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ENERGY, ENVIRONMENT AND SUSTAINABLE
DEVELOPMENT Thematic Priorities: ENERGY, Key
Action 6, Economic and Efficient Energy for a
Competitive Europe Category of RTD project
Demonstration**

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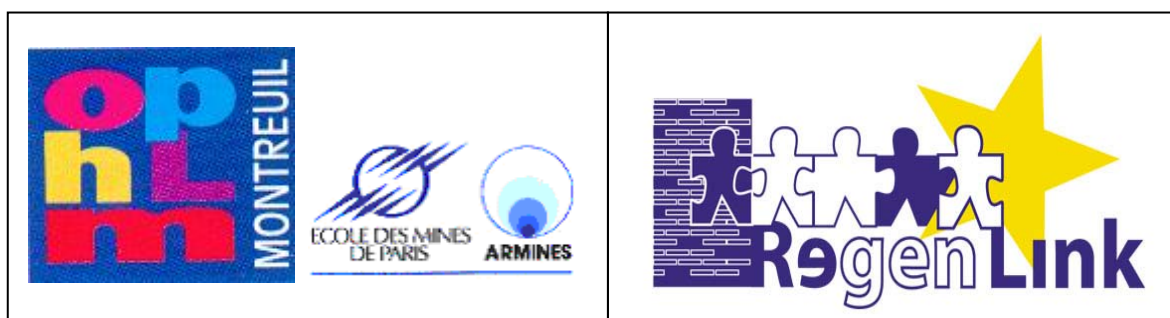
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Publishable Report

Date of report: 31/12/03, revised 26/08/04

Regen-Link - Site 4 : La Noue

Participants Number 5 and 5A : OPHLM de Montreuil and ARMINES / ENSMP

Proposal No.	NNE5-1999-00249
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Thematic Priorities:	ENERGY, Key Action 6, Economic and Efficient Energy for a Competitive Europe
Category of RTD project	Demonstration

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Summary (page 2 of the report)

The project aims to demonstrate that the fulfillment of Agenda 21 objectives, particularly the reduction of greenhouse gases emissions, is also possible in existing buildings 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 applied in a 52 dwelling units block. Increased insulation thickness, advanced glazing, preheating of ventilation air in glazed balconies, water saving and improving the district heating loop control have been implemented.

The objective is to reduce the heating load by 60%. The dwelling block is heated by a district heating using mainly coal fuel, and it is hoped to reduce a large amount of CO₂ emissions. This regeneration project is part of a more global urban project according to an environmental agenda defined by the municipality.

The measured heating energy consumption is 25% lower after renovation instead of the 60% reduction estimated by the calculation. The analysis leads to identify various causes and to propose some improvement. The measured indoor temperature is higher after renovation (+3°), which should increase the heating load by 22% . It was therefore proposed to lower the heating loop temperature. The ground floor is heated after renovation, leading to additional energy consumption (+25% estimation). If we correct the measured value to account for this bias, we obtain a 50% reduction after renovation, leading to a 70 kWh/m²/y heating energy consumption. These results show the specificity of existing buildings compared to new construction : complementary measures are needed to improve the performance (e.g. glazing all balconies to reduce thermal bridges and preheat ventilation air).

The pay back time is estimated from around 2 years for low emissivity glazing, up to 20 years for increasing the insulation thickness, but some techniques are still not economical (glazed balconies, active solar), also due to the fact that no support could be obtained at a regional level. A life cycle assessment has been performed and a 50% reduction of CO₂ emissions has been estimated. It was also suggested to lower the use of coal in the district heating system using partly wood as a fuel.

Some innovative techniques like advanced glazing are very efficient and the dissemination activities will hopefully influence other decision makers in the social housing sector, leading to partial replication of this project.

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1. Project details

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2. Aim and general description

2.1 Aim of the project

The project 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) are 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 thus rarely implemented. Implementation and monitoring of this technique would thus allow a better knowledge of its performance and the 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.

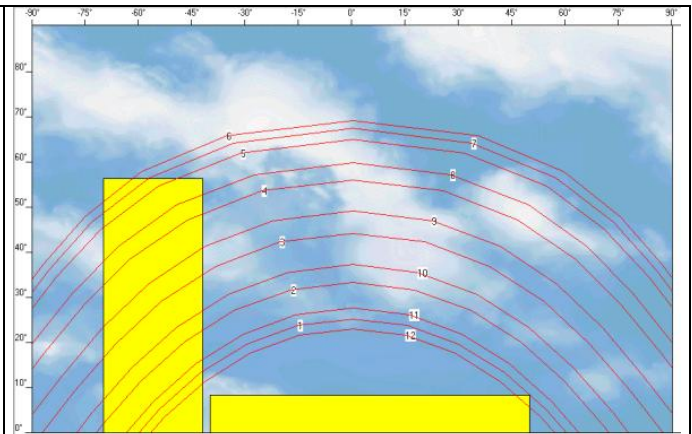
The objective is to reduce the heating load by 60%. The dwelling blocks are heated by a district heating using mainly coal fuel (70%), and it is hoped to reduce a large amount of CO₂ emissions. This regeneration project is part of a more global urban project according to an environmental agenda defined by the municipality. The results of this project concerning the reduction of operation cost and 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.

2.2 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 studied building is situated on the northern side of an open space, which allows a high level of solar exposure of the south façade (cf. the following pictures). The buildings have been built in the sixties, without any insulation and with a large percentage (around 50%) of single glazed windows.



The neighbouring buildings obstruct solar radiation during only limited time



REGEN LINK building before renovation (left)



Neighbouring buildings (east and south)

2.3 Description of the installation

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.

