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Demonstration Project for Energy Efficiency in Multi-dwelling Houses with Individual Heating Radomir town, Bulgaria

CASE STUDIES REPORT

Introduction:

In the frame of the “Demonstration Project for Energy Efficiency in Multi-dwelling Houses with Individual Heating” were used different technologies for refurbishment and different energy saving measures in three multi-dwelling panel buildings. Before the refurbishment these dwellings had the same characteristics. The improvement of the energy performance is different in the three buildings and we should examine each building as a different case study with regard to the different technologies used for the refurbishment.

General data for the three case studies

The demonstration project was financed by the Phare Programme of the European Commission. The Contracting Authority and project supervisor was the Committee of Energy. The project was carried out by the Greek consulting firm EXERGIA S.A. in consortium with ENERGOPROEKT, Bulgaria and ICEU, Germany.

The official starting date of the project was the 23.06.1995. The duration of the project was 41 months.

1. Selection of demonstration buildings

The selection of typical buildings as demonstration sites was very important for the successful implementation of the whole project. The criteria for selection of the demonstration buildings have been defined, viewing the following issues:

- Representative characteristics of the demo buildings;
- Typical energy and heat supply patterns;
- Conditions for project organisation, execution and monitoring;
- Financial and technological issues;
- Occupants and local authorities support;
- Convenience of the demo site location for further scientific exploitation of the demo buildings.

The target group for future introduction of energy efficiency measures in the multi-dwelling houses with individual heating in Bulgaria are the households, occupying these dwellings.

The demo buildings should be typical regarding:

- o Their external envelope – walls: three layer prefabricated components, roof: flat roof with two slabs and thermal insulation over the internal slab, windows: double glazed wooden windows with connected wings and structure – prefabricated components,
- o Number of floors and apartments – 4 to 9 floors, 8 to 36 dwellings in one section (with one staircase);
- o Building orientation – east-west orientation of the apartments and a staircase to the north;
- o Location – demonstration site with longer heating season, acceptable construction, installation and transport conditions;
- o Space-heating mode and energy demand – electric space heaters and solid/liquid fuel fired stoves;

- o Ownership of apartments – owner occupied dwellings;
- o Management and maintenance practice – only emergency repairs;
- o Current state and age of buildings – 10-20 years.

The analysis of the current situation of the dwelling stock in Bulgaria shown that the efforts should be concentrated on the average and small towns where neither district heating nor gas supply are available. The multi-dwelling panel buildings prevail in the building stock. Because of a bad quality of erection their thermal characteristics are compromised and this type of buildings seems to provide a decreased comfort.

Six multi-storey residential buildings, composing a building complex, have been selected as demonstration sites. They are situated at the entrance of Radomir town. The town of Radomir has a population of 17900 inhabitants and 7427 buildings from which 3969 are panel type buildings. The selected building complex has been erected around 1980 using prefabricated concrete panel construction method.

The major part of the demonstration works was decided to take place in three out of the six buildings. Interventions refer both to the:

- Refurbishment of the building envelope and
- Intervention in the space and water heating systems.

2. Description of the buildings

2.1 General characteristics of the building's structure and materials

Block 1 is located on the outskirts of Radomir at an altitude of 750 m. Positioned roughly along a north-south axis; it is situated at the southernmost point of a triangular group of similar buildings. The entrance to Block 1 is located on the west side, Blocks 2 and 3 are accessed from the east. The blocks are close together but not structurally connected. Each floor has three self-contained flats of different sizes provided with a number of balconies, some of which are glazed.

BUILDING	N°1	N°2	N°3	N°4	N°5	N°6
Number of storeys	7	8	8	9	8	6
Number of apartments	21	23	23	27	23	18
Typical floor area (m^2)	217	217	201	217	195	217
Typical storey height (m)	2,8	2,8	2,8	2,8	2,8	2,8

The external walls of the buildings consist of large prefabricated concrete slabs about 20 cm thick. The concrete slabs were delivered to the building side already plastered and/or rendered on either side as required. The density of the interior plaster was assumed to be 1200 kg/m^3, with 1400 kg/m^3 for the external rendering and 2400 kg/m^3 for the concrete. The theoretical U value for concrete panel with plaster layers is about 2.9 – 3.0 W/ m^2K.

