" Low-cost, Low-energy Demonstration Residential Buildings in the Czech Republic"

P. Neuwirthová, SEVEn – The Energy Efficiency Centre

ABSTRACT

SEVEn - The Energy Efficiency Center is a Czech non-governmental, non-profit organization focused on enterprise development, economically effective energy utilization and environmental protection.

Under the sponsorship of the Charles University Environment Centre, using United Nation Development Programme funding, at the present time SEVEn is implementing a project for construction of a low-cost, low-energy residential building.

The project aims at improving energy efficiency of newly built apartment buildings, design implementation of low-energy, low-cost residential buildings, as well as publicizing the practical experience gained amongst the professional and non-professional public.

In addition to construction of actual demonstration apartment blocks, part of the project includes other activities focused on analysis of available financial sources, verification of standards valid in this area and also promotion of education. Linking up with these activities, working seminars with participation of Czech and foreign specialists have been continuously organized.

At the project's core is not only defining repeatable principles and building one demonstration building but, primarily, creating an environment which allows implementation of similar buildings in the future without the need for special subsidies.

Description of the whole project

The objective of the whole project is to reduce the CO_2 emissions of the Czech Republic by improving the energy efficiency of the new buildings to be constructed in the country, and thereby simultaneously reducing the operational costs and increasing the comfort level of the apartments.

a) developing a design and implementation scheme for construction of new low-cost, low-energy buildings;
b) gaining, adopting and disseminating practical experience with developing low-cost low-energy residential buildings among all involved professional groups (architects, designers, developers, construction companies, investors);
c) strengthening the local capacity to develop low-cost low-energy building projects, preparing new energy standards for buildings, and designing a financial mechanism for a widespread expansion of similar buildings; ensuring that the investment costs of low-cost, low-energy buildings are comparable to the costs of a standard building, and that the investment costs of the building are to be covered by a local investor.

The project aims to reduce CO_2 emissions related to energy needs in newly constructed buildings by overcoming barriers that prevent the adoption of low cost low energy building development. The specific barriers in the Czech Republic to the development of those buildings include:

a) lack of practical experience among professional groups with the technical, economic, social and environmental aspects associated with low-cost, low-energy buildings;
b) lack of information to formulate new standards and proposals to promote the construction of low cost energy efficient buildings based on economic, social and environmental benefits associated with them;
c) lack of awareness on the part of decision makers, architects, builders and the general public of the possibilities and benefits of increasing the energy efficiency in buildings with little or no extra costs;
d) lack of expertise in incorporating measures and technologies to increase the energy efficiency in buildings in the planning and construction phases in a cost-effective manner;
e) remaining residential energy-price subsidies; and
f) lack of incentives and financial plans to support the higher up-front costs of currently designed energy efficient buildings.

First Demonstration Apartment House

In co-operation with the town of Sušice as the investor, construction of the first demonstration apartment house with 9 residential units was prepared for housing construction.

For a clear understanding of the objectives of the project, the agreed definitions of the concepts are the following. The capital expenditure will be fully comparable with common housing construction but the resulting energy intensity will be 40-50% lower in comparison with standard design (typical for a newly constructed building).

The Czech Republic lies in the temperate climate zone of Europe, which makes for pleasantly mild summers and winters with only moderate amounts of precipitation. Lowland temperatures in July average 20°C, and in mountainous areas 8 to 11°C. Lowland temperatures in January average -1 to -2°C, and -5 to -7°C in the mountains. In terms of Czechoslovak Standard, computational outdoor temperature in winter is -18^0 C.

For production of this design, an unorthodox approach has been chosen in which, besides a specialized design team, a multidisciplinary team of independent experts from the professional public, university circles and also participat in creation of actual building designs. In a common situation, the architect draws the building to a given terrain and after this other specialists start with the project according to common parameters. It was necessary to invite engineers and economist much earlier. This working team started with the formulation of a conceptual model (volume, orientation, building physics, environmental facilities, ...) and with combining of basic low-energy construction principles (without very expensive technical facilities). After the brainstorming they decided to use a principal of zoning – house with access galleries with a zone of small-unheated rooms (lumber-rooms), cloakrooms at one side and with zone of winter gardens at other side.

At the common apartment houses are the unheated spaces (like entrance halls, stairs) spaced in side of the disposition and in this way are passive heated from the flats. The resulting quality depends especially on the investor requirements and on the designer's willingness and capability to find an optimum solution fulfilling the given demands. In general, it can be presumed that improving thermal insulation of building results in increased costs, which must be reduced through energy-saving designs of all structural elements of the building.

The goal of the demonstration project was to envelop the heated space with unheated space, because thermal insulation with unheated spaces is cheapest. The project aim was to optimize thermal protection of the indoor environment and, at the same time to optimize common building structures.

Comparison of the Demonstration Low-cost low-energy residential House with the other low-energy realizations in the Czech Republic

Up to this day, the Czech Republic has realized only a few demonstration (experimental) housing buildings with lower energy consumption. These realizations have features with extremely high investment cost (several times higher investment cost in comparison with standard buildings) and mostly with untypical planning.