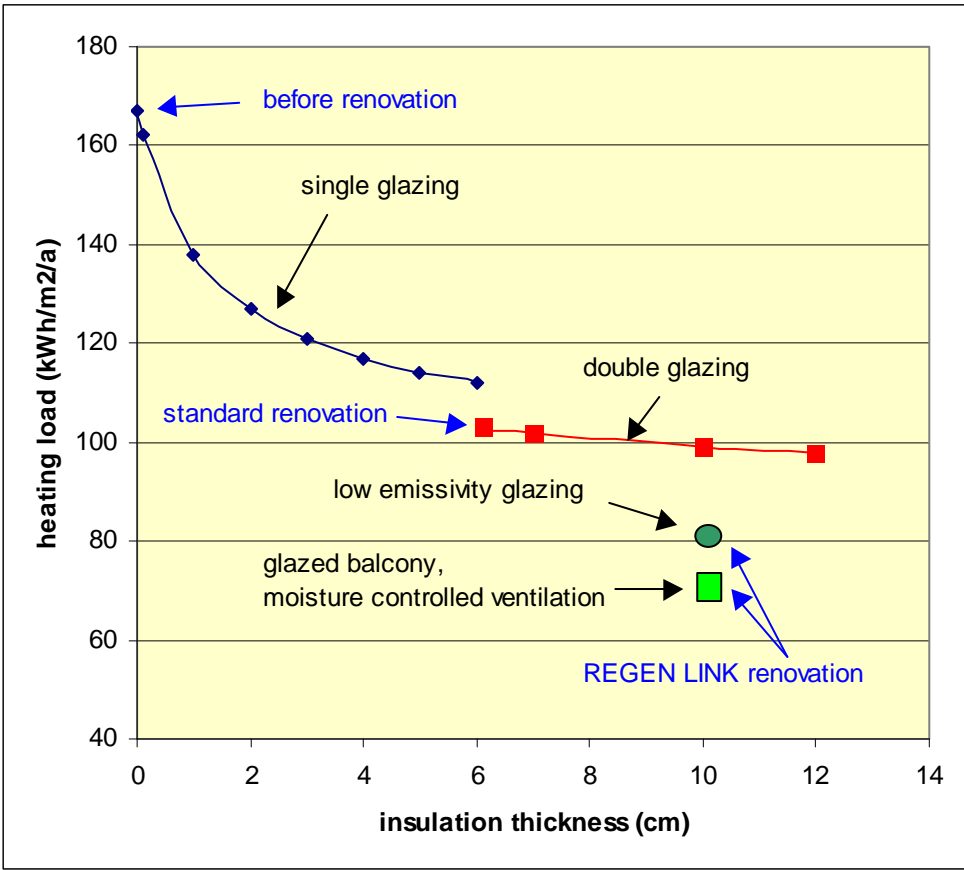
Data on the performance of innovative glazing has been collected from 3 different manufacturers in order to compare various products.

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. The inhabitants have been contacted by OPHLM and 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 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. Globally, the reduction on all facades brings a 2% reduction. 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 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 of other characteristics.

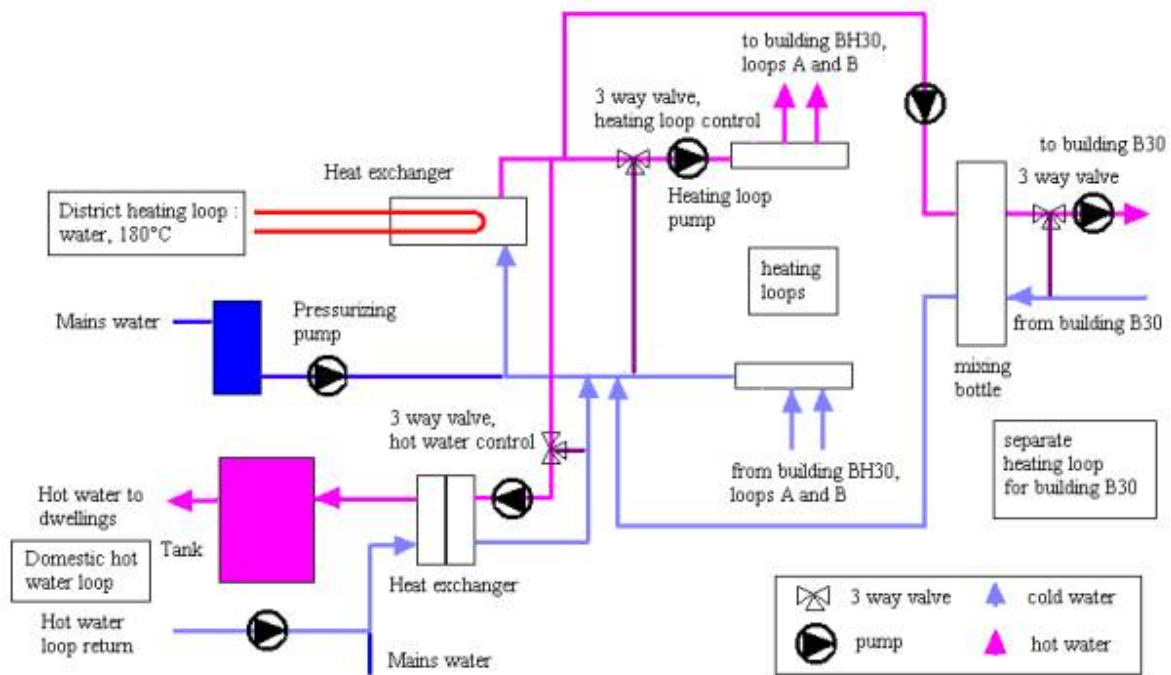


The heating load before renovation is estimated about 170 kWh/m2/a. The measured energy consumption varies between 120 and 180 kWh/m2/a in terms of the year. Measured yearly degree days allow to correct the evaluation in terms of the real climatic data. At the moment, a typical meteorological year (test 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.

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 (cf. next figure).



Heating loop after renovation

The glazed balconies have been studied in order to evaluate the energy saving obtained by preheating the ventilation air, and the thermal comfort in summer and mid-season.

A meeting has been organised by the municipality with the inhabitants to inform them about the project, aiming at sensibilisation on environmental issues. All inhabitants of the longer aisle of the building (dwelling units including a south facing facade) have been visited in order to know if they would accept a glazed balcony, a solar water heater (for the persons living on the upper floor), and monitoring activities. A set of 4 apartments has been selected where these balconies can be constructed. Techniques for the reduction of electricity demand were also proposed by the local energy management agency.

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.

The glazed balconies include air inlets in order to preheat ventilation air before it flows into the dwelling. 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. Moisture controlled inlets are tested in two dwelling units between the glazed balcony and the living room.

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 (cf. next table).

	<p>3 way valve connecting either solar or district heating hot water</p> <p>Problems :</p> <ul style="list-style-type: none"> - 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.
	<p>Back up provided by the hot water loop</p> <p>Problem : the temperature of this loop is around 45-50°C, which is too low for an efficient back up.</p>
<p>Electric back up</p> <p>Problem : both investment and operation costs would be higher compared to the present district heating production</p>	<p>Gas back up</p> <p>Problem : operation cost would be similar but this solution would require a high investment : gas boiler, supplementary ventilation required by safety regulation.</p>

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.

The demand side management campaign has concerned 10 dwelling units (low consumption lighting, no stand by in domestic appliances) among which 5 dwellings have been equipped with A class refrigerators. This has reduced the electricity bill in the apartments.

2.4 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 have 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. The data is collected during periodic on site visits.

