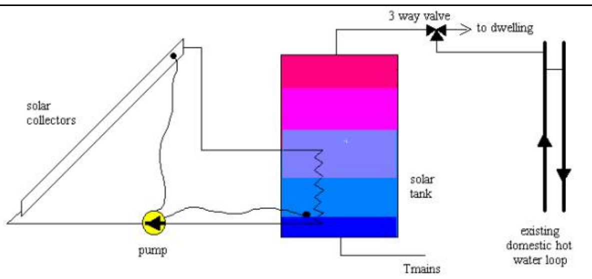
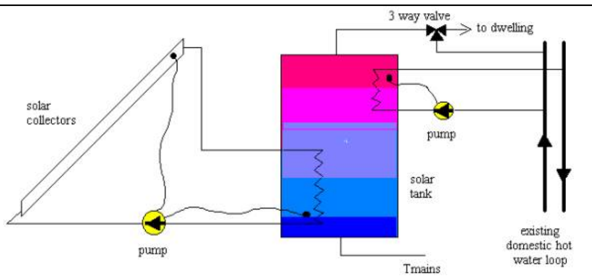
New heating loop (district heating connection)



Heating loop after renovation

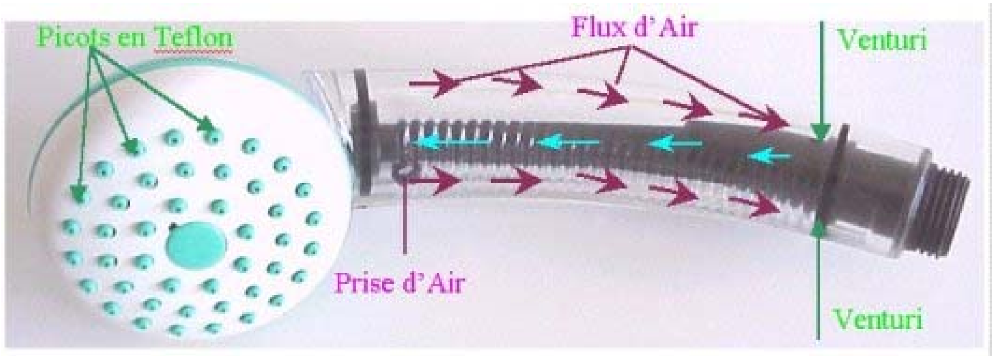
2.2.8 Domestic hot water

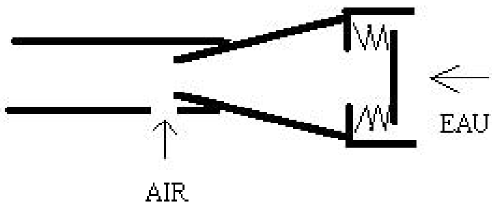
Several possibilities were investigated concerning the solar domestic hot water system. Because no regional support existed at the time the design was performed, no collective system could be afforded. Besides, the district heating exchanger is situated at around 150 m from the concerned apartments, and the heat losses in the pipe would be important. It was therefore proposed to study an individual system. Several possibilities were studied (see next table).

	3 way valve connecting either solar or district heating hot water Problems : the solar system would be connected only if the solar fraction is 100%, i.e. very rarely, there might be a risk of legionella during other periods.
	Back up provided by the hot water loop Problem : the temperature of this loop is around 45-50°C, which is too low for an efficient back up.
Electric back up Problem : both investment and operation costs would be higher compared to the present district heating production	Gas back up Problem : operation cost would be similar but this solution would require a high investment : gas boiler, supplementary ventilation required by safety regulation.

Because no satisfactory solution has been found for the implementation of a solar domestic hot water system, this technique has not been considered in the final design.

Low flow-rate sanitary equipment has been selected. In the shower system, a venturi effect increases the speed of water flow and this provides the same comfort level as a standard shower even if the flow rate is reduced.





Low flow rate sanitary equipment

2.2.9 Use of life cycle assessment

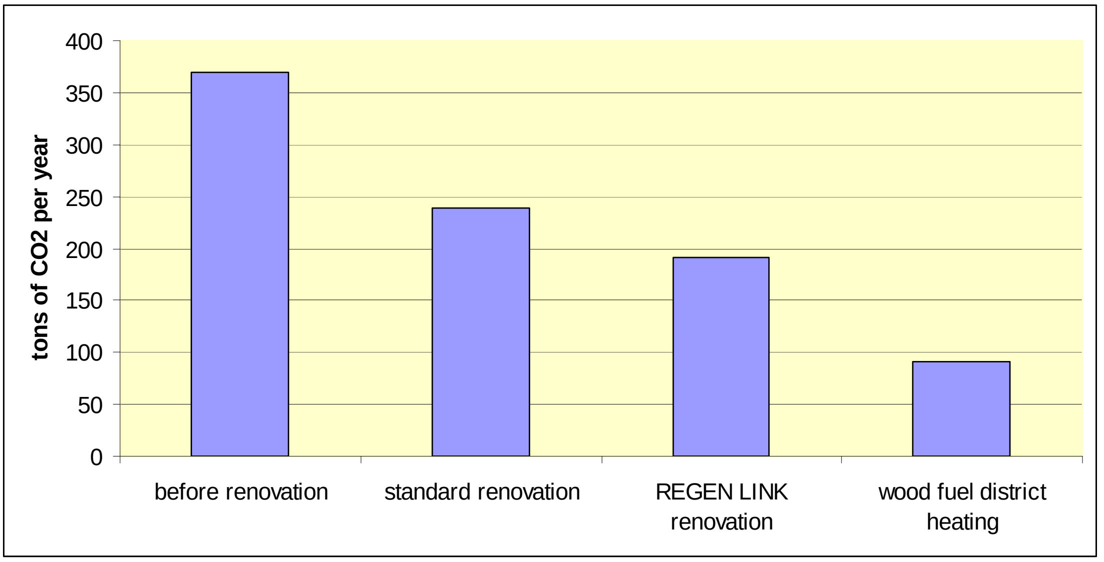
This method consists in quantifying the substances taken from and emitted into the environment (e.g. raw materials, pollutants, waste…), see section 2.3. In a further step, indicators are derived by adding the contributions of these substances to various environmental problems. For instance, the Global warming potential (GWP) corresponds to the climate change issue and it is evaluated by summing the quantities of greenhouse gases using weighting factors defined after the results of the International Panel on Climate Change.

A general framework for the application of LCA in the building sector has been elaborated in the European REGENER project[2] and the EQUER method has been developed according to this framework. This method is presented by Polster[3]. A building is described by a geometry, technical objects (materials, components) and processes (e.g. gas heating, water consumption, waste sorting,…). The heating and possibly cooling loads are calculated using the thermal simulation tool COMFIE. In a second step a life cycle simulation is performed using EQUER. Databases developed by the University of Karlsruhe[4] and the Federal Polytechnic School of Zürich[5] have been considered.