The windows are composite thermo-windows with wooden frames with a theoretical U value 2.6 W/ m^2K. The window frames had cracks and misfits that caused significant heat losses. In many cases outer glasses are not properly tightened to their frames and windows are not sealed. As a result of this, the double-window insulation properties are partially lost. The situation was even worse in areas of common use. The windows in the corridors, main entrances and staircases had broken glasses, cracks and gaps. As the buildings were under-heated, the temperature in these areas does not differ much from the outside temperature.

Many balconies have been modified to an extra small room through glazing with single windows on metal frames. These extra glazing needed an improvement as they were of poor quality.

The roofs consist of two concrete slabs with a thermal insulation on the lower slab. This insulation was very poor. Moisture has been identified on the ceilings of several apartments because of water proofing problems. Such problems have been found even at the first floor as water flows down through piping and other channels of the buildings.

The floors are not insulated. Their structure is reinforced concrete prefabricated slabs 15cm thick.

Basement slabs were not insulated.

Cold bridges were not insulated.

2.2 Space heating and hot water supply

In the past all six buildings were connected to the local district heating system. This system stopped operating due to financial problems and it is not expected to operate again in the near future. As the whole system is either in bad condition or completely destroyed, the required investment to start it up again would be very high.

The consumer installations are of double pipe with conventional substations in the basement. The visual inspection of the systems in the six buildings showed that they are in a relatively good condition without major corrosion problems. However, the systems should be tested under pressure to identify and repair possible leakages. Most of the radiators are still connected to the systems. In a few apartments the radiators have been disconnected by the owners, either to gain some space or to connect them with electrical boilers.

The apartments did not enjoy heat comfort. About 55% of the rooms were not heated at all. The remaining rooms were mostly heated by means of electrical radiators or heat accumulators. Even the “heated” rooms were not heated permanently. In practice, in most apartments there were one room that was heated and a second room that was heated when this was absolutely necessary. The following table summarises the heating practices before the refurbishment:

BUILDING	N°1	N°2	N°3	N°4	N°5	N°6
Total number of apartments	21	23	23	27	23	18
Number of apartments using mainly:						
• Electrical radiators (of different type)	15	18	17	23	15	14
• Electrical heat accumulators	10	6	7	4	7	6
• Wood or coal stoves	1	2	1	1	4	1
• Propane-butane gas	-	-	-	-	-	-
• Other	-	1	-	1	4	-
Total number of rooms (including kitchens, bathrooms, etc.)	90	101	68	116	76	78
• Number of rooms with space heating	40	39	36	53	32	34
• Number of rooms without space heating	50	62	32	63	44	44

Hot water for use was almost exclusively produced in electrical heaters of storage or of through flow type.

The carried out energy diagnosis of block1 evaluated the specific energy consumption of the building at 373,23 kWh/year. This figure is similar for the other five buildings.

3. Technologies of refurbishment

3.1 Insulation of external walls on blocks 1, 2 and 3

The successive layers of the structure starting from the external wall are:

- Glue (on existing plaster)
- Slabs of insulating material – Fibran BT 3,4 and 6cm thick
- Thin layer of plaster – Teracol + cement 0.1cm
- Reinforced fibreglass grid
- External layer of plaster – lime + cement 1.5 cm
- Finishing layer of plaster – FASAGEN AK - 1

The used insulating material is Fibran, extruded polystyrene foam classified within thermal conductivity group WLG 040. Fibran is a new insulating material, which features good thermal insulation properties, low water absorption and high compressive strength. Certified pursuant to ISO 9002. Fibran is manufactured without using halogenated driving gases, thus making it free of all substances that could damage the ozone layer. Consequently, Fibran only contains air in its cells. As well as being ecologically sound, stationary air has very good thermal insulation properties.

Fibran's advantages include the ability to bridge over existing cracks without causing any problems. Moreover, using Fibran linked to plasterboard for exterior insulation is a relatively inexpensive solution for selectively lowering outward heat transfer. It should be noted that facade masonry with a moisture content exceeding 2% by mass should not be fitted with plastered exterior insulation, otherwise the plaster is liable to become very damp in the area of the joints in the thermal insulation board and may even crack.

The boards were bonded to the plasterboard and mounted directly (bonded) on the wall. The plates featured a groove so that the plates can be fastened to the wall using special dowels.

The chosen insulating thickness improved the U value from 2.9 – 3.0 W/ m²K to 0.52 0 W/ m²K.