The first example shows a family house for five family members with a emphasis on energy self-sufficiency and environmental soundness.

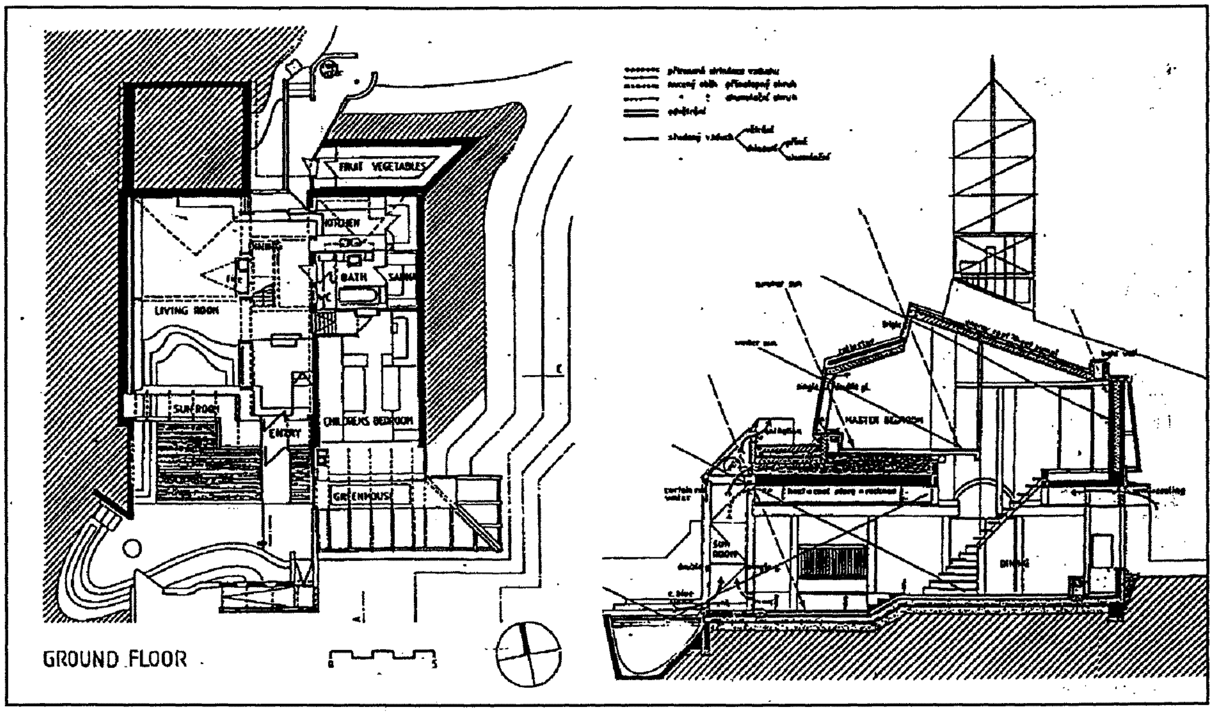


Figure 1 – Low-energy Family House of arch. Hrazdíra

The building's expression is consistently subordinate to bioclimatic technologies. The building is partially filled, the filled part is designed as a brick three-aisled barrel vault with aggregate filling. The construction has very high accumulation. The overground part is designed as a combination of a greenhouse and Trombe wall with maximum opening to the southern side. The built-up area was substituted by corrugating and sinking the house at the ground level and, at the same time, the water basin created a pleasant microclimate.

The masonry is concrete from full bricks with insulation, barrel ceilings from bricks, wooden ceilings are with thermal insulation on the second floor. Greenhouses from wooden profiles have single (production) and double glazing, plus inside double or single glazing. All glazing is at least triple.

Habitable rooms are southern facing. On the ground floor there is a greenhouse along the entire width of the building. Through regulation flap valves, the building can be cooled in hot weather, thus accumulating heat in the aggregate filling on barrel ceilings. Thermal radiation penetrating through the greenhouse is accumulated in parallel in the concrete floor with brick paving. On the top story a Trombe wall is used on the southern side of the front facade.

Warm air from the greenhouse is used for warm-air heating. In addition, utilization of solar collectors to heat up hot utility water is being prepared, as well as a heat pump and wind power plant in the tower above the building.

In the house is installed low-temperature central electricity heating (45 - 55^0 C) with a central accumulation container (6 m3) and reserved boiler susceptible for biomass.

The Second example shows the experimental solar house at the town Brno. It concerns an experimental low-energy to verify reduction of energy consumption recovered in a traditional manner with the help of renewable sources.

The enclosing shell is formed from 45-cm thick bricks with a high accumulation ability, the back part with water reservoirs is from cast concrete of the same thickness. The outer face of the envelope is thermally insulated by 20-cm thick Orsil mineral wool with a ventilated airway and timber formwork.

The roof structure from lightened panels is also insulated by 20-cm thick mineral wool.