The thermal calculations presented in the previous paragraphs are complemented by LCA using the EQUER software. This LCA study shows how the renovation reduces the potential

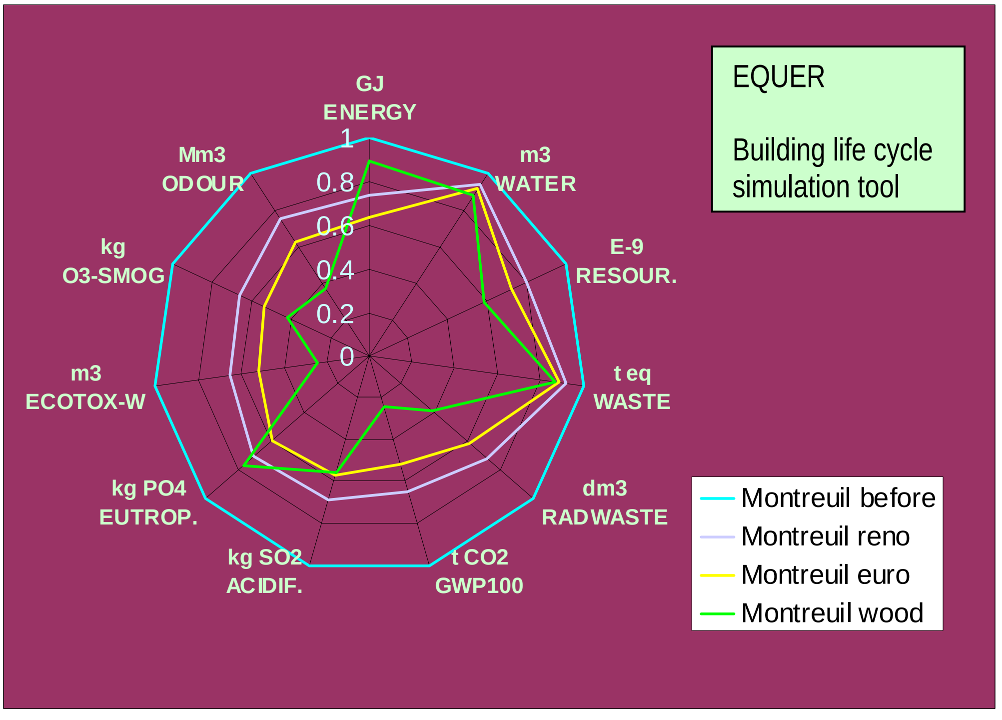
[2] REGENER, 1997, final reports, C.E.C. DG XII contract n° RENA CT94-0033, 563 p
[3] Bernd Polster, 1995, Contribution à l'étude de l'impact environnemental des bâtiments par analyse du cycle de vie, thèse de doctorat, Ecole des Mines de Paris, 268 p.
[4] Kohler N. et al., 1994,Energie- und Sofffluß-bilanzen von Gebäuden während ihrer Lebensdauer, EPFL-LESO / IFIB (Université de Karlsruhe), 221p
[5] Frischknecht R., et al. , 1996, Oekoinventare von Energiesystemen, 3. Auflage, ETH Zürich / PSI Villigen

environmental impacts of the building. The following graphs compare the indicators for the project before renovation ("Montreuil before"), after the standard renovation initially planned ("Montreuil reno"), after the renovation re-designed within the European REGEN LINK project ("Montreuil euro"), and the fourth case corresponds to the use of wood fuel in the district heating system : an alternative has been studied including a 10 MW wood fuel boiler.



Reduction of CO_2 emissions by the renovation measures

The following graph presents a more global picture including all indicators, e.g. the contribution in global warming, energy and water consumption, waste production etc.. Each axis corresponds to one indicator. The case before renovation is considered as a reference and the indicators for the other cases are given in relative values (e.g. the CO_2 emissions are around 50% lower after renovation, 70% lower if wood fuel is used).

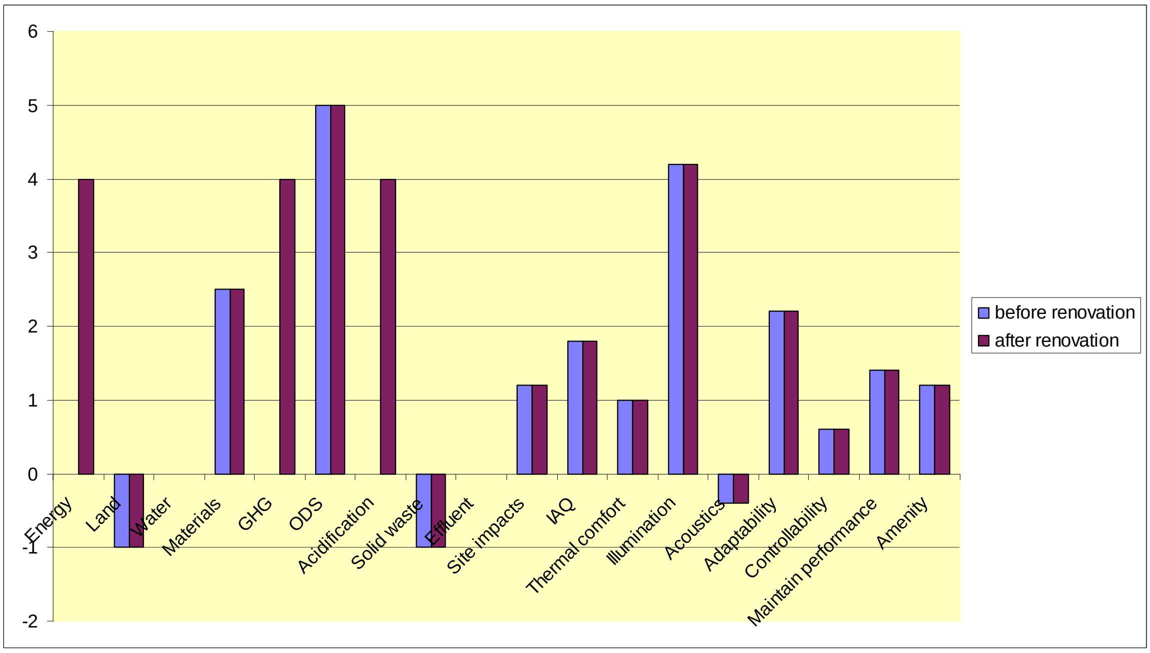


Life cycle assessment results : Reduction of environmental impacts by various renovation alternatives

A modification of the energy performance has a large influence on the life cycle impacts. The combination of thermal simulation and LCA allows an evaluation of the environmental benefit provided by higher quality components, taking into account their effect on the energy performance and the impacts related to the construction and demolition phases. Simpler energy calculations are in some cases not sensitive enough : the error on energy related impacts can be larger than the difference between 2 materials. Another advantage of dynamic thermal simulation tools is the evaluation of thermal comfort : both energy saving and thermal comfort must be achieved.

2.2.10 Use of Green Building tool

The GB Tool combines environmental criteria of a building with issues regarding its urban context. It is thus complementary with the LCA approach presented above. The environmental profile for the same building is given below, comparing the project before and after renovation. Like in the LCA study, the reference considered is the building before renovation. The criteria are rated between -2 and +5.