- data acquisition

The temperature measurements performed in the dwellings are stored locally during 3 weeks and collected on a portable PC. 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

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 the tenants report a too high indoor temperature.

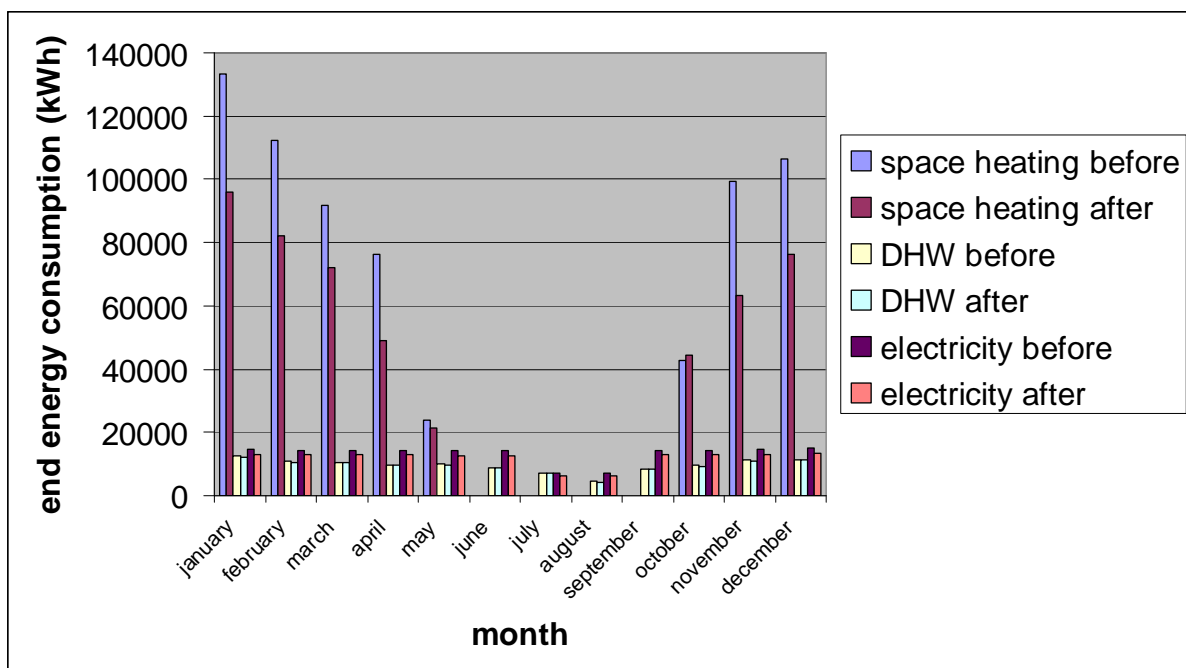
Some of the tenants complain because they feel cold, though a 23°C temperature is measured in their dwelling. This feeling is due to a lower temperature of the radiators : the heat demand of the building being lower, the heating loop and thus the radiator temperature is lower. The tenants might have 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 a higher temperature reduces the performance of the building, which is not optimal for dissemination and demonstration activities.

3.2 Performance

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
kWh/tep	11628	11628	3876
primary energy consumption after renovation (Tep/y)	40,41	9,73	36,74
primary energy saving (Tep/y)	18,61	0,08	4,08
primary energy saving (%)	31,53	0,77	10,00
operation cost reduction (euro/y)	9953,71	40,35	1740,33
specific consumption (Tep/m2/y)	0,0084	0,0020	0,0076

Monthly results are shown in the graph below.



The measured heating energy consumption is 32% lower after renovation instead of the 60% reduction estimated by the calculation. The analysis leads to identify various causes and to propose some improvement. The measured indoor temperature is higher after renovation (+3°), which should increase the heating load by 22% . It was therefore proposed to lower the heating loop temperature. The ground floor is heated after renovation, leading to additional energy consumption (+25% estimation). If we correct the measured value to account for this bias, we obtain a 50% reduction after renovation, leading to a 70 kWh/m²/y heating energy consumption.

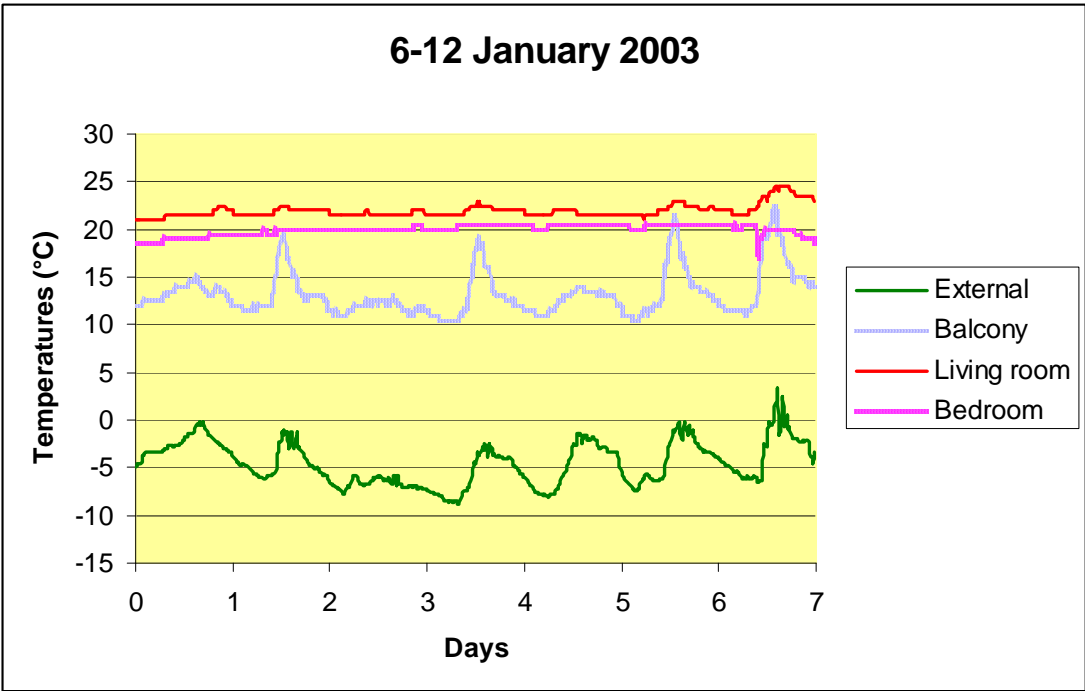
Measurements of the electricity consumption were performed. In the 50 measured units, this consumption varies between 1,350 and nearly 7,000 kWh/a, with a mean value of 3,100 kWh/a. This consumption is higher than the national mean value (2,500 kWh/a per dwelling unit). The electricity consumption depends on the number of occupants and on the life style (domestic appliances,...) and less on the design of the building. The renovation project has been complemented by a sensibilisation campaign performed by the local energy agency.