The major part of the southern wall is transluminated by windows, it is supposed to function as an air collector. The air gap between panes of glass is part of the ventilation system. Air warmed up between panes of glass comes into two reservoirs filled with 120 t of aggregate where it transfers its heat. At night the heat from these reservoirs is again released.

The building has closed air circulation with recovery. On the roof there are 24 Heliostar vacuum flat plate collectors which serve for heating up of water in two tanks with the capacity of 2x50 m^3. The tanks are filled with clean water, which washes the mixture of water. The heat pump utilizes heat contained in reservoirs from the highest achieved temperature to the water hardening and then also the latent heat of water hardening. Warmth recovered in this manner is used for floor heating.

Experimentally verified is achieving an interior temperature of approximately $+5^0$ C during frosty weather without using interior heating. The builders′ intention was to achieve 70%-80% energy saving when compared with standard design.

At the present time the building is used for study and scientific purposes, although presentation of the architect's work as an example of a "correct model educational low-energy family house". Capital expenditures for the uncompleted work exceeded CZK 18 million (474 000 USD).

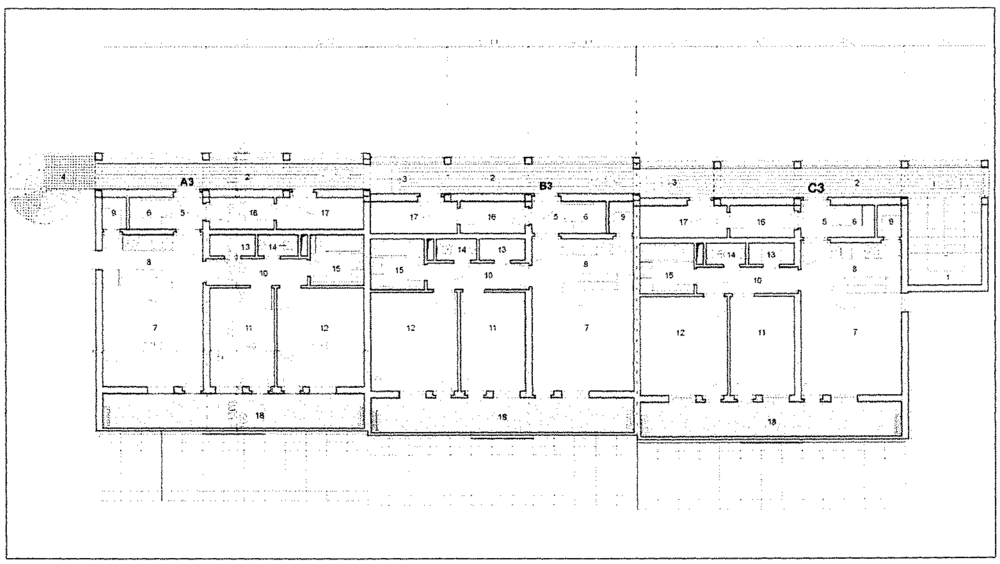
Figure 2 – The Experimental Solar House at Brno

Architectural Design of the Demonstration Apartment House

The architectural and structural design used is based on generally known principles of low-energy architecture and strives to combine and develop them in a suitable manner to conditions in the Czech Republic.

In the search for optimum shape and system combinations, (current knowledge and procedures are used) allowing modeling of architectural and physical properties of constructions, properties of the indoor environment and the energy intensity of the building. To ascertain optimum combinations of values of many parameters, dynamic modeling methods (ESP-r) were used (especially for counting of the inner temperatures in different zones).

The main feature of the proposed solution is simple and regular arrangement of dwelling space in the form of a slab block with residential space protected from the north by an unheated area of door space and storage space. Residential units are located in the layout centre and protected from the south by winter gardens en closed with simple, partially openable glazing. Subordinate to the simple shape of the building with an optimum ratio between internal volume and external surface, is the outside placement of vertical routes - entrance to flats through balcony corridors. At the same time, half-closed galleries form the building's protection against direct effects of wind.



Legend	
2, 5, 10	Entry corridor
6, 9, 13, 16, 17	Small unheated rooms (lumber-rooms)
8	Kitchen
7	Living room
11, 12	Rooms
15	Bathroom
14	Toilet
18	Winter garden

Figure 3 – Typical floor projection

Structure Design

The building is designed with a small-span transverse supporting structure. Concrete-block transverse bearing walls are proposed. Common floor structures are also designed as concrete, using filigrane panels and inlays from recycled plastic. Use of the thermally massive bearing structure is motivated by the effort to create a pleasant, stabilized indoor environment, especially in summer. The Supporting structures of the galleries and winter gardens are independent, separated from the thermally insulated interior space. These structures, as well as for the external part of the envelope, are planned to be built of wood.