GB Tool results for the building before and after renovation

The renovation studied here concerns the building and not the urban level, so that most indicators are identical before and after renovation :

- the 4 storeys building is surrounded by empty spaces (sport space, greens and square), so that the land use per inhabitant remains high,
- the water use and effluent is typical, the area dedicated to waste sorting is low because no waste sorting is organized yet by the municipality,
- the ODS indicator (ozone depletion) is very high because there is no air conditioning, the material indicator is average (the renovation is better than a new construction but few recycled materials are used), the site impacts are limited, though the neighbouring buildings are sometimes shaded),
- the indoor air quality is average, the illuminance is very good because of the high glazing area, the thermal comfort is high because of the high thermal mass, solar protection and

cross ventilation but the indicator is rather low because there is no humidity control (though measurements show that the humidity remains naturally within comfort conditions), there is no noise attenuation between dwellings so that the acoustic indicator is weak,

- the central heating system allows little individual control ; adaptability, maintenance performance and amenity are rather average,
- three indicators are largely influenced by energy (greenhouse gases -GHG-, primary energy and acidification) and are greatly influenced by the renovation.

The weak points are :

- the use of land

There are large green spaces between the buildings, leading to a high land consumption ; but this contributes to improve the external environment and quality of life.

- solid waste

Sorting and collecting domestic waste is planned by the municipality.

- Acoustics

There is little noise around the buildings. The external insulation layer and double glazing should improve the acoustic performance, but the noise transmission from a dwelling to another should remain the same. This may explain the poor score, but there should have been a difference between the score before and after renovation : may be the weighting factors considered in this version of GB tool are not optimal.

- Thermal comfort

The heavy concrete masonry leads to a high thermal mass and this should improve the thermal comfort. Though, the score on thermal comfort is low due to the absence of humidity control system. May be the GB Tool gives too much emphasis to this aspect compared to the temperature.

2.3 Description of the performance of the monitoring/measuring system

The one year monitoring aims to study the energy performance of the building concerned by the REGEN LINK project (named “B30”), and also the level of thermal comfort in the apartments.

Climatic data

Measurement of climatic data has been performed on the terrace roof of the building : two platinum sensors, protected from solar radiation by a ventilated envelope, have been used to measure the external air temperature. Two first class pyranometers have been used to measure the global horizontal and vertical south solar radiation (EC guideline 89/336/EC, in conformity with standards EN-50081-1 and EN-50082-1). Using these two measures, the diffuse radiation can be estimated, allowing hourly calculations of solar radiation on all facades. External relative humidity has been measured using a Hobo sensor.

detailed monitoring of the project

The energy consumption of the building is measured using heat meters in the district heating sub-station. The space heating energy consumption depends on the building envelope, but also on the behavior of the inhabitants, who can act on the radiators taps, ventilation, and internal gains. In order to allow interpretation of the results, the temperatures in the dwellings are measured, in the south and north oriented parts separately because of the structure of the apartments.

Measurements have been performed in three apartments : one “Regen-Link” and two “improved Regen-Link” renovation type, i.e. including glazed balconies and argon filled double glazing. The renovation project concerns an occupied residential building. Therefore, it was not possible to insert wires in the walls. Visible wires would not be acceptable by the residents. Thus, wireless sensors have been chosen and installed in various places in the dwellings : the living room facing south, one bedroom facing north and when relevant in the glazed balcony. We have chosen "thermo-buttons", in which temperature measurements can be stored for a period of e.g. 3 weeks using a 15' time step.

data acquisition

The temperature measurements performed in the dwellings are stored locally during 3 weeks and collected on a portable PC during periodic on site visits. Several sensors can be installed and programmed in order to increase the storage duration to e.g. 1.5 month. Climatic measurements are collected on a data acquisition system, then collected on a portable PC.

Interpretation of the measures and performance checking

The monthly energy balances have been used to check the performance by comparing design calculations and measurements. Advice has been derived concerning the heating loop temperature control.

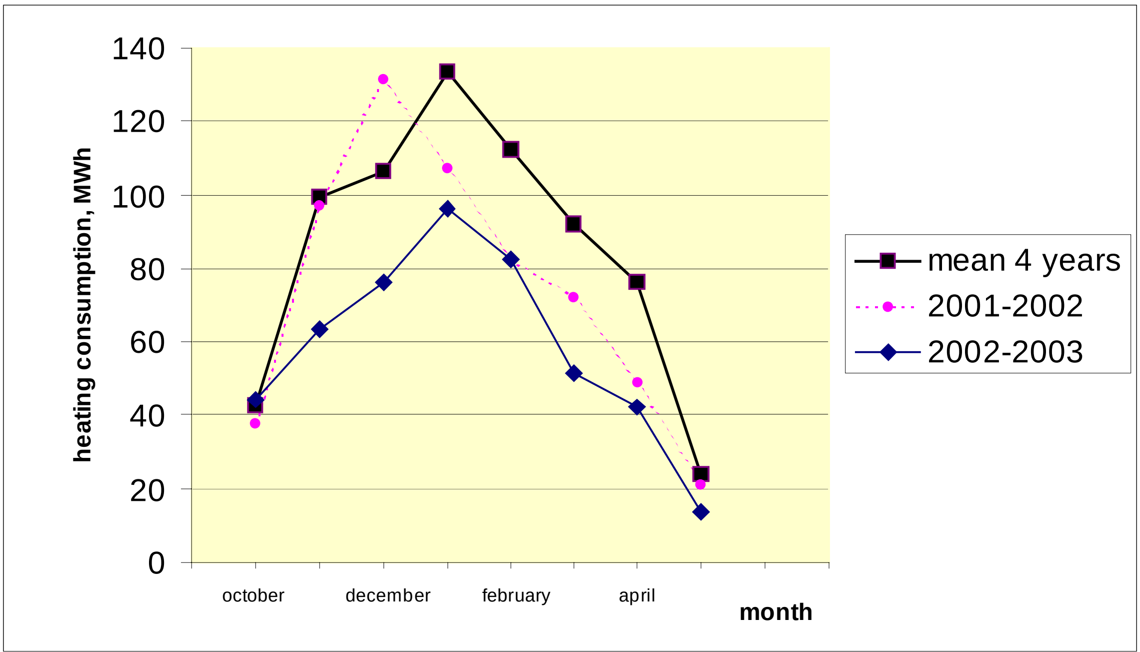
Enquiry has been performed in order to know the opinion of the inhabitants about the thermal comfort, how they use the glazed balconies (connecting door between the balcony and the living room, summer-winter position of the ventilation, etc.), if there is any consequence of the renovation on acoustic comfort, quality of life, social aspects.

3. Operation and results

3.1 Operating History

View of the building after renovation

The monthly energy consumption for space heating is measured, and the values before and after renovation can be compared, see next graph.



Monthly energy consumption for space heating before (4 years average) and after renovation (2002-2003)

The reduction of the annual energy consumption has been 32%, which is lower than the estimated 50% reduction. The reasons are probably the following. After the renovation of the building, the monitoring has shown that the indoor temperature was higher than before renovation : 22-23°C instead of 19-20°C. The heating loop temperature has been decreased in order to adapt it to the lower heating demand of the building. It seems that this temperature should be further decreased because tenants report a too high indoor temperature.

Some of the tenants complain because they feel cold, though a 23°C temperature is measured in their dwelling. This feeling is due to a lower temperature of the radiators : the heat demand of the building being lower, the heating loop and thus the radiator temperature is lower. The tenants might have the impression that the radiator does not function well. An information activity is needed. Such sociological problems explain that OPHLM is not willing to decrease too much the heating loop temperature. Nevertheless it was decided to progressively decrease temperatures in the dwellings, e.g. by 0.5°C every 6 months.