3.2 Water proofing and thermal insulation of roof on blocks 1, 2 and 3

The successive layers of the structure starting from the first (lower) slab are:

- Existing coat of Keramsit
- New coat of Keramsit Thin layer of plaster – Teracol + cement 0.1cm
- Keramsit concrete 2mm thick

The successive layers of the structure starting from the second (upper) slab are:

- Equalizing cement plaster
- Bitumen primer coat
- Water-proofing membrane "NORDGUM"
- Water-proofing membrane "NORDGUM" with mineral coat

The top-storey ceiling, two concrete slabs, was provided with a 5cm-thick layer of Keramzite concrete, a very environmentally friendly fill that is similar to expanded perlite. This fill improved the U to 0.80 W/ m²K.

3.3 Insulation of the basement ceiling on blocks 1, 2 and 3

The insulation of the basement ceiling was performed by mounting "Fibran GT" boards 39 mm thick on the concrete slab using plastic dowels.

3.4 Repair of existing wooden windows on blocks 1 and 3

In Block 1, it was decided to retain the wooden frames of the thermo-windows. As the transmission values of double-glazed windows and windows with insulating glazing hardly differ, it is often not worth replacing double-glazed windows or winter windows if they are in a good condition.

<u>The advantages of a wooden frame:</u>

- low heat conductivity (λ = .14 W/mK) and low dry unit weight (p = 400...700 kg/m²)
- Flexible with regard to cross-sections, structure, size
- Recyclable material
- Low thermal expansion ($\varepsilon = 5.10^{-6}$ m/mK), which means that a wooden window adjusts to masonry much better than a plastic window; therefore, the masonry surrounding cannot tear or "break out".

A plastic window has high thermal expansion ($\varepsilon = 80*10^{-6}$ m/mK), which means that one should restrict oneself to window sizes!

The plastic window has a low modulus of elasticity ($E = .255*10^{4}$ N/mm²) and therefore it requires reinforcement from aluminium or steel. Furthermore, the reinforcement acts as a heat build-up.

3.5 Replacement of windows and closing of balconies on block 2

The wooden windows and balcony doors of block 2 were replaced with PVC windows with an U value < 2,0 W/m²K. North facing balconies of block 2 were closed with PVC windows.

3.6 Replacement of the main entrances' doors on block 1, 2 and 3

The wooden joinery of the main entrances was replaced with PVC windows and doors.

4. Improvement of the heating systems

4.1 New boilers in blocks 2 and 3

New boilers for space heating were installed in blocks 2 and 3. In the following table are given the main characteristics of the boilers:

Type of unit:	Special automatic boiler with a blower
Output:	80.0 kW
Year of construction:	1997
Fuel:	Oil
Distribution:	Central
Annual utilisation ratio:	0.912
Boiler efficiency:	0.935
Stand-by losses:	0.001
Stand-by time:	6,000.000 h/a

This unit operates in the low-temperature range.

4.2 Operation geared to energy-saving in blocks 1 and 2

A whole series of energy-saving measures in the area of heat control that are purely mechanical and so require practically no investment whatsoever were implemented in blocks 1 and 2. The most important of these measures are as follows:

- Presetting heat radiation (valve lift stop on each of the heating unit valves). This was designed to provide an even distribution of room temperature in all of the rooms of the building. The circulation pump's capacity should also be set as necessary.
- Optimum adjustment of the heating curve with weather-dependent flow temperature regulation. Correctly setting the target value helps maintain the desired mean room temperature in the building throughout the heating season without the need for readjustment.
- Fixing of thermostatic valves on radiators
- Fixing of timer-controls on radiators
- Additional regulation
- Fixing of heat meters on radiators

4.3 Installation of electrical heat accumulators for space heating in block 3

In block 3 were installed electrical heat accumulators for space heating in all premises.

4.4 Installation of electrical heaters for hot water in blocks 1, 2 and 3

For hot water supplying were installed electrical heaters in each flat.

5. Case studies

5.1 Case study 1: Radomir block 1

General description of the building:

Type of building: multi-dwelling building of seven storeys

Type of construction: prefabricated concrete panels

Number of flats: 21

Year of construction: 1980

Typical floor area: 217 m²

Typical storey height: 2,8 m

Heating: individual heating

Technologies of refurbishment:

Building envelope:

- Thermal insulation of exterior walls with extruded polystyrene
- Water proofing and thermal insulation of roof with Keramsit
- Basement ceiling insulation with extruded polystyrene
- Repair of existing wooden windows
- Replacement of the joinery of the main entrance
- Air stops in the building joints

Space and water heating:

- Installation of new boilers and space heating systems
- Installation of hot water electrical heaters