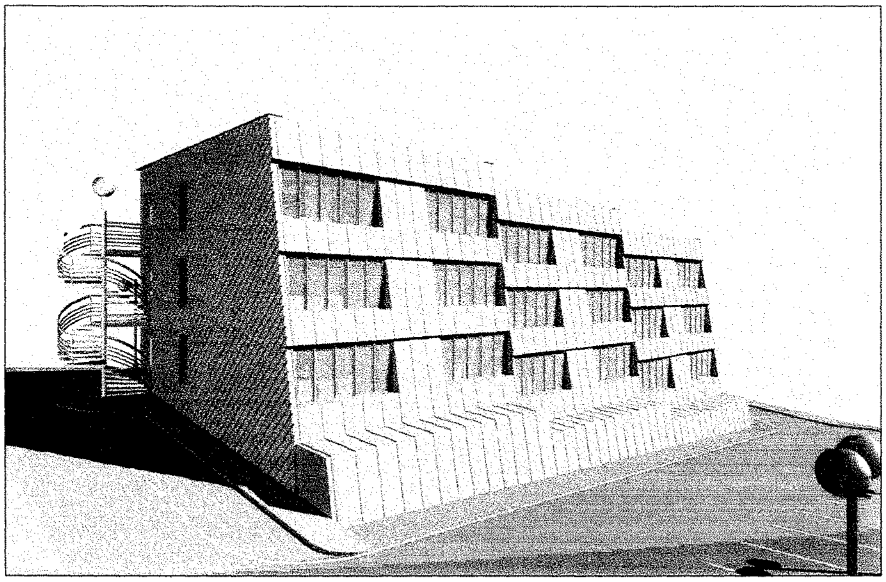


Figure 4 - Southwest view

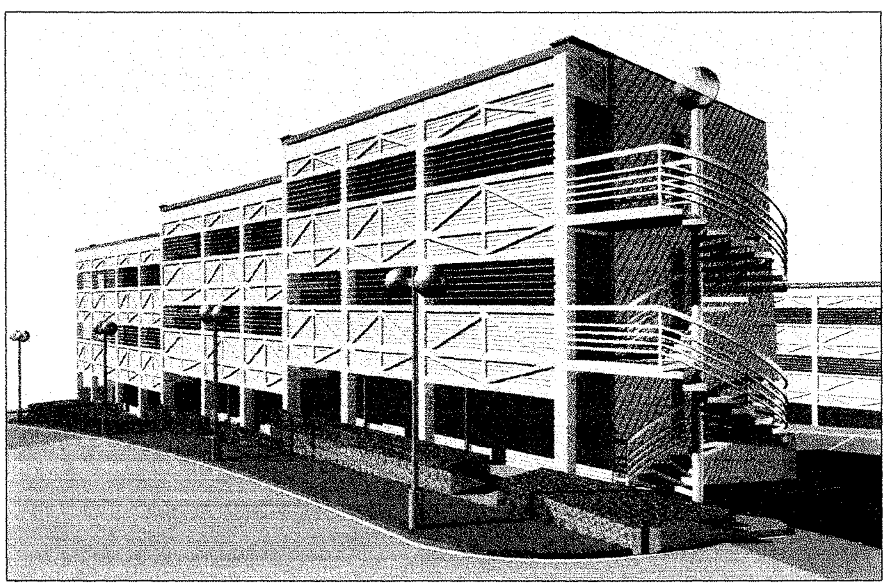


Figure 5 - Northwest view

Envelope structures are designed as sandwich-type allowing the use of relatively cheap thermal insulation made of mineral fibers.

Enclosing shell adjacent to the gallery is designed in the complex with unheated parts of flats. The design is based on the assumption that thermal insulation uses heat-insulating properties of the primarily unheated rooms (closets) and objects located in these rooms.

Structure of the enclosing shell adjacent to the gallery:

- External planking
- External 50-mm thick thermal insulation on the basis of mineral fibres
- Internal 50-mm thick thermal insulation on the basis of mineral fibres, inserted into a horizontal wooden grid
- In the door space and closets - vapour barrier, PE sheet 0.2 mm thick, or Sarnavap 1000
- Internal gypsum baseboard

Enclosing shell in the gable is designed in a laminated form with the bearing structure of the usual cross wall and with a 160-mm thick heat-insulating layer. The structure of the roof envelope is designed with the aim to exclude the risk of water condensation in wooden elements.

Structure of the enclosing shell in the gable:

- Internal lime-cement plaster
- Concrete-block masonry, 200 mm thick
- Vertical wooden grid 50/80 every 100 mm anchored in the concrete masonry (zinc-plated anchor) filled by Nobasil thermal insulation, 80 mm thick
- Oblique wooden grid 50/80 every 1000 mm filled by thermal insulation on the basis of Nobasil mineral fibres, 80 mm thick
- Protective layer (waxed paper, diffusively permeable sheet etc)
- Ventilated air void pocket, 25 mm thick, deliminated by a "counter board"
- Oblique board coating with details adapted to water outflow

Structure of the internal reinforcing wall:

- Internal lime-cement plaster, 15 mm thick
- Concrete masonry units filled with concrete, 200 mm thick
- Thermal insulation, 80-mm thick, inserted into the framed grounds 50/50 every 600 mm
- Gypsum plasterboard, 12 mm thick

Enclosing shell in the winter gardens:

- Outer plank facing
- External layer of 80-mm thick thermal insulation on the basis of Nobasil mineral fibres inserted into the horizontal framed grounds 50/50 every 800 mm
- Internal layer of thermal insulation on the basis of Nobasil mineral fibres 80 mm thick inserted into the horizontal framed grounds 50/80 every 600 mm
- Sarvanap 1000 vapour barrier
- Gypsum plasterboard, 12 mm thick

Because of the necessity of optimizing investment costs, windows are minimal to meet the health requirements for natural illumination of internal space so. Windows will be equipped with heat-insulating shutters, which should be used particularly to reduce thermal losses during long winter nights.