Other reasons that could explain the higher consumption are :

- the occupancy of the ground floor, more educational activities have been organised after the renovation of the building, leading to additional energy consumption (+25% estimation),
- some tenants open the windows during a long period (e.g. 2 hours each morning in the bedrooms) : some information and sensibilisation activities had to be performed in order to promote a more energy-responsible behaviour,
- rather high values of thermal bridges have been considered in the calculations even for the building after renovation because insulation is interrupted near the slab between the ground floor and the first floor, around the roof, around windows and in the balcony slab. Therefore it does not seem that thermal bridges can explain the discrepancy between the measured and the calculated consumption.,
- The considered ventilation flow rate corresponds to the mechanical ventilation characteristics, accounting also for air infiltration. But this last term should be small thanks to the new air tight windows and solid concrete walls.

If we correct the measured value to account for this bias, we obtain a 50% reduction after renovation, leading to a 70 kWh/m^2/y heating energy consumption.

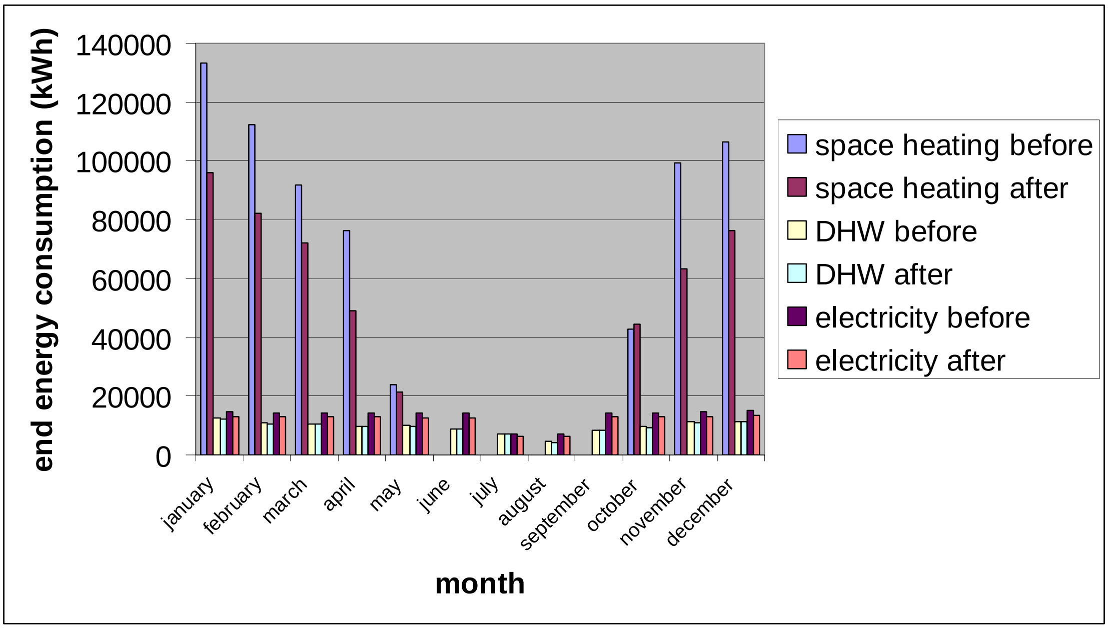
3.2 Performance

3.2.1 Global energy balance of the project before and after renovation

	space heating	domestic hot water	electricity
cost (euro/kWh)	0,046	0,046	0,11
annual final energy consumption before renovation (kWh/m2)	150	23	32
annual final energy consumption after renovation (kWh/m2)	100	23	29

energy saving (%)	32	1[6]	10
Final / primary energy ratio	1	1	2.58
annual primary energy consumption after renovation (kWh/m2)	100	23	76[7]

Monthly results are shown in the graph below, including final energy for space heating, domestic hot water (DHW) and electricity.



Measurements of the electricity consumption were performed. In the 50 measured units, this consumption varies between 1,350 and nearly 7,000 kWh/a, with a mean value of 3,100 kWh/a. This consumption (30 kWh/m2/year, or 730 kWh/person/year) corresponds to the order of magnitude of the national average value. The electricity consumption depends on the number of occupants and on their life style (domestic appliances,…) and less on the design of the building.

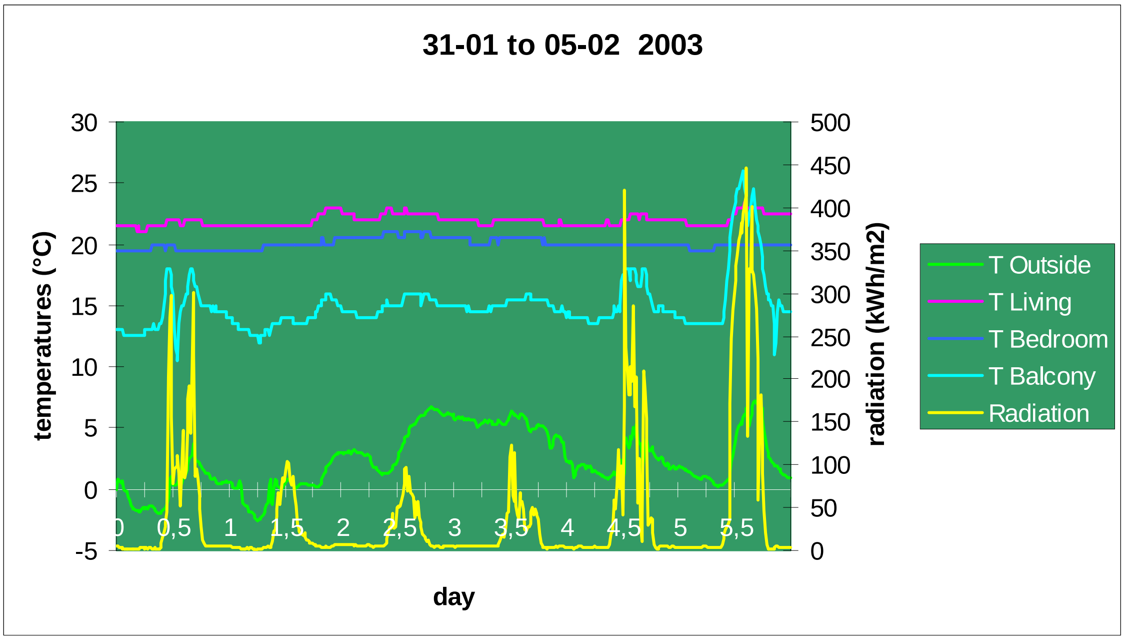
The refrigerator contributes by 40%, lighting corresponds to 10% as well as television, washing machines 7%. The electricity consumption could be reduced to around 2,000 kWh/year/dwelling using energy efficient appliances and lighting. But this reduction is related to the choice of the inhabitants and not to the renovation work performed. The renovation project has been complemented by a sensibilisation campaign performed by the local energy agency.

In the building sector, comfort is an essential parameter in addition to energy performance. Also, the performance is related to the indoor temperature. It is thus essential to measure this parameter. Example temperature profiles are given below.

3.2.2 Indoor temperature in winter

The following graph corresponds to an apartment with a glazed balcony, and a typical winter period.