According to a study performed by this local energy agency, the mean electricity consumption per dwelling is 3,050 kWh/year. This corresponds to 30 kWh/m²/year, or 730 kWh/person/year. 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 in the frame of Regen Link.

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.

Indoor temperature in winter

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

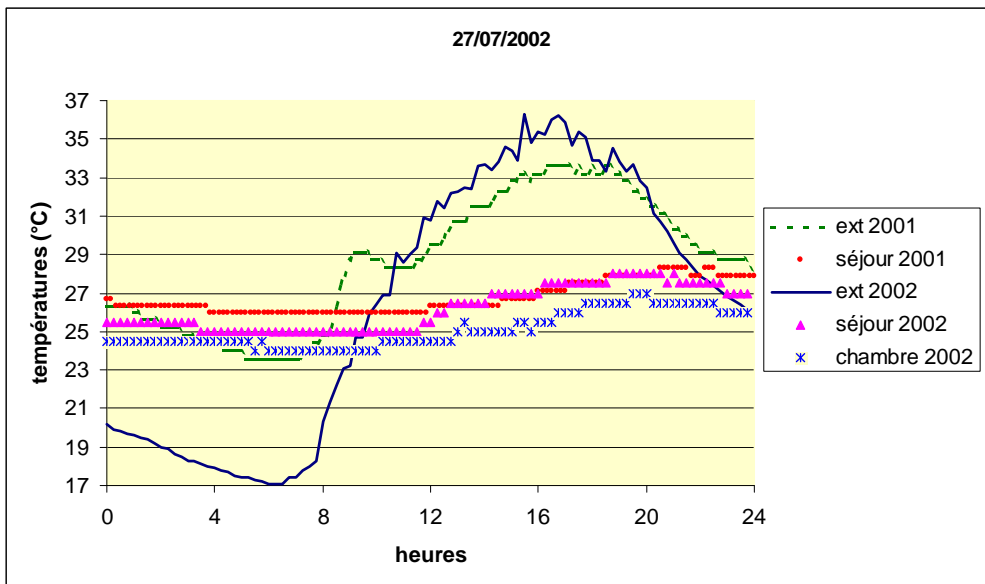


Typical winter week

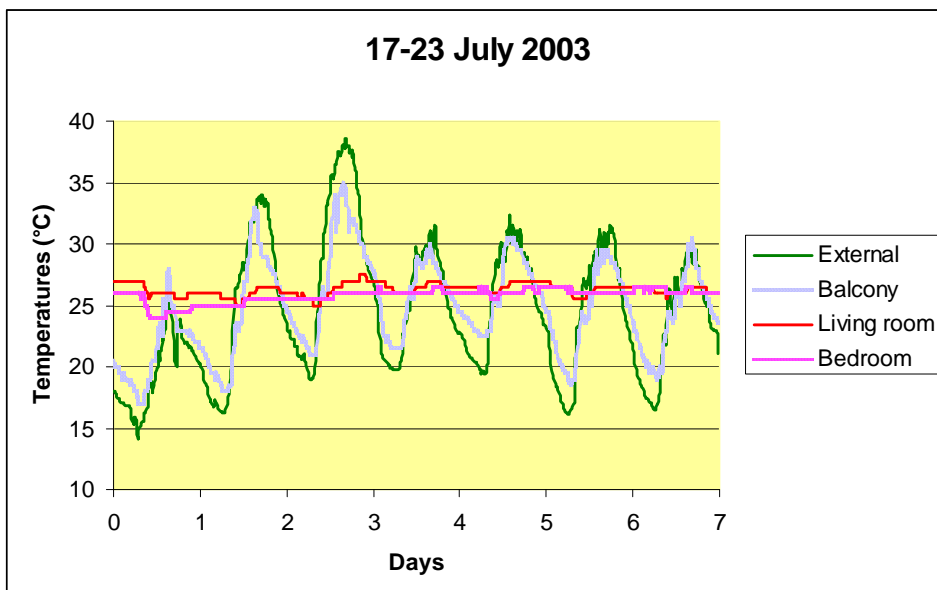
The bedroom radiator is sometimes closed, because this bedroom is not always occupied. Its windows may sometimes be opened to ventilate the room. On the other hand, the living room is often overheated.

Thermal comfort aspects 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. The external temperature was a little higher than in the hottest week of 2001, but the inside temperature is a little lower. The improved insulation of the building and the high thermal mass helps to protect from overheating : with a 35°C external temperature, the indoor temperature remained below 28°C. This graph shows that the renovation has also improved thermal comfort in summer : though the external temperature has been higher in 2002 compared to 2001, the indoor temperature remained lower.



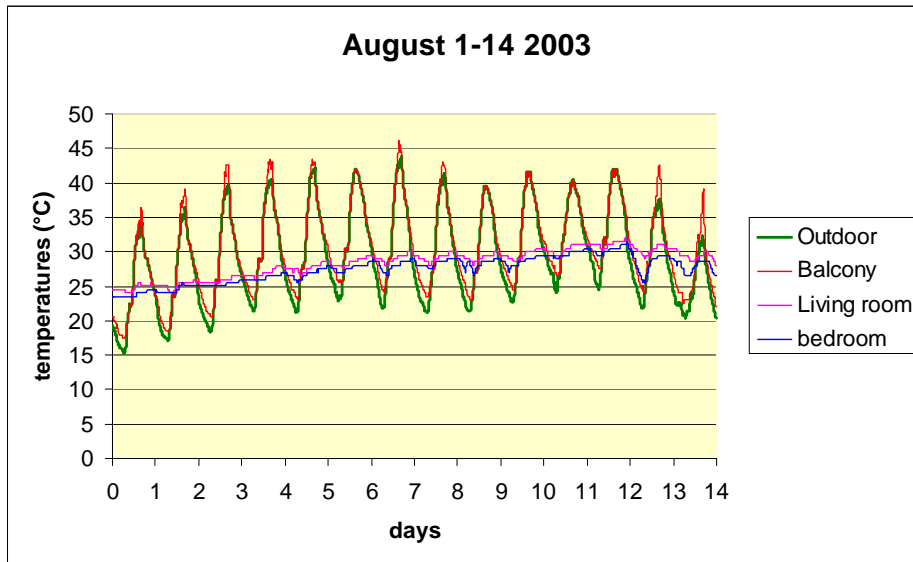
The following graph shows the temperature profiles in an apartment with a glazed balcony, during a typical summer week



