#7586

Technology and Performance Aspects of the Ecolonia Demonstration Project.

Hans Oldengarm
TNO-Bouw
Postbus 29
NL 2600 AA Delft
The Netherlands

INTRODUCTION

Ecolonia is a demonstration project of 101 low rise houses where an integral approach has been applied for the introduction of energy efficient and environmentally conscious technologies. The design development process started in 1989 and the construction was completed by the end of 1992. The set of performance targets for the Ecolonia was derived from the Dutch National Environmental Policy Plan. This plan has been established by the government to support energy and environmental initiatives of the building industry. In the Environmental Plan three major policy lines were presented:

1. Energy conservation
2. Integral lifecycle management
3. Quality improvement

These policy lines have been adopted as leading objectives for the development of the Ecolonia project. The technologies demonstrated had to be practical alternatives to conventional solutions and the costs to purchase and operate the houses were intended to be comparable to conventional new houses. In this paper the technology and performance aspects will be highlighted. The paper is written from the viewpoint of the expert team that gave advisory guidance during the design development process and the subsequent site construction. In an other contribution [1] to this conference the planning aspects of the Ecolonia project are discussed.

PROJECT DESCRIPTION

One of the basic ideas of Ecolonia was to invite a number of architects to submit predesigns on basis of a programme of requirements. Nine architects were selected with a wide variety of backgrounds. Each architect was commissioned to focus his design to a certain topic with specific requirements. For each leading objective three topics were chosen as listed below.

Energy conservation:
design 1: special attention to the reduction of heat losses
design 2: special attention to the use of solar energy
design 3: special attention to imbued energy and domestic energy use

Integral lifecycle management:
design 4: special attention to the use of recycled building materials and to domestic water conservation
design 5: special attention to organic architecture, long durability and low maintenance
design 6: special attention to adaptability and flexibility

Quality improvement (of the indoor environment):
design 7: special attention to improvement of acoustic quality
design 8: special attention to health and safety
design 9: special attention to bio-ecological architecture

The combination of different architects and different topics resulted in a large variety of designs. Figure 1 shows the urban design plan. At the start of the project an advisory expert group was established to guide the design development process. The advisory team consisted of experts from different expertise areas: building physics, solar energy, acoustics, HVAC design, indoor environment and building materials. The expert team assisted during the further project development as outlined below:

[redacted] [redacted]

PROJECT PHASE	EXPERT TEAM TASKS
Pre-design	Recommendations
Final design	Performance assessment
	Calculations
	Recommend use of materials
Construction phase	On-site inspections
Commissioning	Performance tests
Occupation phase	Monitoring
	Infrared survey
	Knowledge transfer

The principal task of the expert team was to assess the designs on the basis of the programme of performance requirements. Most of the technical requirements have been formulated in the form of performance target values. The performance areas considered are:

Reduction of energy use:
- Energy Performance
- Thermal insulation levels
- Air tightness of the building envelope
- Passive solar energy
- Solar heating of domestic hot water
- Heating and ventilation systems

Integral lifecycle management:
- Use of building materials with low environmental impact

Improvement of indoor environment:
- Air tightness of ground floors (to prevent infiltration of moist air)
- Thermal bridges and condensation
- Moisture proofing
- Acoustical quality
- Thermal comfort

During the occupation period specialized institues will be invited to monitor specific aspects:
- radon concentration monitoring (by RD-TNO)
- monitoring of indoor air quality (by RIVM)
- monitoring aspects relevant for bio-ecological architecture (by NIBE)
- inquiries of the occupants (by the University of Rotterdam)
- collection of energy consumption data (by the University of Rotterdam)

Below a brief explanation is given of the major aspects considered by the advisory expert team.

USE OF BUILDING MATERIALS

During the design development process a material ranking system was offered to the architects to avoid the selection of environmentally adverse building materials. In this system preferences are given for the application of building materials with respect to their overall environmental impact. The major criteria for material selection were:
- minimize environmenatal impact for the entire lifecycle
- reduce the use finite natural resources
- reduce construction waste
- increase the use of recycling of building materials
- use substitutes for materials with any adverse environmental impact
- maintain a long term performance
- minimal use of polluting materials
- use materials with low imbued energy

In addition to these some specific recommendations were given, like: do not use tropical wood, avoid the use bituminous materials, avoid CFC emitting products, etc.