6 Only 4 apartments were equipped with low flow rate sanitary equipment
7 including lighting and domestic appliances

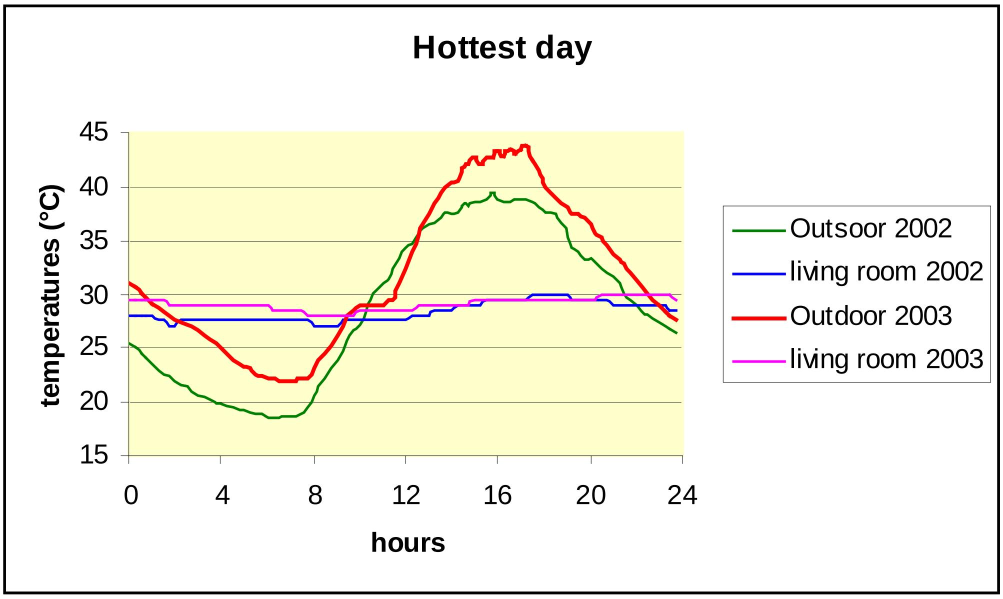


Measured temperatures and solar radiation during a typical winter period

The bedroom radiator is sometimes closed, because this bedroom is not always occupied. Its windows may sometimes be opened to ventilate the room. On the other hand, the living room is often overheated. The temperature in the balcony is much milder than the outdoor temperature.

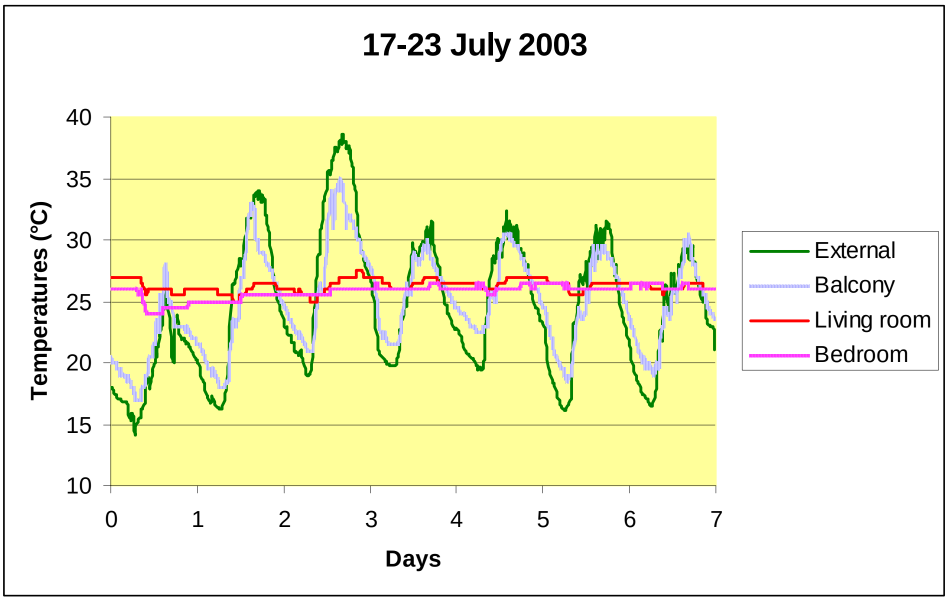
3.2.3 Thermal comfort in summer

Measurements have been performed regarding the thermal comfort in summer in the apartments. The following graph shows the temperature profile during the hottest week of the summer 2002, and a week with a similar outdoor temperature in 2003. The external temperature was higher than in the hottest week of 2002, but the inside temperature is the same. The improved insulation of the building and the high thermal mass helps to protect from overheating : with a 40°C external temperature, the indoor temperature remained below 30°C. This graph shows that the renovation has also maintained thermal comfort in summer.



Hottest day, with balcony (2003) and without (2002)

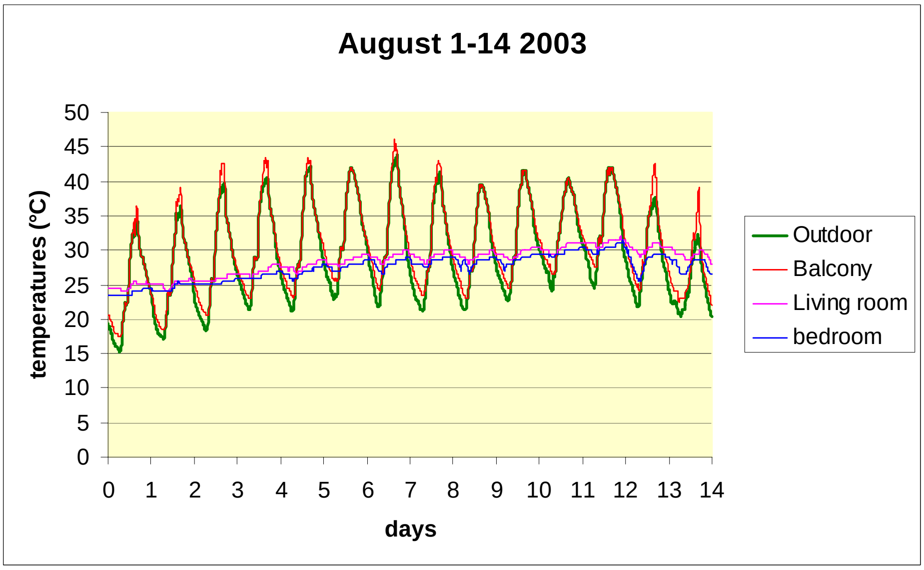
The following graph shows the temperature profiles in an apartment with a glazed balcony, during a typical summer week



Typical summer week

The balcony is generally ventilated and its temperature is near the external ambient temperature. The dwelling temperature remains moderate due to the high thermal mass of the building, the careful management of solar protection by the tenant, and possibly night ventilation.