Typical summer week

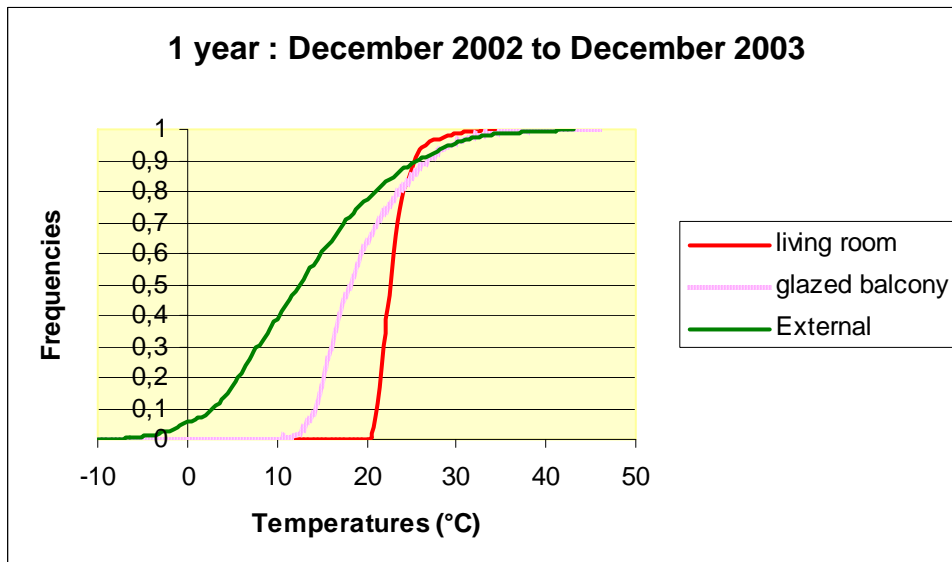
The balcony is generally ventilated and its temperature is near the external ambient temperature. The dwelling temperature remains moderate due to the high thermal mass of the building, the careful management of solar protection by the tenant, and possibly night ventilation.

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.



Accumulated frequency curves

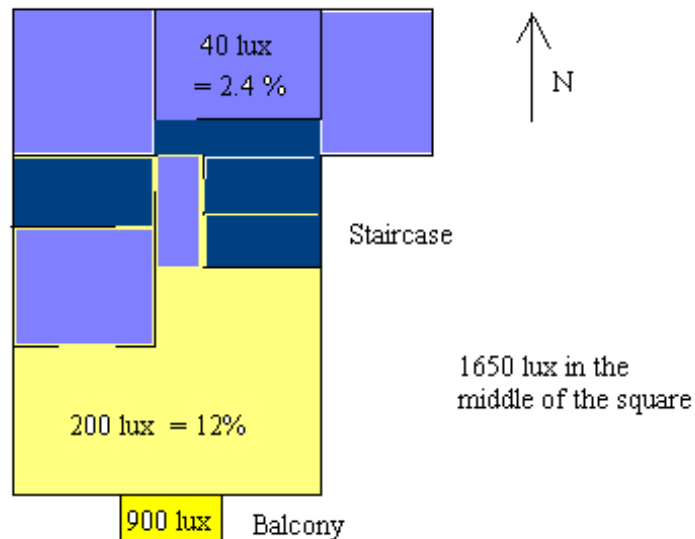
These curves are given below for the external temperature, the temperature in the living room and in the glazed balcony of a dwelling.



Accumulated frequency curves

Daylighting

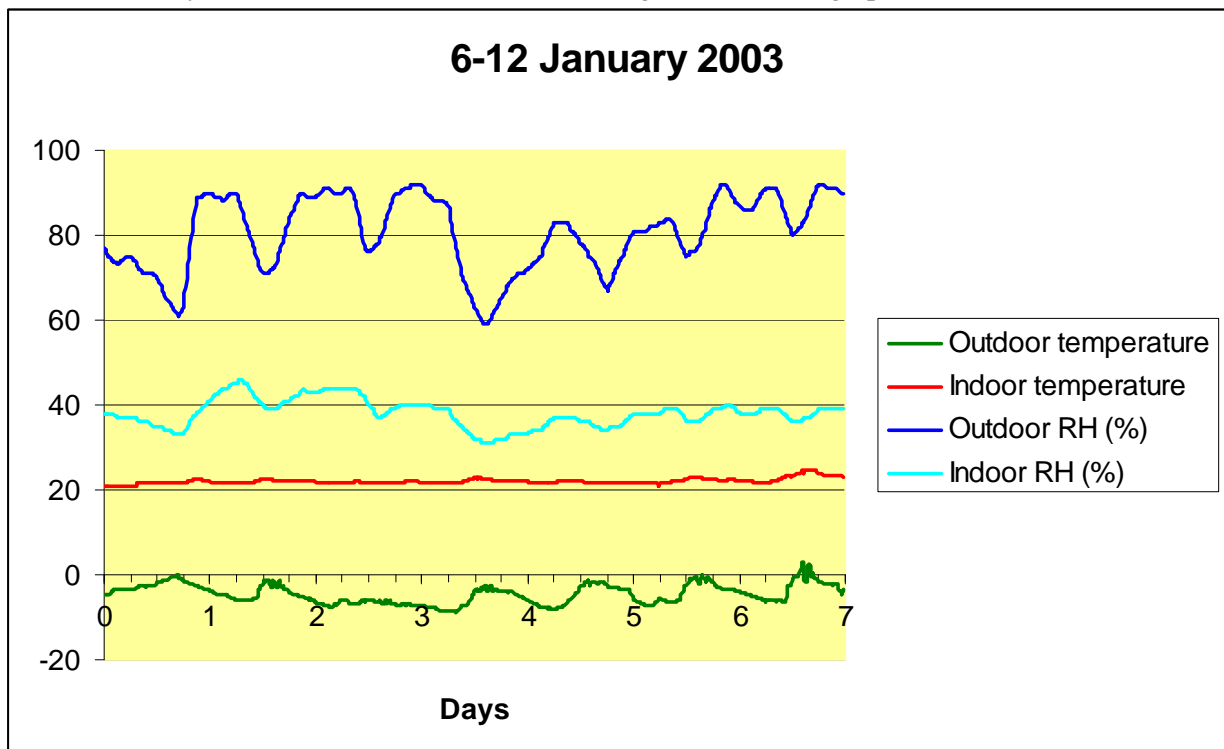
A luxmeter has been used to evaluate daylight factors by dividing the illuminance measured inside a dwelling in different rooms by the external illuminance (diffuse sky). The results are presented in the following graph.



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.