Window structures have uniform height of 1200 mm with sill walls at the height of 900 mm. The size of balcony doors is 700/2100 mm with a full, thermally insulated 900 mm high bottom part. The variable windows' width depends on the depth of rooms and rooms′ height in the building.

Wooden window structures are designed with minimum width of shading frames. Double-glazing units are considered with thermally reflective layers.

Windows will be provided with heat-insulating shutters (U=1.0 m2K/W) which should be used mainly to reduce thermal losses on long winter nights and also to reduce heat gains in summer. Window shutters are provided with a reflective layer from the internal side.

The purpose of full closure of winter gardens by a glazing layer is passive utilization of solar power to reduce the temperature gradient of the external enclosing wall (use of the greenhouse effect for warming up the winter garden space) as well as to reduce convention around the outer wall's surface.

With regard to the above-mentioned reasons, reduction of the overall heat transmission coefficient is not justified. Due to the energy balance, it is more suitable to improve the U-value of window structures in the enclosing shell.

The building has a single pitched roof, which also forms the ceiling above the topmost story. The actual roof structure is designed as double-skinned with a wooden bearing structure and roof covering on the basis of profiled sheets.

Table 1. Thermal Resistance for envelope structures

Construction	Thermal Resistant "R"	
	Czech Norm (m^2K/W)	Available Value (m^2K/W)
Roof	4,35	5,70
Floor on the soil	1,90	2,66
North walls	2,90	3,35
Shield walls		4,13
Winter garden walls		3,35

Table 2. "U" Value for Windows

Construction	"U" Value	
	Czech Norm (W/m^2K)	Available Value (W/m^2K)
Windows	2,90	1,60
Windows with blinds		1,05

Building Space Conditioning Facilities

Heating and ventilation of the low-energy residential house will provide warmth in winter and necessary healthy sanitary air change throughout the year. When designing the structural concept, requirements for low energy consumption and low costs for the system were respected.

The building is heated by a central hot-water system with a gas boiler allowing low-temperature operation. Heating is delivered through panel radiators, together with heating ladders in bathrooms. Regulation of the heating system is uniform throughout the building, in combination with thermostatic valves in individual heating appliances in places of thermal gains.

To achieve maximum saving of the thermal energy necessary for ventilation, a system of individually controlled apartment ventilation with heat recovery has been chosen.

Air inlets to individual flats are in habitable rooms, air flows out from bathrooms, kitchens and toilets. Cooking smells are removed through a circulation digester filled with active coal.