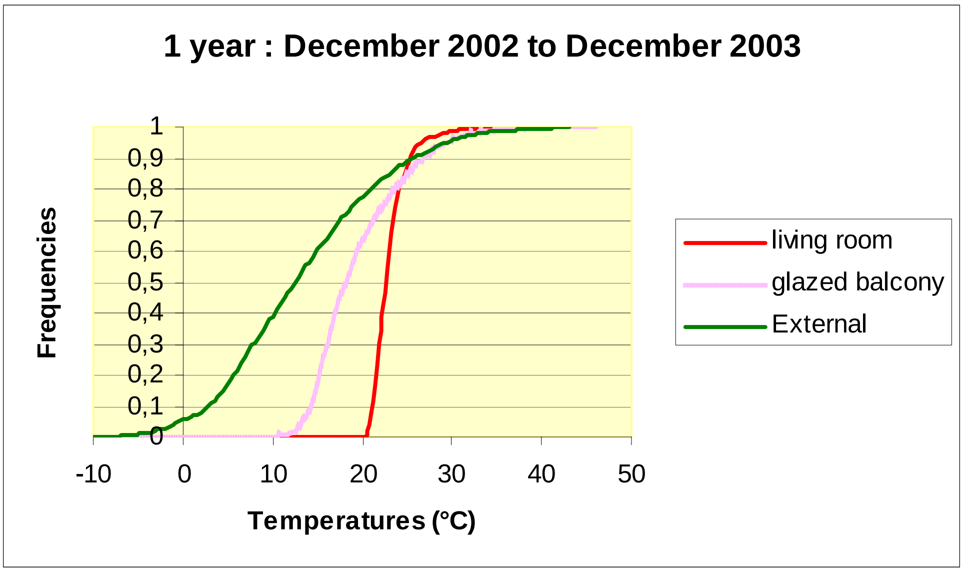
The summer 2003 was particularly hot in Paris, but the temperature in the dwellings remained around 10°C lower than the outside temperature, as is shown on the next graph.



2003 Heat wave in Paris (15,000 deaths in the elderly population)

3.2.4 Accumulated frequency curves

These curves are given below for the external temperature, the temperature in the living room and in the glazed balcony of a dwelling.

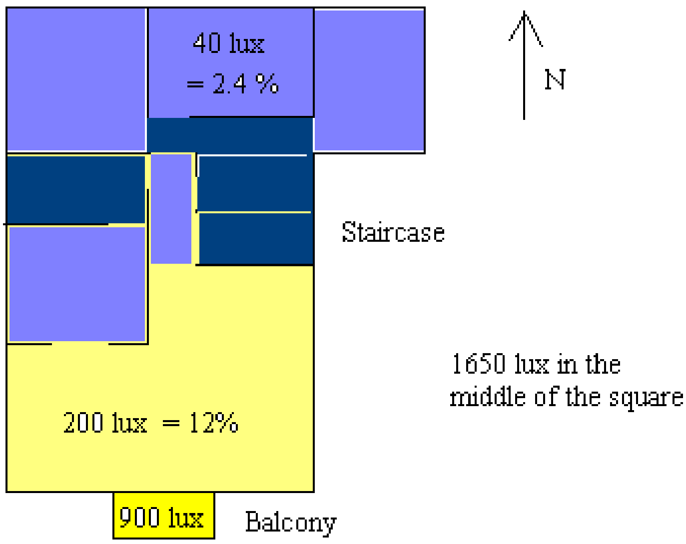


Accumulated frequency curves

For instance, the 50% frequency corresponds to 12°C outside (i.e. the outdoor temperature was higher than 12°C during 50% of the year), 18°C in the balcony and 22°C in the dwelling.

3.2.5Daylighting

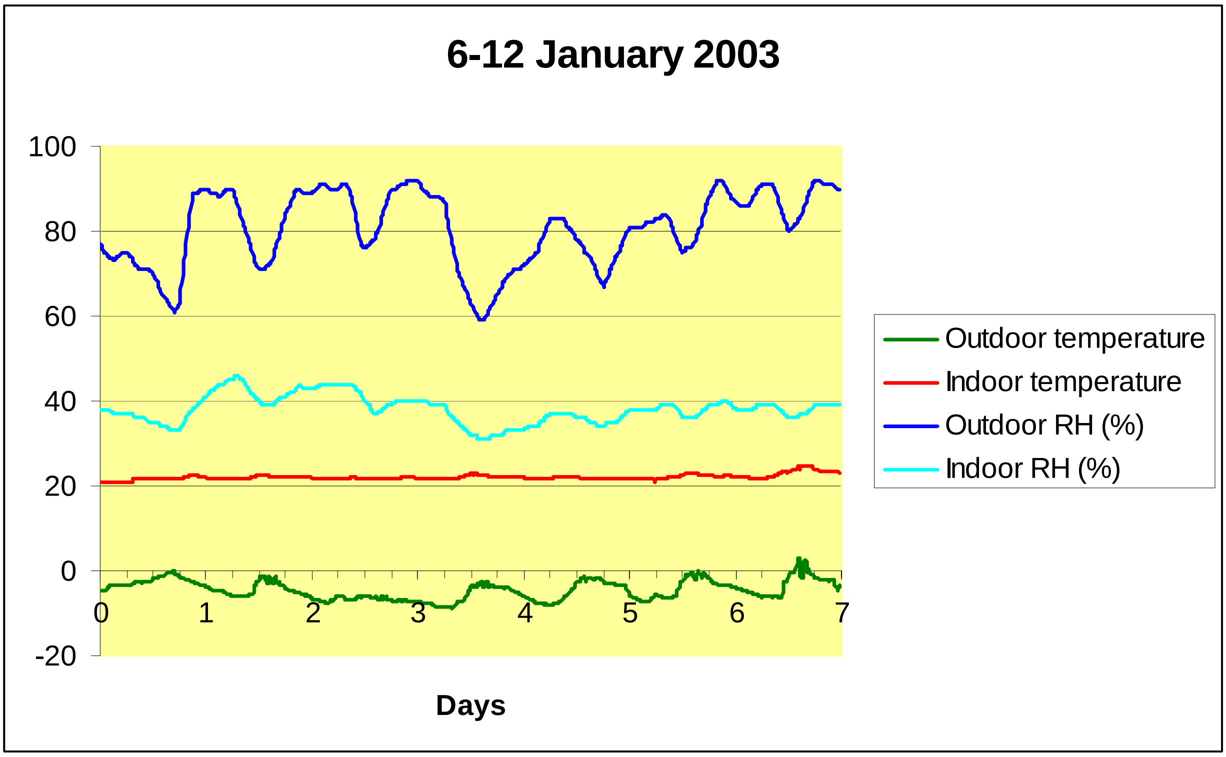
A luxmeter has been used to evaluate daylight factors by dividing the illuminance measured inside a dwelling in different rooms by the external illuminance (diffuse sky). The results are presented in the following graph.



The daylight factor has not been significantly changed by the renovation project : it remains high due to the high glazing area in the facades. This quality is much appreciated by the tenants.