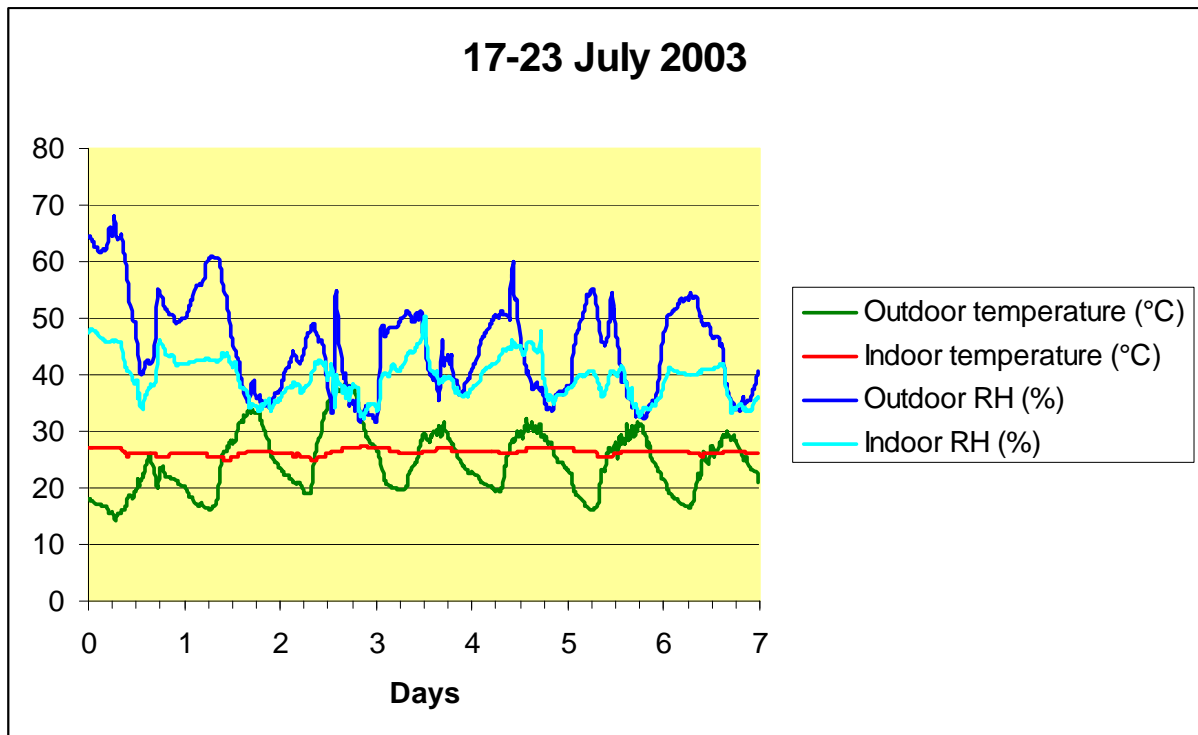
Humidity

The measurements concerning climatic and indoor parameters have been performed during the heating season. As mentioned earlier, the temperature in the dwellings is often above 22°C. The internal humidity is around 30 to 40% when the heating is on (cf. next graph).



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 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 CO₂ 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 are cheap and easy to integrate in such a project. They 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 venture 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, thus 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 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 petrol have been saved during the first operation year. This resulted in avoiding the emission of 76 tons of CO₂, 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 Economic viability

The total investment cost of the project is 184,536 €. 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.

3.7 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% hydro-electricity and 8% coal and gas thermal plants). This mix leads to a GHG emission factor of 343 g CO₂ per kWh.

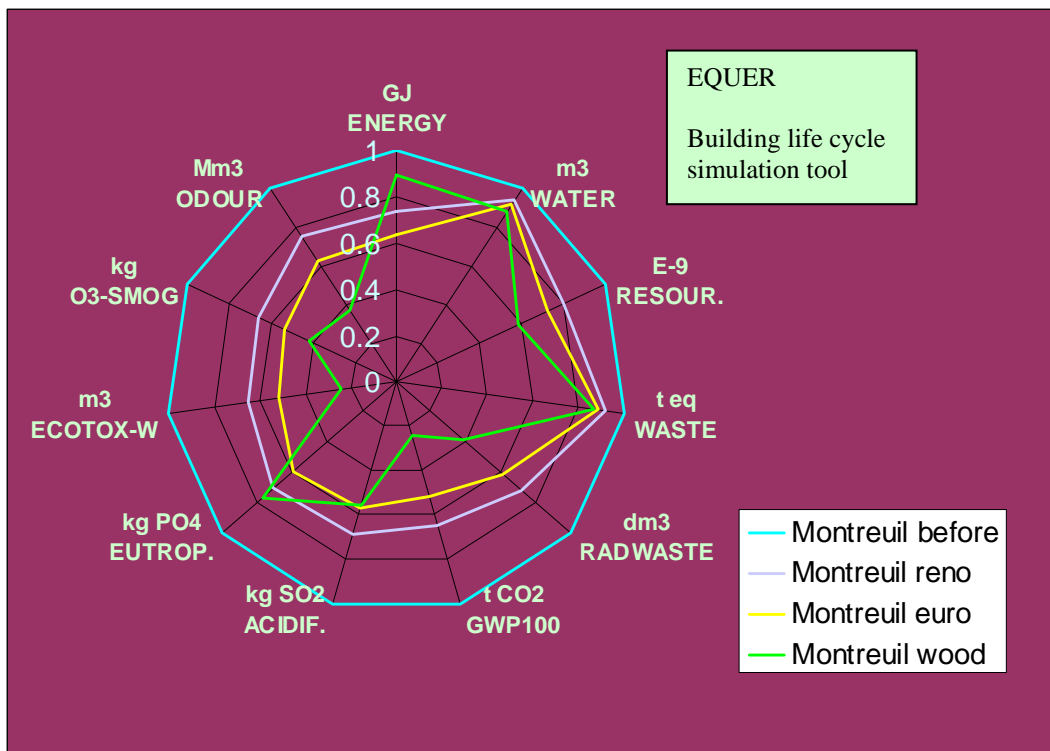
The French electricity mix given above leads to a corresponding emission factor of 87 g CO₂ per kWh.

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 Equivalent Petrol]
Heating	217000	District heating	74,4	18,7
Electricity	17000		1,5	4,4
Total	234000		75,9	23,0

The Building life cycle assessment tool EQUER has been used. The energy mix for the district heating leads to high GHG emissions. An alternative has been studied including a 10 MW wood fuel boiler. Several environmental indicators have been evaluated, e.g. the contribution in global warming, energy and water consumption, waste production etc.