Calculated energy savings:

Annual fuel requirements per m² of gross building area (including non heated spaces):

- Before the refurbishment 197,8 kWh/m²
- After the refurbishment 106,7 kWh/m²
- **Energy savings 46%**

Before the refurbishment

5.2 Case study 2: Radomir block 2

General description of the building:

Type of building: multi-dwelling building of eight storeys

Type of construction: prefabricated concrete panels

Number of flats: 23

Year of construction: 1980

Typical floor area: 217 m²

Typical storey height: 2,8 m

Heating: individual heating

Technologies of refurbishment:

Building envelope:

- Thermal insulation of exterior walls with extruded polystyrene
- Closing with aluminium windows and thermal insulation of balconies on North side
- Water proofing and thermal insulation of roof with Keramsit
- Basement ceiling insulation with extruded polystyrene
- Replacement of old wooden windows and balcony doors by new double glazed aluminium ones
- Replacement of the joinery of the main entrance
- Air stops in the building joints

Space and water heating:

- Installation of new boilers and space heating systems
- Installation of hot water electrical heaters

Calculated energy savings:

Annual fuel requirements per m² of gross building area (including non heated spaces):

- Before the refurbishment 191,9 kWh/m²
- After the refurbishment 101,5 kWh/m²
- **Energy savings 47%**

During the refurbishment

5.3 Case study 3: Radomir block 3

General description of the building:

Type of building: multi-dwelling building of eight storeys

Type of construction: prefabricated concrete panels

Number of flats: 23

Year of construction: 1980

Typical floor area: 201 m²

Typical storey height: 2,8 m

Heating: individual heating

Technologies of refurbishment:

Building envelope:

- Thermal insulation of exterior walls with extruded polystyrene
- Water proofing and thermal insulation of roof with Keramsit
- Basement ceiling insulation with extruded polystyrene
- Repair of existing wooden windows
- Replacement of the joinery of the main entrance

Space and water heating:

- Installation of electrical heat accumulators
- Installation of hot water electrical heaters

Calculated energy savings:

Annual fuel requirements per m² of gross building area (including non heated spaces):

- Before the refurbishment 166,2 kWh/m²
- After the refurbishment 89,7 kWh/m²

➢ **Energy savings 46%**

After the refurbishment

6. Comparison of the results

Types of implemented energy saving measures:

Type of intervention	Build. 1	Build. 2	Build. 3
1. BUILDING ENVELOPE			
Thermal insulation of exterior walls	X	X	X
Closing of balconies		(X) north side	
Water proofing and thermal insulation of roof	X	X	X
Basement ceiling insulation	X	X	X
Windows replacement		X	
Repair of existing wooden windows	X		X
Replacement of the main entrances	X	X	X
Air stops in the building joints	X	X	
2. SPACE AND WATER HEATING			
Boilers and space heating systems	X	X	
Electrical heat accumulators			X
Hot water electrical heaters	X	X	X

Annual requirements for fuel:

ANNUAL REQUIREMENT FOR FUEL PER M² OF THE WHOLE BUILDING'S AREA	OLD	NEW
Building №1 (oil in kWh/m²)	197,8	106,7
Building №2 (oil in kWh/m²)	191,9	101,5
Building №3 (electricity in kWh/m²)	166,2	89,7

ANNUAL REQUIREMENT FOR FUEL PER M² OF HEATED AREA	OLD	NEW
Building №1 (oil in kWh/m²)	244,9	132,1
Building №2 (oil in kWh/m²)	238,4	126,1
Building №3 (electricity in kWh/m²)	206,5	111,4

Economic effect:

The economic effect of the measures for thermal insulation of the buildings' envelopes is based on the presumption that the buildings are normally heated.

MEASURES FOR THERMAL INSULATION	PAY-BACK PERIOD			
	Building № 1 oil	Building № 2 oil	Building № 3 electricity	Total
Thermal insulation on walls	6,9	6,6	14,0	**8,2**
Thermal insulation on roof (without water-proofing insulation)	4,0	3,7	8,6	**4,7**
Thermal insulation and water-proofing insulation on roof	13,3	12,5	28,9	**15,7**
Thermal insulation on the basement's slab	7,4	7,3	19,1	**9,4**
Repair of wooden windows	2,4		5,3	**3,9**
Change of windows		20,0		**20,5**
Total energy efficient measures on the building's envelope	**6,0**	**10,8**	**12,0**	**9,2**
Total energy efficient measures on the building's envelope and installation of local heating system	**8,9**	**13,5**	**13,6**	**11,7**

General country data

Country: BULGARIA

Climate and geography

The Republic of Bulgaria is located in the southeastern part of Europe in the Balkan Peninsula. The country borders on Turkey and Greece to the south, Former Yugoslav Republic of Macedonia and Serbia to the west, Romania to the north and the Black Sea to the east. The total area of the country is 111 000 km².