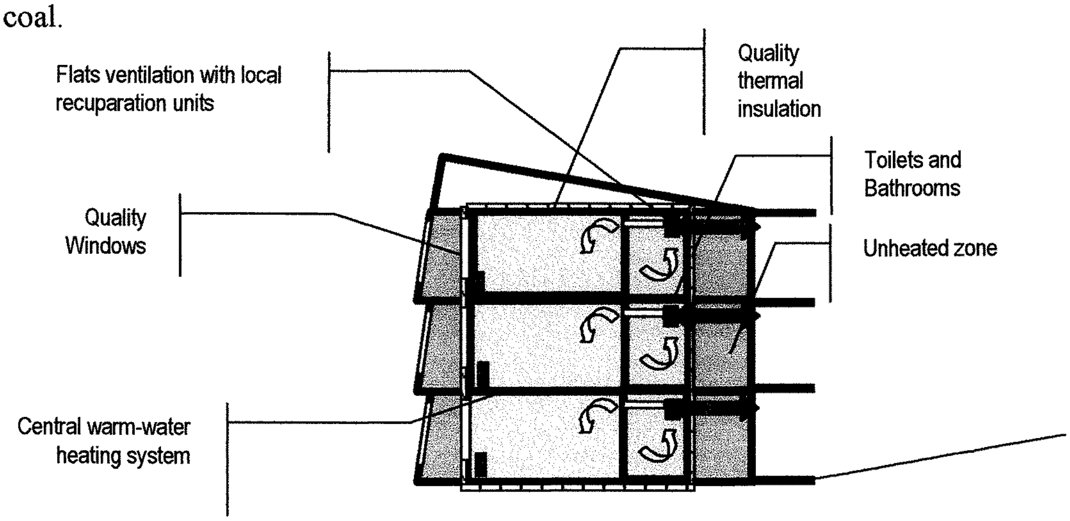


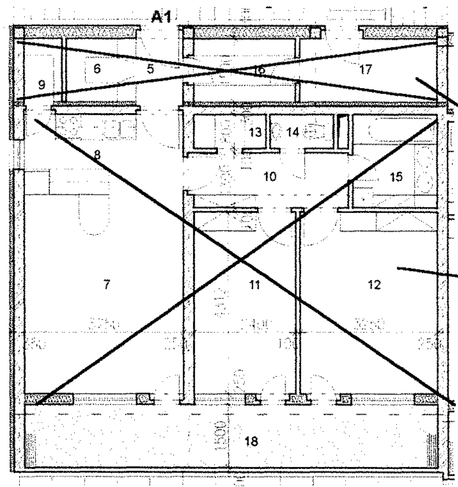
Figure 6 – Scheme of heating system and ventilation

When designing the building, the possibility of utilizing active and passive solar energy systems was investigated. Considered in the project's initial phase was use of a roof solar collector and an energy gravel storage tank located in the basement. Fresh air supplied to the building would be preheated in the gravel tank, then in the recovery unit, and subsequently heated up to the required temperature in the air heater in the air-conditioning unit. Although this approach to solar energy utilization evidently brings ventilation energy saving, the capital costs significantly exceed the energy gain; therefore, it was not used in the final optimized design.

For passive energy collection, all the building's window areas face south. Solar energy is primarily used to increase the average temperature in the recessed balconies and, thus, limit energy losses through outer walls and windows. For cost reasons, windows are used for passive collection recovery only to a limited extent.

Conclusions

Results of optimization studies show that the energy consumption issue must be understood in a wider context, especially in connection with investment and operational costs of the building.



Average non-heated flat area:	12,28 m^2
Average utilized flat area without loggia:	68,25 m^2
Average utilized flat area with loggia:	80,92 m^2
Average heated flat area:	55,97 m^2

Table 3 –Heated and utilized area of the building

Total Heated Area of the Building	m^2	503,77
Total Unheated Area of the Building	m^2	110,52
Total Utilized Area without Lodge	m^2	614,25
Total Utilized Area with Lodge	m^2	728,28
Total Consumption for the Heating and Hot Water Preparation	kWh/year	32 951
Total Consumption Based to the Utilized Area	kWh/m^2	53
Total Investment Cost	CZK (USD)	11 300 000 CZK (297 400 USD)
– Based to the Heated Area	CZK/m^2 (USD/m^2)	22 430 CZK (590 USD)
– Based to the Total Utilized Area	CZK/m^2 (USD/m^2)	15 516 CZK (409 USD)

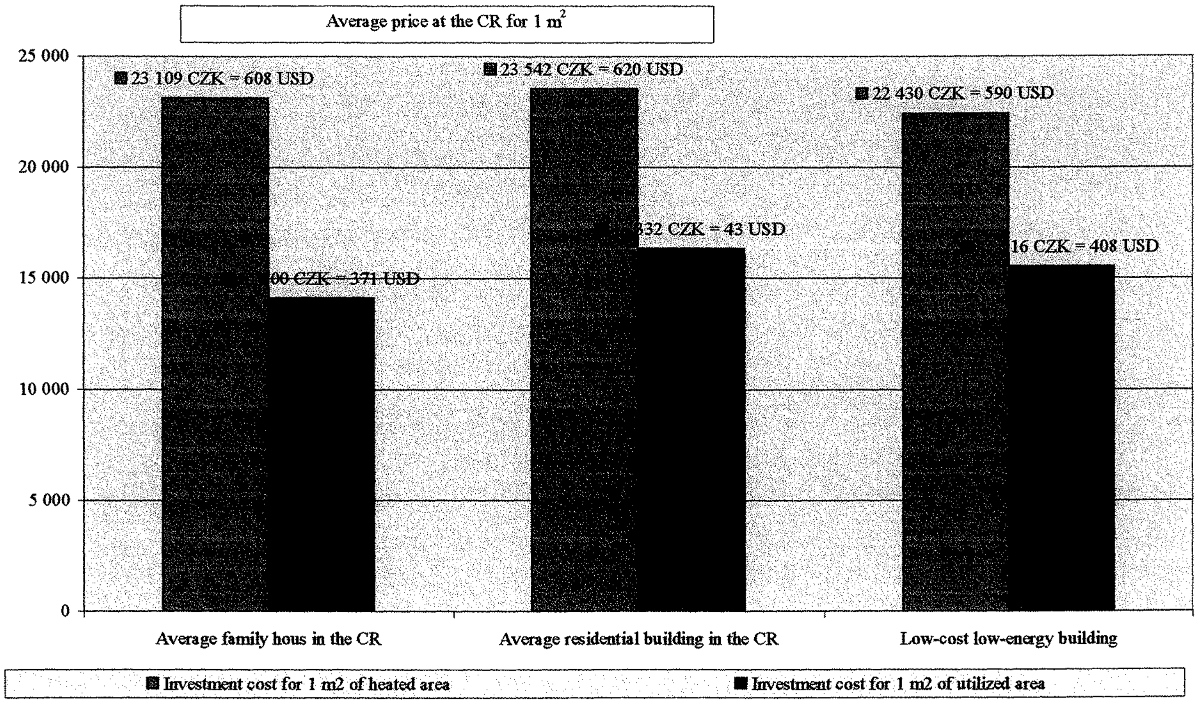


Figure 7 –Investment Cost of Low-cost Low-energy Building in Comparison with Average Investment Cost of Residential Buildings in the Czech Republic