The results are presented on the following graph. Each axis corresponds to an indicator. The project before renovation is considered as a reference. Three alternatives after renovation are compared : the standard renovation (“Montreuil reno”), the renovation performed in the REGEN LINK project (“Montreuil euro”), and the REGEN LINK renovation using wood fuel in the district heating system (“Montreuil wood”). These alternatives are represented by relative values : for instance the CO₂ emissions are reduced by 30% with the standard renovation, by 50% with the REGEN LINK renovation, and by 75% if wood fuel is used in the district heating system.



Life cycle assessment results

4. Publicity, commercialisation and other developments

4.1 Publicity and publications

The project is described in 2 brochures and the web site : www.regen-link.org . It has also been presented during a seminar about energy efficient social housing, organised by the local energy agency in Rennes September 27, 2001, during a continuing education course organised by ADEME (French agency for environment and energy efficiency) for institutional clients (in charge of building social housing, high-schools and other public buildings), and during a conference organised by CEKAL, an organisation involved in the labelling of glazing in France, during the BATIMAT trade exhibition.

A paper has been presented during the Sustainable building 2002 Conference in Oslo (cf. §5.). A brochure in French has been realised for the regional agency for environment, ARENE.

4.2 Outlook

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.

- 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 10 € 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. Lessons learned/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 CO₂ 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 CO₂ emissions is around 8 Euros. The corresponding cost for increasing the insulation thickness is around 70 Euros per ton CO₂. But the investment is much higher for other techniques like glazed balconies and solar domestic hot water, leading to over 400 Euros per ton CO₂. 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 CO₂ 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 in France,
- 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. References

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

7. Photographs

Please **include photographs showing the installation** as a whole and all important or interesting components.

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



A separate heating loop has been realized in the district heating sub-station (cf. 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 (cf. the next photographs) by the company TRADIRENOV.



Renovation of the glazed balconies (July 2002)



Renovation of the 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



SESAME DATA SHEET

Please use plain common fonts (e.g. Arial, Times Roman etc.) with at least size 10.

COMMISSION OF THE EUROPEAN COMMUNITIES Directorate-general for Energy 200, rue de la Loi B-1049 Brussels Tel. 02/299.11.11 fax 295.05.77 Telex COMEU B 21877			Project Nr.: <u>NE5/1999/249</u>	Updated: 18/12/2003
			Programme: THERMIE Legal Base:	
Title: REGEN LINK			Decision: Reference:	
Principal Contractor: OPHLM de Montreuil Associated Contractors: ARMINES / ENSMP			Site of Project: Montreuil Project leader: Jean-Luc BONABEAU Tel.: +33 1 49 20 36 49 Fax: +33 1 48 58 02 28 E-mail: jeanluc.bonabeau@free.fr	
Sector:			Period of project: end Project duration: 4 years	
Type of phase:	Total Cost of project	Eligible Cost of project	EC Contribution	
	€	€	%	€
Design	73,408	71,083	35	24,879
Construction	184,536	178,692	35	62,542
Commissioning	8,612	8,339	35	2,918
Monitoring	73,105	70,790	35	24,777
Reporting	17,761	17,199	35	6,020
Dissemination	17,302	16,754	35	5,864
Total:	374,724	362,857	35	127,000

Keywords	Building Renovation Insulation Advanced glazing Ventilation District heating
Aim of project: (1000 characters max.)	<p>The project aims to demonstrate that the fulfillment of Agenda 21 objectives, particularly the reduction of greenhouse gases emissions, is also possible 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, will be studied and applied in 52 dwellings among a 536 units regeneration project.</p> <p>The objective is to reduce the heating load by 60%. The dwelling blocks are heated by a district heating using mainly coal fuel, and it is hoped to reduce a large amount of CO₂ 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 environmental benefit of innovative techniques like advanced glazing and humidity controlled ventilation will hopefully influence other decision makers in the social housing sector.</p>
Project description: (3000 characters max.)	<p>Montreuil is a city of around 96.000 inhabitants in the Greater Paris area. The neighbourhood called La Noue, rather isolated from the rest of the city, has been selected by the municipal environment service to conduct a pilot social and</p>

	<p>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 present project is concerned with these 536 dwellings. The corresponding buildings are either blocks of 4 to 8 storeys or highrise buildings of 18 storeys. The buildings have been built in the sixties, without any insulation and with a large percentage of single glazed windows (around 50%).</p> <p>The regeneration includes the thermal insulation of the facades, the replacement of existing single glazed windows by double glazed PVC windows, and the replacement of the ventilation extraction vents. In one of the buildings, a more energy efficient retrofit will be performed on 52 dwelling units. The thickness of insulation is higher (10 cm instead of 6). Low emissivity double glazed windows have been implemented. In 4 dwelling units, argon filled double glazing have been used in the north facade. In these dwellings, glazed balconies have been installed on the south facade in order to preheat ventilation air. Low flow-rate sanitary equipment has also been installed. The district heating plant has also been studied in order to perform a life cycle assessment, evaluate the reduction of CO₂ emissions with the present coal fuel and study if wood fuel can be partly used.</p> <p>Thermal simulation and life cycle assessment have been used during the design phase of the project to compare various technical choices, for example the choice of the glazing type (hard coating or soft coating low emissivity glazing).</p> <p>The work is conducted in cooperation with the local energy agency of the city, and possible demand side management measures are studied concerning lighting, domestic appliances and advice to inhabitants.</p> <p>Temperatures in the dwellings are measured before and after renovation in order to evaluate the evolution of the thermal comfort. The heating energy consumption is measured in the concerned building, and in a neighbouring building which has been renovated in a standard way. The comparison with measures before renovation will allow an estimation of the energy saved by a standard renovation and with the REGEN LINK project.</p> <p>The "common tasks" planned in the project allow an exchange of information between the 8 participating sites about various economic, social and environmental boundary conditions. Dissemination activities are also performed.</p>
<p>Results (3000 characters max.)</p>	<p>The design, renovation and commissioning phases are completed and monitoring activities have begun. The main results so far are the following.</p> <ul style="list-style-type: none"> - Design phase <p>One main objective of the renovation project is to improve the image of the buildings, and this has influenced the choice of the insulation technique : mineral wool with an external cladding has been preferred to polystyrene with a surface rendering. A thermal simulation tool has been used to evaluate the thermal performance of the building, including its heating load and thermal comfort, and to compare various choices.</p> <p>Sensitivity studies have been performed, for instance the thickness of the insulation layer has been varied. The first centimeters allow an important reduction of the heating load, higher thicknesses are less efficient. The value of 10 cm has been chosen for technical and economical reasons. According to the calculations, in the mid-European climate of Paris, hard coating low emissivity glazing is adapted to a south facade : its U-value is a little higher than using soft coating, but the solar transmittance is also higher and the net gains are higher. On the contrary, the solar radiation is not so high on the other facades and soft coating low emissivity glazing should be preferred. After implementing high insulation and advanced glazing, the ventilation-related heat losses are very important. It was difficult to preheat the ventilation air in a heat exchanger because air ducts are needed and they are not easy to install in an existing building. Preheating of ventilation air in glazed balconies has thus been preferred. The</p>