The climate is temperate with four distinctive seasons and varies with altitude and location. The Black Sea coast features a milder winter as opposed to the harsher winter conditions in the central north plains. For example, the average monthly temperatures for the capital city Sofia range from –3,7°C in December to 28,2°C in August. The duration of the heating season varies between 160 and 220 days for the different locations.

The average wind speed is 1,2m/s (1,3m/s in winter time), while prevailing winds are west or northeast.

The following table presents the average monthly temperatures for various Bulgarian cities, situated in the north, the west, the south and the east part of Bulgaria.

Month / Town	Pleven	Sofia	Pazardzhik	Varna
January	0.9	-1.9	0.0	2.0
February	7.8	5.4	6.1	7.4
March	9.6	7.5	8.7	8.4
April	11.1	9.2	10.6	10.2
May	19.1	16.0	17.0	16.4
June	22.4	20.2	22.4	21.0
July	24.3	22.0	23.9	25.1
August	21.7	19.3	21.3	22.9
September	17.6	15.0	16.8	18.1
October	12.1	10.9	12.1	13.8
November	7.4	6.6	7.2	10.6
December	-2.5	-0.1	0.8	1.8
Average annual value	**12.6**	**10.8**	**12.2**	**13.1**

Average monthly temperature, °C (2002)

The heating degree days for indoor temperatures of 20°C vary between 2100 and 3500 for different regions in Bulgaria. For Sofia and Radomir these are 2500 on average.

Demography

The population of the country dropped from 8 950 000 in 1985 to 7 845 800 in 2002. Apart from the negative natural growth, the drop was caused mainly by a steady emigration trend. More than 500 000 people have left the country over the last decade. Currently 69% of the population lives in urban areas and 31% in rural areas. The average live expectancy is 68.54 years for men and 75.37 years for women.

Basic social and economic indicators

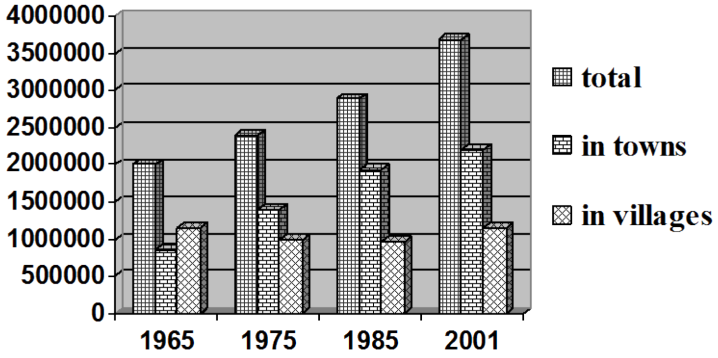
There were big changes in the economic situation in Bulgaria during the last 15 years. The GDP dropped from 45390 millions Levs[1] in 1990 to 17433 millions Levs in 1997. After 1997 the economic situation in the country shows a steady trend to improvement. The GDP reached 32324 millions Levs (16527 millions EURO) in 2002.

The net average annual household income per capita reached 1985 Levs (1015 EURO) in 2002.

[1] 1 Euro = 1,9558 Levs

The building stock

Towards 01.03.2003 the housing stock in Bulgaria amounted to 3 688 802 dwellings from which 328 726 in buildings for temporarily inhabitation (rest houses, villas, etc.) and 7 851 are primitive dwellings. The amount of the other dwellings is 3 352 225 and represent an increase of 9.4% in comparison with the registered dwellings during the 1992 Public Census. The uninhabited housings represent 15.9% of the whole dwelling stock, this is due mainly to the decrease of the population (from 1992 to 2001 the population has decreased by 554 333 people).