A concise motivation for the principal building materials that have been selected for the Ecolonia houses is given below. Typical contruction details are shown in figures 2 and 3.

Thermal insulation: Mineral wool was predominantly selected, because this material was considered to be the best choice with respect to the criteria mentioned above. Foamglass was selected as a an acceptable option for designs having external insulation. Several architects proposed the use of cellulose material. There is very little experience with this type of insulation material in Dutch buildings, because the conventional type of cavity walls are not suited for application of cellulose. The expert team decided to accept the material for use in wood frame elements for design 4 because of its topic on the use of recycled materials.
Lime-sandstone: In the majority of the designs this material was used for bearing and non-bearing walls because this material was preferred when considering the environmental criteria mentioned before. In conventional housing the use of concrete is more common. For design 3 cellular concrete was selected because in this design the low imbued energy was a topic.
Concrete: The use of concrete was restricted to the foundations and the floor elements. In all concrete structures crushed concrete waste was utilized as substitute for the conventional gravel admixture.
Topmix layers: In conventional houses the floors are finished with few centimetres of cement mortar. For the Ecolonia houses it was decided to use as much possible anhydrite topmix layers. Anhydrite is a secondary gypsum material derived from the desulphurisation process at power stations. Further advantages of the use of such a topmix layer are the favourable working conditions (the topmix is poured like a liquid) and the its potential to achieve the desired airtightness.
Roofing materials: For sloped roofs the conventional ceramic roofing tiles have been used. For flat roofs EPDM membranes were preferred opposite to the conventional bituminous products. EPDM is regarded to have a satisfying potential for recycling.

ENERGY PERFORMANCE

One of the elements in the Environmental Policy Plan is the future introduction of an energy performance target in the new building regulations. It is expected the energy performance will be legislated in 1994. In advance to future situation specific energy performance targets were developed for the Ecolonia project. The target value for the annual energy consumption, including domestic electricity, was set to 300 MJ per m3 building volume. For designs with an energy conservation topic a more ambitious target of 220 MJ per m3 was adopted. A wide range of technologies have been proposed by the architects to meet these targets. Only existing and proven technologies were accepted. These include:

- high performance windows
- improved insulation levels
- the use of passive solar heat
- the use solar domestic water heaters
- heat recovery from ventilation exhaust air
- high efficiency boilers for space heating

The energy performance of all designs have been assessed by using a simplified calculation method comparable to the draft European Standard PrEN 832 [2]. This method takes into account the effect of utilized internal and solar gains. Design modifications have been suggested by the expert team until the energy requirements were met.

INSULATION LEVELS

To anticipate the new (1992) national building regulations the Ecolonia target for thermal transmittance was set to $U = 0.37\ W/m^2K$ (thermal resistance target: $R = 2.5\ m^2K/W$) for building envelope structures. To meet the energy performance requirements some designs needed an improved insulation level. For the energy conscious designs insulation levels up to $U = 0.22\ W/m^2K$ have been applied. All ground floors were provided with 10 cm insulation, which is unusual thick compared to common practice in the Netherlands. Because of the unusual thick insulation layers much more attention had to be paid to the design of structure joints to avoid thermal bridges and to achieve the desired air tightness. High performance windows have been widely used in the Ecolonia houses. The U-values are ranging from $1.4\ W/m^2K$ (double glazing, reflective coating, 16 mm argon gas filled cavity) to $U = 1.9\ W/m^2K$ (reflective coating only). For bedrooms the conventional double glazing ($U = 3.0\ W/m^2K$) was considered to be acceptable for most designs.

AIR TIGHTNESS OF THE BUILDING ENVELOPE

[redacted] [redacted]

The new national building regulations require a minimum air tightness of the building envelope. The minimum level is set to 200 dm^3/s air flow rate at 10 Pa pressure difference (this corresponds to an air change rate of approximately n_{50} = 2 ach (air change per hour) at 50 Pa pressure difference). For the Ecolonia project more ambitious targets have been adopted. For houses with air heating and/or balanced ventilation an improved air tightness was judged to be necessary. The expert team decided that the target should be n_{50} = 0.4 ach for these designs. At the commissioning of the houses blower door tests were made. The results of these tests showed that in many cases the Ecolonia target values were exceeded by a factor two or three. In these cases improvements were made by sealing the excessive air leakages found during the tests. Many air leakages were found to be provoked by the use of lime-sandstone elements in the exterior structures. The general problem appeared to be that air tight joints at window frames and roofs were difficult to achieve. These problems could have been avoided by better detailing during the design process.