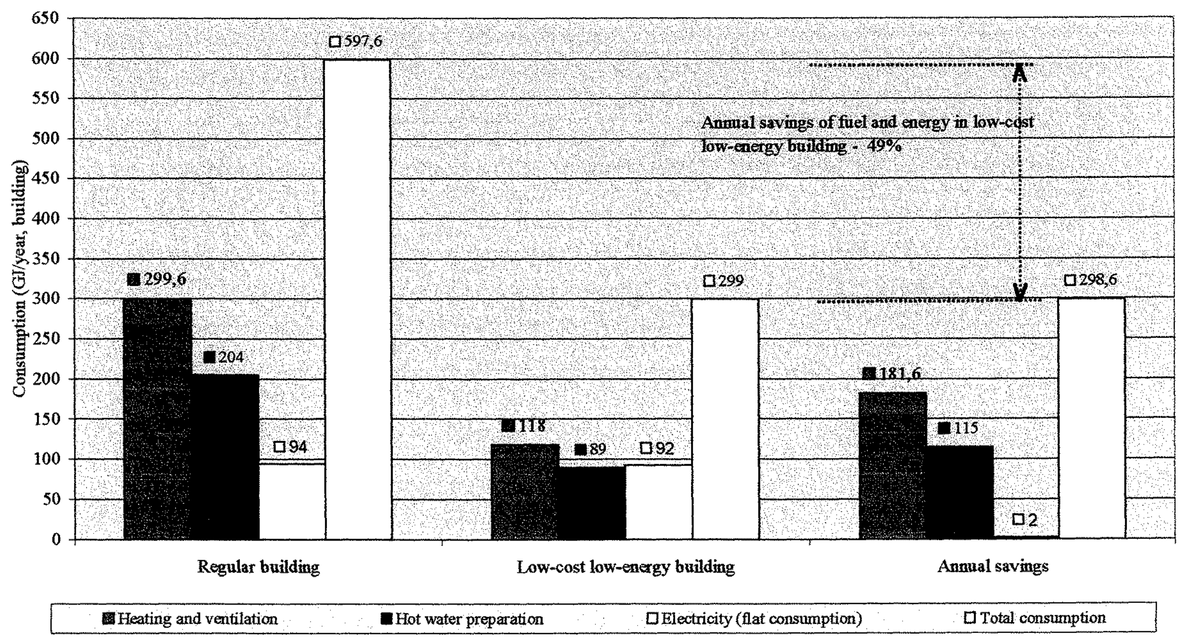


Figure 8 – Consumption of Fuel and Energy in Low-cost Low-energy Building in Comparison with Regular Building