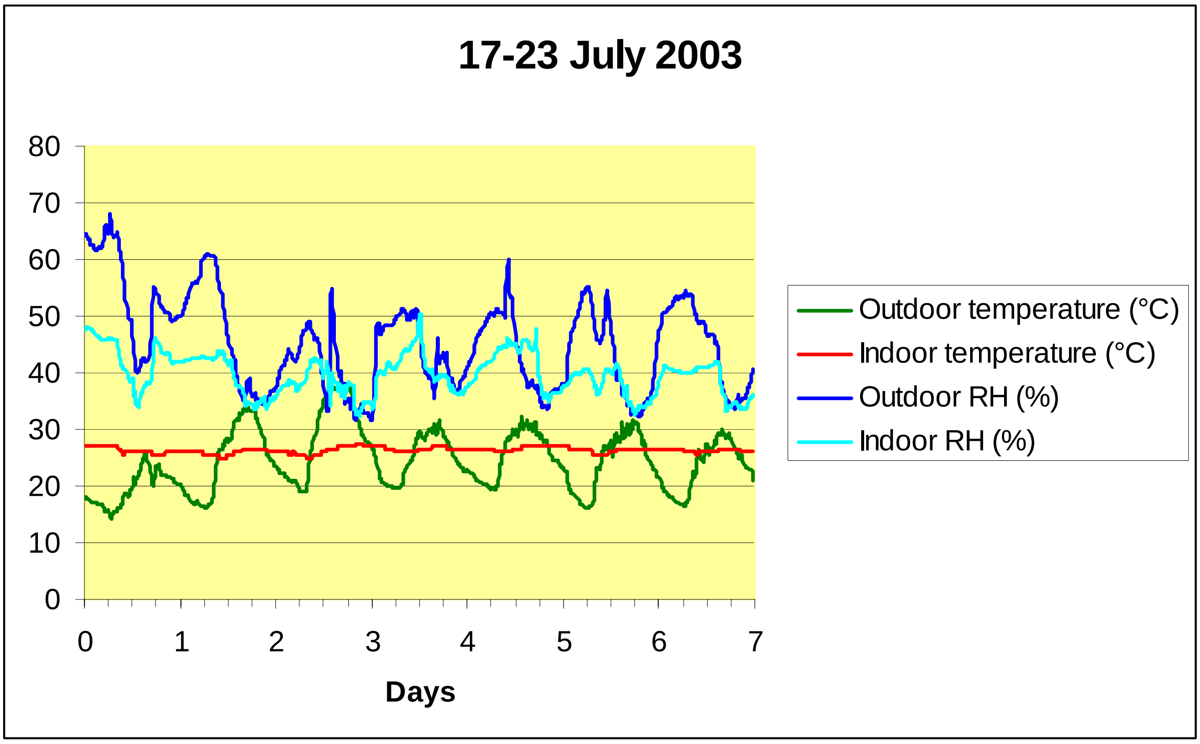
3.2.6 Humidity

In winter, the internal humidity is around 30 to 40% when the heating is on (see next graph). The relative humidity comfort level (30 – 70% interval) is achieved both in winter and summer (measured values between 30-50%) without any control system.



Typical winter week, indoor and outdoor climatic conditions

A typical humidity profile in a summer week is given in the graph below.



Typical summer week, indoor and outdoor climatic conditions

3.3 Success of the project

The project was not very "high tech", because the building is situated in a low income neighbourhood, and because there was no regional support for energy efficiency when the proposal has been elaborated (and presently the regional support remains low compared to other regions in France and in other countries). Despite these unfavourable conditions, the project has shown that important energy saving can be achieved at a reasonable cost (more than 30% and may be higher if the temperature control is improved).

The decision makers in building regulation were very much interested in this result because the climate protection objectives, expressed by the Prime Minister, impose to reduce by a factor 4 the CO_2 emissions by 2050. The poor quality existing building stock constitutes a major problem, and this project gives a better insight about the present technical state of the art.

According to the sensitivity analysis performed using dynamic simulation, the most economical measure is the implementation of advanced glazing. Increasing the insulation thickness, compared to standard renovation, leads to a pay back time of around 20 years because the energy saved by the standard 6 cm insulation layer is higher than e.g. by doubling this thickness.

Low flow rate sanitary equipment is cheap and easy to integrate in such a project. It can also lead to energy saving according to the users behavior. The flow rate in the shower is divided by a factor 2 but the level of comfort remains the same because the water speed is increased by a Venturi effect. This inexpensive technology should be promoted widely. Solar domestic water heating was unfortunately not well adapted to this particular building because of the location of the district heating heat exchanger, and because of the back up energy prices. But it is now more supported at a national and regional level and will be implemented in other projects in the same city.

Tenants survey

Though tenants' opinion is often highly subjective (e.g. feeling cold because the radiator is less warm than before renovation, though the internal temperature is 23°C), it is essential to collect their feedback about the project in order to identify the main success and limits, and to disseminate this knowledge for possible replication.

In general, the tenants are satisfied with the renovation, but some are complaining and the main issues are listed below :

- the rent has been increased,
- the energy expenses have not been reduced during the first year, which may be due to the accounting system, and also because fixed costs haven't been reduced by the district heating company, though the maximal power has been reduced ; these fixed costs are included in a long term contract, and this contract is being re-negotiated,
- due to the façade insulation, the windows are now recessed and some tenants complain because they cannot so easily check their children or car from the window,
- the glazing area has been reduced, particularly in bedrooms,
- the glazed balcony is difficult to manage when the tenant is absent : it cannot be ventilated due to the risk of storm and rain entering the balcony, therefore its temperature can be high and this can damage the plants (the plants and pots are heavy and difficult to move, particularly for an elderly person).

This illustrates the difficulty of implementing techniques in existing buildings, in comparison with new construction. Some techniques are easier to manage (e.g. replacing single glazing by advanced glazing) than others (e.g. glazed balconies).

One success of the project has been to raise awareness among the employees of the social housing company, OPHLM de Montreuil. Other projects have been designed after the REGEN LINK demonstration project, including active solar domestic hot water systems, and higher environmental quality buildings.

The project is part of a pilot project regarding the environmental quality of the neighbourhood. Workshops have been organised by the municipality with the residents, and the energy and water saving measures undertaken in the REGEN LINK project are appreciated, particularly by low income families.

Globally, 23 ton equivalent oil have been saved during the first operation year. This resulted in avoiding the emission of 76 tons of CO_2, and we hope to improve these results in the next years by a better control of the water temperature in the heating loop.

3.4 Operating costs

The project should not have much impact on the operation cost because the maintenance is performed by the same company for the district heating system. The reduced energy consumption reduces the water temperature in the heating loop and could increase the life span of some components, this effect being marginal.

3.5 Future of the installation

The building is owned by OPHLM de Montreuil, and the apartments should be rented during the next 30 years at least. The life span of the external insulation, windows, glazed balconies and district heating loop is expected to be around 30 years.

The heating system may be modified by replacing the radiators, possibly installing a more precise control system allowing the temperature to be more homogeneous in the different parts of the dwellings (particularly south versus north oriented rooms) and in the different parts of the building (e.g. upper floor situated under the roof).

3.6 Environmental impact

Space heating and domestic hot water are provided by district heating, the energy mix being 70% coal, 12% fuel, 5% gas and electricity in summer (78% nuclear, 14% hrydro-electricity and 8% coal and gas thermal plants). This mix leads to a GHG emission factor of 343 g CO_2 per kWh.

The French electricity mix given above leads to a corresponding emission factor of 87 g CO_2 per kWh.

The International energy agency figures are considered concerning the equivalence between 1 MWh heat and electricity, and TEP (primary energy). The results of this simplified environmental balance are given in the next table.

	Energy Savings [kWh/year]	Fuel type [oil, coal or gas]	CO_2 equivalents [tons of CO_2 /year]	TEP / year [Tonne Eq. Petrol]
Heating	217000	District heating	74,4	18,7
Electricity	17000		1,5	4,4
Total	234000		75,9	23,0

The emission of around 76 CO_2 tons is avoided yearly, which corresponds to a 26% reduction of greenhouse gases emissions.