PASSIVE SOLAR ENERGY

The Environmental Policy Plan encourages the use of passive solar heat. For this reason the architects were asked to exploit passive solar energy where possible. The solutions given by the architects are south facing windows and sunspaces for some designs (see figure 3). Due to restrictions arising from urban planning demands it was not possible to obtain south faced orientations for all dwellings. One architect found a solution by designing a "split-level" type house. Due to the urban planning restrictions his design was projected to an east-west orientation. The split-level layout allowed the passive utilization of solar energy through some south faced windows.

SOLAR HEATING SYSTEMS

Within the framework of the national energy conservation programs, subsidies are provided for investments in solar heating systems. This facilitated the introduction of solar systems in the Ecolonia project. All houses with a south facing roof are provided with collectors for solar domestic hot water heaters. Standard commercial available systems have been selected. The system consists of a 2.7 m^2 solar collector and a 200 litre storage tank. The annual primary energy savings for this system are estimated to be 7000 MJ (equivalent to 200 m^3 natural gas). In 4 houses a more unconventional system is installed that is coupled to the space heating system. Computer simulations were used to achieve an optimal design for this system.

HEATING AND VENTILATION SYSTEMS

Available technologies have been applied in the Ecolonia project. An overview of applied heating and ventilation systems is given in table 1. To meet the energy performance targets all houses were provided with high-efficiency condensing boilers and to meet the environmental requirements a boiler type with a low NO_x emission was selected. The majority of the houses are heated by conventional water filled radiators. To achieve an efficient operation of the condensing boiler large radiator capacities have been selected (supply and return temperatures of 70 and 50 °C at design conditions). In some designs the living areas are heating by floor heating and supplementary radiators. In one design the living area is provided with a full floor heating system, which is rather unconventional. In another design the architect proposed an unconventional wall heating system (see figure 4). Since the technology is very similar to floor heating the wall heating system was accepted by the expert team. About half of the houses are provided with a heat recovery system to gain heat from the exhaust ventilation air. Cross flow heat exchangers are used, except for one design where a high-efficiency (80 %) storage system with alternating air flows is used. For two designs the ventilation heat recovery is integrated in the air heating system (see figure 5). For houses where a combination of radiator heating and heat recovery is used the air supply is provided with auxiliary heating to avoid comfort problems at low outdoor temperatures.

AIR TIGHTNESS OF GROUND FLOORS

In the Netherlands most low rise houses have a crawl space. Until some decades the Dutch houses were provided with wooden floors and precautions were made to maintain a dry climate in the crawl space to prevent moisture damages. Later concrete or stone type floors were introduced and from that time on moisture effects have been neglected. At the same time most new houses were built in polder areas with relatively high ground water levels. Crawl spaces showing open water during a large part of the year became very common. During 1980's it was recognized that this situation was a important source of the huge of number houses exhibiting moisture and mould problems. Many investigations showed that the most important phenomenon was the infiltration of moist air from the crawl space through air leakages in the lower ground floor. For existing houses these problems were solved by retrofit measures like sealing. Since 1992 new houses a subject to the new building regulations. A limit value for the air tightness of ground floors was introduced and at same time a standard test method was established. Expressed in terms of an equivalent leakage area the limit value is 7 cm2 for the entire ground level area. This requirement was rather new for the building industry and therefore this aspect was accepted to be considered in the Ecolonia design development. This topic is also in concordance with Ecolonia objective to improve the indoor environment. The result was that considerable attention was paid to the realisation of airtight ground floors. The aim to achieve was this facilitated by the decision to apply an anhydrite cast topmix layer on the concrete floors. For this type of top layer it is an absolute requirement to waterproof the concrete floors before the liquid anhydrite mixture is spread out on floor surface.