	<p>simulation tool predicted a satisfactory level of comfort in summer and mid-season if the balconies are ventilated during these periods.</p> <p>The too low temperature in the hot water loop makes it impossible to use this loop as a back up for a solar water heater. An electric back up would be more expensive for the residents than the existing system without solar equipment because the cost of one kWh provided by district heating is much cheaper. Thus, it was decided to abandon the active solar option, and in compensation 4 glazed balconies instead of 2 have been built.</p> <ul style="list-style-type: none"> - Renovation phase <p>The insulation of the facades and the replacement of windows have been realised in autumn 2001 and spring 2002. The facade insulation and the construction of the glazed balconies had to be coordinated. The water tightness at the connection between the external insulation cladding and the structure of the balconies had to be carefully studied.</p> <ul style="list-style-type: none"> - Commissioning phase <p>The insulation thickness has been checked as well as the implementation near windows in order to reduce thermal bridges. The most difficult check concerns the glazing type. The indication concerning the thermal quality of the glazing is not precise : TR = "thermique renforcée" in France means any type of low emissivity glazing (soft or hard coating, air or argon filled). It is thus very difficult to check that the appropriate glazing has been implemented and we have to trust the contractors.</p> <ul style="list-style-type: none"> - Monitoring phase <p>Temperatures and daylight factors have been measured before renovation. The high thermal mass of the building reduces temperature swings (e.g. 24 to 28°C inside when the outside temperature swung between 23 and 34°C). The dwelling include rooms towards two different facades which makes it easier to increase the ventilation if needed. The high glazing proportion of the facades near the living rooms is in favour of daylighting (around 12% daylight factor in a living room). The heating load before renovation is around 150 kWh/m²/year, depending on the climate. It has been reduced to around 100 kWh/m²/year.</p> <p>Measurements after renovation show that the thermal comfort in summer has also been improved : the higher insulation also protects from hot external temperatures.</p>
References (700 characters max.)	<p>Bruno Peuportier, Assessment and design of a renovation project using life cycle analysis and Green Building Tool, Sustainable Building 2002 Conference, Oslo, September 2002</p> <p>Bruno Peuportier, Niklaus Kohler and Chiel Boonstra, European project REGENER, life cycle analysis of buildings, 2nd International Conference « Buildings and the environment », Paris, June 1997</p> <p>Bernd Polster, Bruno Peuportier, Isabelle Grieder and Jacques Michel, Transparent insulation in a public housing project in France, 3rd European Conference on Architecture, Florence, May 1993</p>
Potential users (1000 characters max.)	<p>The project allows a precise evaluation of the cost and benefits of various innovative techniques. This information is very useful for decision makers in charge of similar projects : managers and technical staff in social housing companies, in charge of similar renovation projects, architects and consultants.</p> <p>The results will be also transmitted to :</p> <ul style="list-style-type: none"> - the regional delegation of the national energy and environment agency, ADEME, which also supports this project, - local energy agencies like Montreuil Vincennes Energie, which provide advice to building owners and professionals, - the regional agency in charge of energy and environment, ARENE, which organises technical visits in order to promote energy efficiency, - local energy information centres, which have been created recently in the Greater

	Paris Area and which perform sensibilisation activities for a wider public.
Company description (250 characters max.)	The public housing association OPHLM de Montreuil is managing a large scale building stock including several thousands dwelling units. They are responsible for the management of this stock and the satisfaction of the inhabitants. ARMINES is a research organisation and forms a joint research unit with Ecole des Mines de Paris. The institute for energy studies has developed tools (thermal simulation, life cycle assessment) and contributed in various demonstration projects.
Size of company (number of employees)	OPHLM de Montreuil : 250 ARMINES : 520
Manufacturers (1000 characters max.)	The main contractors involved in the projects are : <ul style="list-style-type: none"> - CEGELEC , in charge of the facade insulation, - LES ZELLES, in charge of windows replacement. LES ZELLES is a subsidiary of SAINT GOBAIN, a major glazing manufacturer and which produced the soft coating low emissivity glazing used in this project, - TRADIRENOV, in charge of the construction of the glazed balconies, in which PILKINGTON hard coating low emissivity glazing have been implemented, - SADC, in charge of the adaptation of the district heating loop, - ECO-TECHNIQUES, providing the low flow rate sanitary equipment, - ALDES, manufacturing the ventilation system.
Estimated energy production saving in KW _{th} h and/or KW _e h or TOE*	The estimated energy saving for the whole building is 234 MWh/a, i.e. 23 TEP/year. According to the energy mix of the district heating system, this should avoid the emission of 76 tons CO ₂ each year.
Estimated payback:	The renovation cost is 185,000 € The yearly saving is 217,000 kWh heat and 16,000 kWh electricity, corresponding to 11,700 € The pay back time is thus around 16 years.
Status:	Not yet started <input type="checkbox"/> On going : Design <input type="checkbox"/> Manufacturing <input type="checkbox"/> Erection <input type="checkbox"/> Commissioning <input type="checkbox"/> Monitoring <input type="checkbox"/> Completed X
State of progress (1000 characters max.):	The whole renovation work is completed : insulation of the facades, replacement of the windows, installation of glazed balconies and low flow rate sanitary equipment, separation of the building heating loop. The type of glazing in the facades and the glazed balconies has been selected after a sensitivity study using thermal simulation. The glazed balconies include air inlets in order to preheat ventilation air before it flows into the dwelling. A monitoring system has been installed to measure the global solar radiation on a horizontal plane and on a vertical south plane, and the external ambient air temperature (2 sensors). Temperatures have been measured in 3 dwelling units, in each unit in the living room facing south and in one bedroom facing north, also in 2 glazed balconies. The energy consumption for space heating and domestic hot water is also measured. Monitoring results are available for a whole year after renovation.
Published literature:	Bruno Peupartier, Assessment and design of a renovation project using life cycle analysis and Green Building Tool, Sustainable Building 2002 Conference, Oslo, September 2002 Web site : www.regen-link.org

* 1 MW_{th} .h = 0,086 TOE (or TEP)
 1 MW_e .h = 0,258 TOE (or TEP)