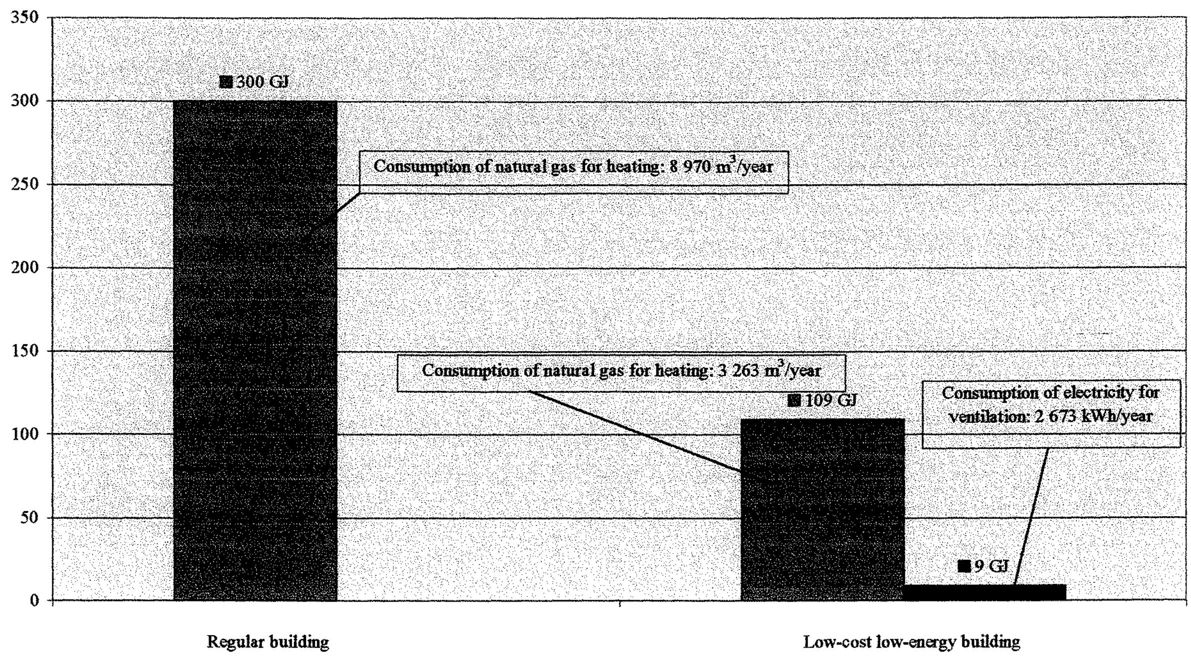


Figure 9 – Consumption of Fuel and Energy for Heating and Ventilation

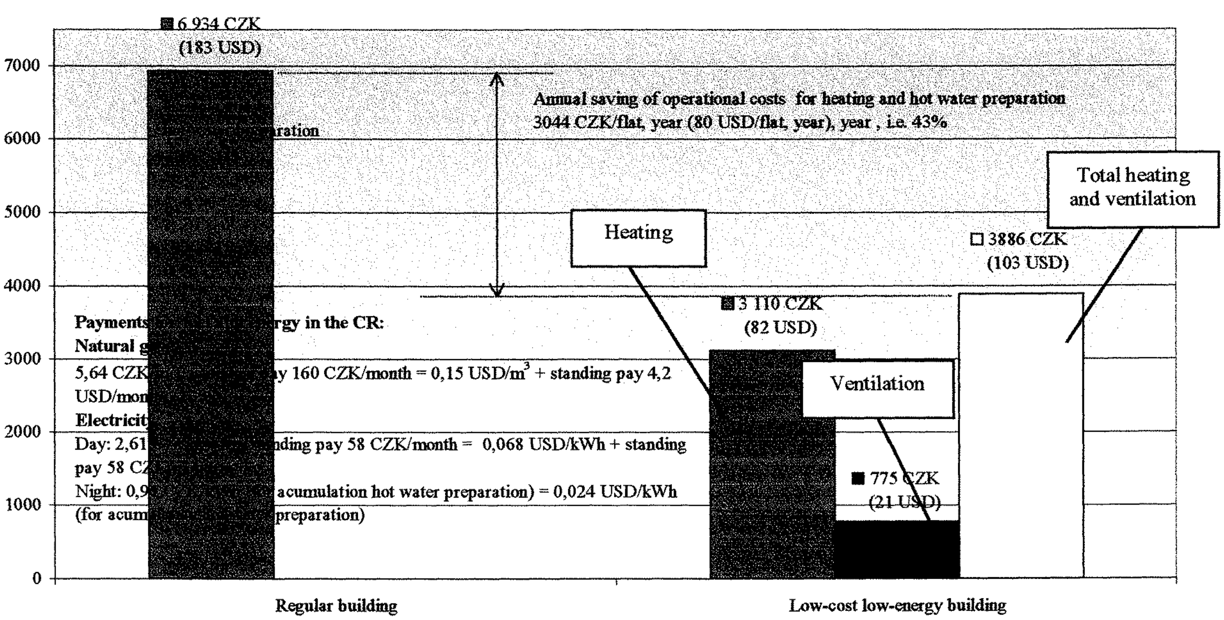


Figure 10 –Year Operational Cost for a Residential Unit in Comparison with Regular Building According to the Czech Requirements (in 2000 Prices)

The definition of the term "low-energy" or "energy saving" in not distinct defined in Czech norms. For the orientation is possible to use the definition of the Czech Energy Agency according to the next table.

Table 3 –Heated and Utilized Area of the Building

Building	**Energy Consumption for Heating** (MWh/200 m^3)	
	New Building	**Reconstruction**
Requirements till 1992 Residential Buildings	7,3 (104 kWh/(m^2a)	9,3 (133 kWh/(m^2a)
Energy Savings Projects for the Czech Energy Agency Residential Buildings Family Houses	5,0 (71 kWh/(m^2a) 5,5 (79 kWh/(m^2a)	-
Modernization of Existing Buildings Residential Buildings Family Houses	-	Minimal 30% of Savings Max 7,0 (100 kWh/(m^2a)

It starts from traditional valuation of buildings, there is determined year consumption of energy for heating of the norm flat with 200 m^3 size. Flats and Houses with different size are re-counted for this capacity.

Energy consumption of the demonstration apartment house as designed is 53 kWh/m^2 a year (3,6 MWh/200 m^3), with capital costs of CZK 11 300 000CZK (297 400 USD)/apartment house with 9 living units (flats). Average heated area is 60 m^2, total flat's utilized area is 81 m^2.

The ultimate goal of this project is to attain environmental benefits with no additional investment costs. After reaching a sufficient penetration rate in the residential sector and decreasing the investment costs sufficiently, low-cost low-energy buildings are expected to become attractive to private investors even without any special subsidy schemes. Besides the residential sector, the low-cost/low-energy concept could also be replicated in the commercial sector.

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