THERMAL BRIDGES

This aspect was adopted in Ecolonia as an important item because of the relation with objective to improve the indoor environment. The major concern was to prevent surface condensation and mould growth. A second motivation was that a thermal quality criterion for thermal bridges is given in the new building regulations which is very new to the building industry. The new requirements are formulated in the form of a minimum value for the temperature ratio, calculated with a finite difference method as described in a national standard. The calculation procedure is similar to the new draft European standard PrEN 32573 [3]. In the design stage many improvements have been suggested on basis calculations by the expert team. Special concern was necessary for structures in contact with ground.

MOISTURE PROOFING

Some of the proposed constructions were critical because of a risk for interstitial condensation. In particular flat roofing was subject to a critical analysis by the expert team. The hygrothermal performance of constructions was evaluated by using a dynamic model that also takes into account the effect of hygroscopic materials. An important assumption to be made was that building materials may be become wet during the construction period. Later, during the site inspections by the expert team, it was concluded that such an assumption is of crucial importance. Some structures have a real risk of moisture being trapped between two vapour retarding layers. To reduce the moisture risks the expert team recommended the application of a so-called hygro-diode membrane. However, this type of vapour retarder was not available in the Netherlands.

ACOUSTICAL QUALITY

During the last decades the acoustical quality of houses has been a subject to various evolutions in the national laws, standards and building codes. All aspects have been integrated into the new building regulations since 1992. Two major items have been of concern in the national housing policy: the effect of external noise (traffic noise) and the effect of noise transfer between dwellings. Due these developments the acoustical quality for new houses has been improved gradually. Acoustical quality was introduced as an topic in the Ecolonia project because it is one of the elements in the leading objective to improve the indoor environment. For the Ecolonia designs a set of requirements has been adopted that meets the targets in the new building regulations.
To reduce the sound transfer between houses all architects were asked to use a cavity wall construction with separated floors for the partition walls between dwellings. One architect was asked design a house with an improved acoustical quality. For this specific design the following targets were assigned compared to the standard targets:

- improve traffic noise attenuation with 5 dB
- improve index for airborne sound between dwellings with 5 dB
- improve index for impact sound between dwellings with 5 dB

To achieve the high impact sound attenuation between dwellings a unconventional partitioning of the foundation elements was applied in this design. Other special features of this design are the availability of a silent room and the use of acoustical dampened ventilation grilles mounted in the window frames.

THERMAL COMFORT IN WINTER

The design of the heating and ventilation system and their controls have a decisive influence on the thermal comfort

during the winter period. The expert team analyzed the system designs, in particular with respect to the sizing of the system capacities, the positioning of the air diffusers and the system controls. Some designs needed special attention because unconventional systems were proposed, such as the air heating systems and the wall heating system. The sizing of the air heating was critical for two reasons: the relatively large thermal mass of the houses and the design feature of using only one central air inlet per room. A central air inlet system was selected to limit the costs of ductwork. In combination with large window areas, as proposed in one design, comfort problems may be expected. In this case the air heating system was judged to be acceptable after some layout modifications of the house.
From the viewpoint of thermal comfort floor heating systems were preferred by the experts, but because of costs it was not accepted for all designs. Because of its expected favourable health prospects, floor heating was strongly recommended for the design with the "health" topic.

THERMAL COMFORT IN SUMMER

For passive solar houses overheating can be a problem during the summer period. Therefore, some designs were analyzed by the expert team to assess the thermal comfort in summer. Some modifications have been proposed, based on computer simulation results. Further, the architects were asked to consider the application of fixed or moveable external shading devices. Some specific design features in the Ecolonia project are the use of exterior window shutter system,
the use of vegetation as shading for the sunspace and the use of fixed shading elements at the south facade.

CONCLUDING REMARKS

Ecolonia is the first demonstration project in the Netherlands where an extensive attention is given to the integral approach to build energy-efficient houses with a minimal adverse environmental impact. During the design development stage as well as during the construction stage much knowledge and experience was gained by all groups that where involved. The Ecolonia project demonstrates the feasibility of energy- and environmental conscious houses. However, it was also recognized that new materials and new techniques may give arise to restraints and barriers in the building industry because of their traditional and conservative attitude. Knowledge and experience gained in the Ecolonia project is not only of importance for future projects but also for the future policy of the housing authorities.