3.7 Economic viability

The total investment cost of the project is 265,000 € (standard renovation) plus 185,000 € (demonstration project), which corresponds to 5,000 € + 3,500€ per dwelling unit. The energy saving leads to save 11,734 € yearly. The maintenance and operation cost should be negligible. As a result, the pay back time is around 16 years.

The commercial pay back time may be somewhat lower, if the implemented technologies become widely spread so that their price goes down.

The service life of the renovated components should be around 30 years, so that their implementation is viable.

The average pay back time is 16 years, but some techniques are more economical than others :

- Low emissivity and argon filled glazing (very economical : 2 years)
- Low flow rate showers (very economical)
- Moisture controlled ventilation (rather economical)
- Thicker insulation (20 years pay back time)
- Glazed balconies (rather uneconomical but appreciated by the residents)
- Solar domestic hot water (no regional support in 2002, which did not allow their implementation, support is now provided by the region).

4. Lessons learned

Some limits have been identified in the project described here, and this analysis could lead to improvement and advice for further projects.

thermal bridges

It seems very difficult to include some insulation down the external walls and into the ground in order to reduce thermal bridges at the foundation level. On the other hand, it would be possible to provide insulation above the external walls around the roof, so that upper thermal bridges are avoided. External insulation suppresses thermal bridges near the intermediate floors, except if there is a balcony. Glazing the balconies reduces these thermal bridges but this measure is expensive.

glazing

The generalisation of argon filled low emissivity double glazing seems worth advising, because the overcost compared to standard double glazing is low and the corresponding energy saving is high. Highly transparent glazing should be used on south facades.

ventilation heat losses

The fresh air can be warmed in a glazed balcony. An efficient alternative is to use a heat exchanger so that the fresh air is warmed by the out-flowing warm air. This could be proposed in further projects. This measure requires air ducts from the heat exchanger (situated e.g. on the roof) to all air inlets into the dwellings. These air ducts could be situated between the existing façade and the new external insulation layer. An alternative is an individual heat recovery system in each apartment.

integration of solar energy techniques

The integration of a solar domestic hot water system has been studied but the absence of regional support and some technical constraints (distance between the back up system and the users) made this measure very difficult to implement. A decentralised back up system could be installed, requiring 2 pipes and a heat exchanger from the district heating station. A regional support would still be needed because the cost of active solar systems is still high.

If the above mentioned technologies become standard practice, their cost could be reduced, particularly regarding the solar domestic hot water systems : an important part of the present cost is related to manpower, which is due to the fact that such systems are still uncommon. On the other hand, the cost of increasing the insulation thickness is considered unlikely to vary a lot. The cost of glazed balconies is high because these components are realised on site and they are difficult to standardise because their geometry depends on the project. The present cost of argon filled low emissivity glazing is around 5 € per m^2 more than a conventional double glazing. This difference could also be reduced in the future if this technology becomes the standard. Preheating of ventilation air and reducing thermal bridges may also become standard practice and the related costs should decrease.

The technologies implemented in this project concern a large number of similar social housing apartment buildings that have been built according to the same standard in most cities in France. The conclusions of this project have thus a high replication potential and the results will be disseminated widely in the social housing sector.

A pay back time can be estimated assuming a reduced cost for glazing, and considering only the most efficient techniques (insulation, glazing, water saving). The total investment cost of the project would then be around 150,000 €. The corresponding energy saving leads to save around 10,000 € yearly. The maintenance and operation cost should be negligible. As a result, the pay back time is around 15 years. It should be noted that energy is not the only reason to replace existing windows and to renovate the façade, so that part of this cost would have to be spent anyway.

Some specific pay back times can also be evaluated for some techniques. For instance, replacing standard double glazing by advanced glazing costs 6,500 € for this project and saves 82,000 kWh yearly, leading to a 3,770 € yearly. The pay back time for this specific technology is thus less than 2 years.

5. conclusions

Thanks to the financial support from the European Commission, it has been possible to improve the thermal quality of the building, to benefit from the experience of European partners and to promote innovative techniques. The energy consumption of the building has been decreased by 32%, the emission of 76 tons of CO_2 is avoided each year and the thermal comfort of the building has been improved.

These results are lower than the values initially evaluated. The cause has been identified, and measures have been proposed in order to reach higher performances. Particularly, the indoor temperature is higher after the renovation work, and it is proposed to decrease this temperature : a 2°C decrease (from 22 to 20°C) would reduce the heating energy consumption by around 15%.

Other energy efficient construction or renovation projects have been initiated, allowing replication of some of the demonstrated technical innovation.

Some of the techniques like advanced glazing have a low pay back time, less than 2 years, making replication easier. The corresponding cost of avoiding one ton CO_2 emissions is around 8 Euros. The corresponding cost for increasing the insulation thickness is around 70 Euros per ton CO_2. But the investment is much higher for other techniques like glazed balconies and solar domestic hot water, leading to over 400 Euros per ton CO_2. These cost would be lower if these techniques become standard practice. But Greater Paris Area is the only region in France where individual solar domestic hot water systems are not supported by the Region. Collective systems may be supported after a very complex analysis of the whole building stock of the owner, therefore the number of installations is very limited, and the cost remains high.

Globally, assuming a 30 years life span for the components installed in this project, the cost of 1 ton CO_2 emissions avoided is around 80 Euros. This cost can be lowered by selecting the most efficient techniques. Social housing companies in general cannot easily afford the investment cost, and cannot get their money back because the energy is saved by the residents who benefit from reduced operation cost of the building. May be such investment could be made by industries in a clean development mechanism approach.

Climate protection objectives imply a reduction of the energy consumption by a factor 4. Presently such a reduction can only be achieved using rather expensive technologies, so that market mechanism have certainly to be complemented by regulation.

If such a project would be repeated, the main lessons would be :

- to plan a longer design phase, allowing a participatory process involving the residents,
- to perform lobbying actions at a higher political level in order to promote a regional support for renewable energy and energy efficient techniques,
- to generalise the use of advanced glazing, i.e. argon filled low emissivity double glazing,
- to study the reduction of thermal bridges with the contractor in charge of façade insulation,
- to study the preheating of ventilation air with a specialised industry,
- to study the installation of a back up loop allowing a collective solar hot water system with a district heating back up.

Despite these limits, the project performs better than standard renovation projects in our region and the regional energy and environment agency (ARENE) has agreed to realise and disseminate a brochure explaining the main results of this project to a target group constituted of social housing owners, municipalities and other decision makers.

6. Photographs

The external insulation of the facades has begun in December 2001 (see next photos) and the windows have been replaced.





A separate heating loop has been realized in the district heating sub-station (see next photograph).

The commissioning has been performed in several steps (the contractors being different) : replacement of windows, external insulation, construction of glazed balconies. The glazed balconies have been designed by the architect in charge of the project, Mr. Serge Constantinoff (Ligne 7 Architecture).

The renovation of the building has been completed with the installation of the glazed balconies in autumn 2002 (see the next photographs) by the company TRADIRENOV.

	
Renovation of tle glazed balconies (July 2002)	Renovation of tle glazed balconies (December 2002)

This last step ends up the renovation phase.

	
Building before renovation (2000)	Building after renovation (2002)

Completion of the glazed balconies and of the overall renovation

	(December 2002)

Indoor views

glazed balconies


ventilation system


References

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