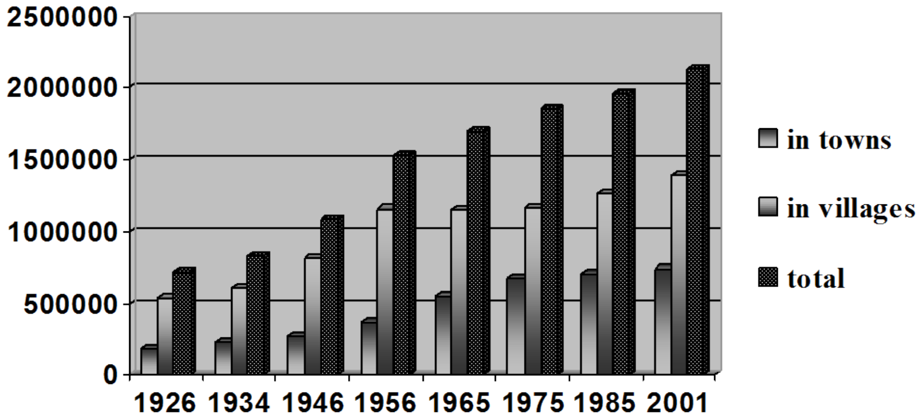


Housing stock by Public Census years

The amount of the housing stock is 422 dwellings per 1000 capita, which is a good figure. Nearly 16% of the dwellings are not inhabited, this could be a good factor with regard to the possibility for a higher mobility, but most of them are in unattractive regions or in bad condition.

The dwelling buildings stock

Towards 01.03.2003 the dwelling buildings stock in Bulgaria amounted to 2 124 533 buildings from which 740 450 are in the towns and 1 384 083 in the villages. For the period 1926 – 2001 the trend is towards increasing the number of dwelling buildings. The highest increase is in the period 1946 – 1956. For the last 15 years the dwelling buildings stock has increased with 8.2%.



Dwelling buildings stock by Public Census years

The oldest part of the building stock (erected before 1919) represents 2.35% of the whole building stock and includes 90278 dwellings.

49.7% of the buildings are erected after 1970.
Most of the dwelling buildings in the country are one-storied single family houses (64.1%) and two-storied single or double family houses (31.4%). 4.5% of the dwelling buildings are multi-storied buildings. The housings in high dwelling buildings (6 and more storeys) are 16453.

	TOTAL	number of storeys			
		1	2	3-5	6 and more
In towns	740450	410987	247846	65239	16378
In villages	1384083	951668	419364	12976	75
TOTAL	**2124533**	**1362655**	**667210**	**78215**	**16453**
%	**100**	**64.1**	**31.4**	**3.7**	**0.8**

Dwelling buildings stock by number of storeys

The inhabited buildings with more than 20 housings in them represent only 1.3% of the whole inhabited dwelling buildings. In spite of their small percentage, in such buildings live more than 33% of the population. The original intention of the big multi-dwelling buildings was to satisfy as much households as possible with dwellings, but during the years this intention has shown many disadvantages. As in these buildings there are many households with different characteristics and different income, their maintenance is extremely difficult. Following this, after 1990 the erection of big buildings with more than 20 housings has decreased significantly.

	1985	2001	%
1 housing	1459482	1259087	-13.7
2 housings	112135	156913	+39.9
3-5 housings	40472	50846	+25.6
6-9 housings	9790	11671	+19.2
10-19 housings	9145	11183	+22.2
20-49 housings	10286	11378	+10.6
50 and more housings	6548	8741	+33.5
total	**1647858**	**1509819**	**-8.4**

Inhabited dwelling buildings according to the number of housings in them

Housing stock by type of construction

From 1958 to 1990 a lot of dwelling buildings were erected with prefabricated concrete panels or with cast-in-situ concrete external walls. This lead to a negative impact on the physical qualities of the dwelling fund and the built environment as a whole.
There are 11 128 dwelling buildings erected with prefabricated concrete panels. These buildings include 787 096 dwellings where live more than 2 000 000 people.
Since 1990 the erection of buildings with prefabricated concrete elements has been stopped.

Missing data

Refurbishment total costs: the demonstration project in Radomir was carried out in the period 1996 – 1998. In this period in Bulgaria there were big economical changes, including a huge inflation rate and a denomination of the Lev in 1999. Following this, the figures from 1998 would not give a real idea about the prices of a refurbishment.

Refurbishment potential carbon savings: there is no available data. It should be underlined, that the calculated energy savings are in case of normally heated dwellings. Before the refurbishment most of the dwellings were under-heated. Following this, the main result of the refurbishment is an increase of the thermal comfort, not real energy savings. With the development of the economy and the increase of the incomes, we can expect energy savings from these measures in the following years, as more and more people will heat normally their dwellings.