REFERENCES

[1] Berns, W. Titie unknown, this conference.
[2] Draft PrEN 832 (CEN), 1992, "Thermal Performance of buildings - Calculation method of energy use for heating - residential buildings.
[3] Draft PrEN 32573 (ISO 12573).1992."Thermal bridges in building constructions - Heat flow and surface temperatures - General calculation methods.

TABLE 1 Overview of heating and ventilation system types in the Ecolonia designs.

DESIGN	HEATING SYSTEM	VENTILATION SYSTEM
1	3-zone air heating	balanced ventilation combined with heat recovery integrated in the air heating system
2	radiators (70-50)	balanced ventilation with alternating storage heat recovery
3	floor heating + radiators (70-50)	balanced ventilation with cross-flow air-to-air heat recovery
4	radiators (70-50)	exhaust mechanical ventilation system
5	radiators (70-50)	exhaust mechanical ventilation system
6	2-zone air heating	balanced ventilation with cross-flow air-to-air heat recovery
7	radiators (70-50)	exhaust mechanical ventilation system
8	floor heating + radiators (70-50)	balanced ventilation with cross-flow air-to-air heat recovery
9	wall heating	natural ventilation

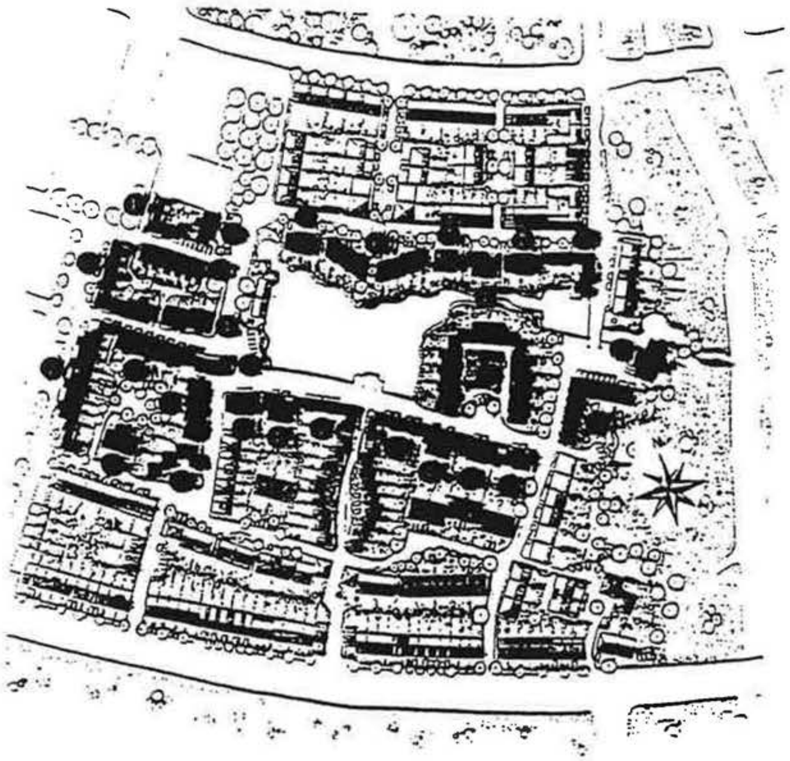
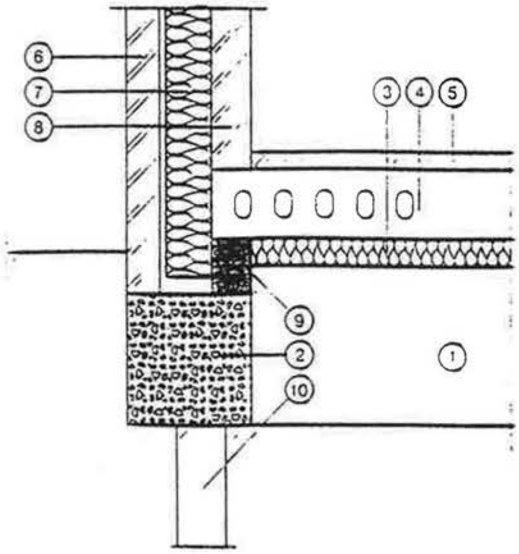


Figure 1 Urban design plan of the Ecolonia project



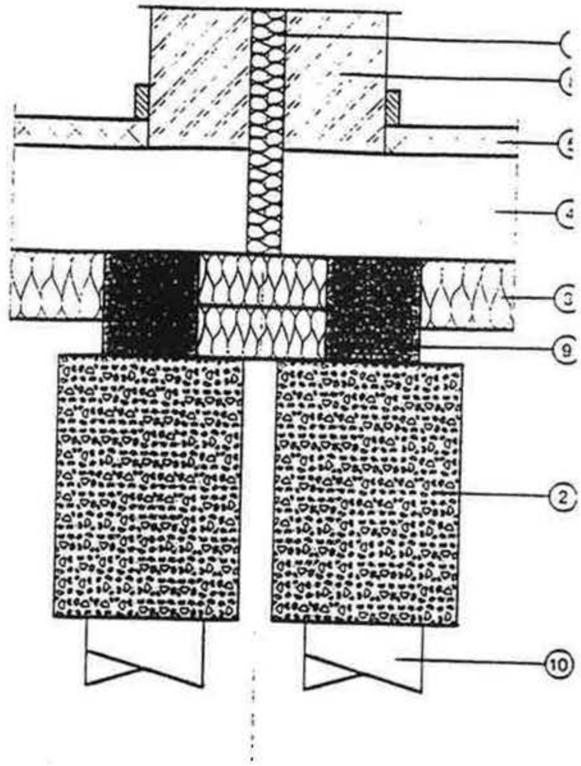


Figure 2:
Typical construction detail applied in the Ecolonia houses.

Figure 3:
Construction detail showing the partioning of the foundation of "Acoustical Quality" design topic.

Legend		
	1: crawl space	6: brickwork
	2: conrete foundation *	7: min. wool
	3: min. wool	8: lime sandstone elements
	4: concrete floor slab *	9: lime sandstone bricks
	5: anhydrite topmix layer	10: concrete pile *
	*: 20 % crushed concrete waste	

Figure 4: One architect introduced attached sunspaces in his design to comply his specific topic on the use of solar energy.

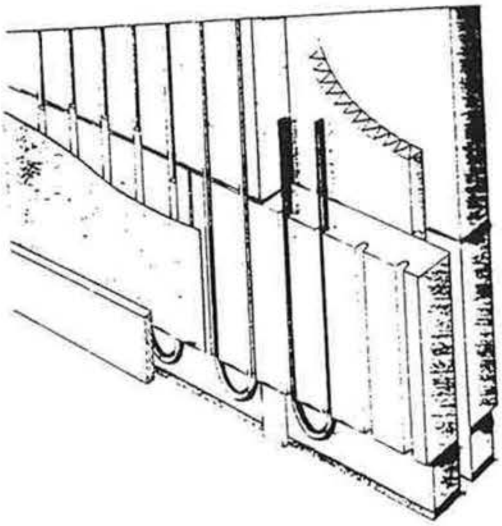


Figure 5: Wall heating system, introduced by the architect who followed the "bio-ecological" principles.

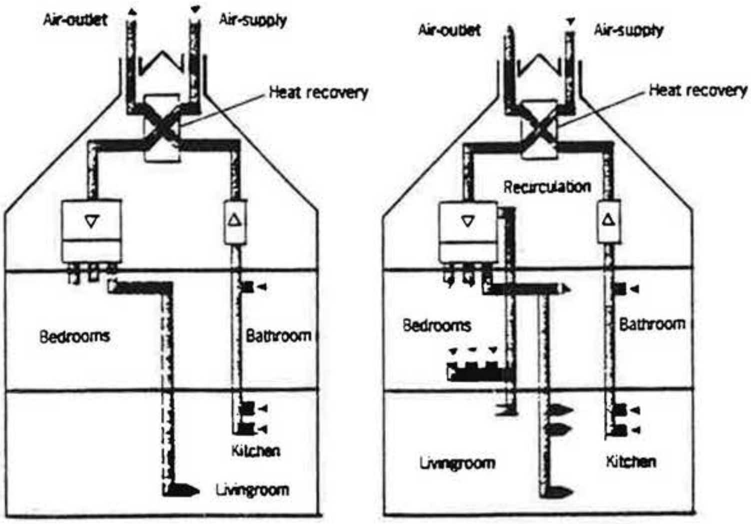


Figure 6: Principles of combined air heating and air-to-air heat recovery.