

Analysis of results after implementation of energy saving measures in public buildings

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Energy audit of educational buildings of the University of Food Technologies (UFT) is performed. A project for renovation of these buildings has been developed and accomplished in this view. The data from the invoices for heating of these buildings for more than three full heating seasons after the project accomplishment have been collected and analysed. The results show 25.56% reducing of energy consumption for heating of Block 1, respectively 46.73% for heating of Block 3 and 60% for heating of Block 4. The energy savings for all three blocks is 40.4%.

Keywords: energy efficiency, energy savings, UFT

INTRODUCTION

Climate change and security of energy supply are two major challenges needing urgent action. They have common causes and common solutions. Except of that, the future seems marked by permanently rising price of energy, which we use in our life.

Analyses based on Eurostat data show retardation of Bulgaria in basic energy-economical indicators for sustainable development. Bulgaria is the most energy-intensive country - respectively 7.46; 6.81; 6.37; 6.81; 7.41; 6.12; 2.62 and 4.7 times more energy intensive than Austria, Denmark, France, Germany, Italy, Greece, Hungary and Turkey. Except of that, Bulgaria is one of the most dependent countries with regard to imports of energy resources in Europe – 71.6 %. Heating in buildings is the largest consumer of energy and generator of CO₂ emissions, released into the environment. The new EU member countries use more than 40% of their energy in buildings. In fact up to 80% of this energy can be saved by renovating the existing buildings and implementation of cost-effective energy conservation measures (ECMs) [1, 2, 3, 4, 5].

The aim of this paper is to report the results of ECMs implementation in educational buildings of University of Food Technologies (UFT) according to the project "Energy efficiency, improve access for people with disabilities in UFT and modernization of information services", realized with the financial support of OP "Regional Development", co-financed by European Union through European Regional Development Fund.

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MATERIALS AND METHODS

The above mentioned project has been developed and won on the basis of energy audits of the educational building blocks 1, 3 and 4 of the UFT carried out in 2010. Details of their geometric, structural and energy characteristics are presented in our previous publication [6].

The building of Block 1 was put into operation in 1962. It is a building with monolithic structure of 4 floors, built up area of 2520 m² and heated area of 10138 m². The exterior walls have a global heat transfer coefficient of 1.48 W/(m²K). The windows were in poor condition – with deformed frames and unsealed. The floor is mainly floor of a heated basement above the ground and only 132.9 m² are exposed to outdoor air. The roof of the main building is cold roof with ventilating airspace and over the tower is a cold roof. The heating system is "Tichelman" type with upper distribution and forced circulation. The heating station is common to the blocks 1, 2 and 3 and is equipped with all measurement. Losses in the distribution network are estimated at 5.6%.

Based on the available funding for the project, only 1 ECM (replacement of old windows by new ones with aluminium frame, thermal bridge and double glazing with 1 "K" glass) was provided and realized.

The building of Block 3 is composed of two bodies - monolithic and sectional with a hot link between them. The build up area is 2130 m² and the heated area is 5580 m². The monolithic body is a sequel of Block 1 with three floors and a heated basement with exterior walls of grid bricks. The roof is a cold roof with ventilating airspace. The sectional body consists of a heated basement and two floors. The walls are built of grid bricks. The roof is made

of reinforced concrete slab with waterproofing. The windows were in poor conditions – with deformed frames and unsealed. The two-pipe heating system has lower distribution and forced circulation. The horizontal piping is well insulated. Vertical pipes are not insulated, but are in good condition. Losses in the distribution network are estimated at 6.1%.

The following ECMs were provided and implemented as a result of the energy audit:

1. Thermal insulation of all outside walls: with 7 cm fiber.

2. Replacement of old windows with new ones with aluminium frames, interrupted thermal bridge and double glass package having 1 "K" glass.

3. Thermal insulation of the roof with 10 cm mineral wool (for the monolithic body over the ceiling plate in the roof space and for the sectional body - externally).

The building of Block 4 is a monolithic building with 4 floors. In adjacent to main building one-store buildings are situated: a Teaching laboratory and a Boiler room. The built area is 1740 m² and the heated area is 5044 m² (boiler room is not heated). The heating system type «Tichelman» was in bad condition. Supply and return lines were located in a technical channel below the ground floor and were in very bad condition, with compromised insulation. There were difficulties with the correct maintenance of supply and return lines. Losses in the distribution network were estimated at 12.4 %. Internal heating system was amortized with glider cast iron radiators. In premises with a North exposure it could not maintain the required temperature. The lack of thermostatic room temperature control did not allow the regulating the heat supply in the two branches of the installation – North and South. The windows were in poor condition – with deformed frames and unsealed. The fourth floor belonged many years to another organization and after being released it was found that some of the windows have been left open for a long time. The science laboratory (former gymnasium) had the heating system switched off because of the many leakages.

As a result of the energy audit, and then of the project implementation, the following ECMs have been put into practice:

1. Thermal insulation of all outside walls: with 7 cm fiber.

2. Replacement of old windows by windows with aluminium frames, interrupted thermal bridge and double glass package having 1 "K" glass.

3. Thermal insulation of the roof: for the main building - inside of the ceiling plate with 10 cm mineral wool and gypsum-paper wall, and for the

two adjacent one-stored buildings - outside with 12 cm mineral wool.

4. Thermal insulation of the floor exposed to outdoor air: outside with 7 cm fibre.

5. Replacement of the horizontal distribution network of heating system (removing over level 0). Installation of three horizontal circles: one northern and two southern circles (for the ground floor and the other floors).

6. Replacement of vertical pipes and radiators with aluminium ones.

7. Installation of energy-efficient variable-speed pumps in the boiler room.

8. Replacing the heat source – passing from central heating towards a condensing boiler of a new generation, operating on natural gas.

The project was implemented from September 2011 until the end of April 2012.

RESULTS

More than three full heating seasons after implementing the ECMs have analysed. Data from the invoices for heating of Blocks 1, 3 and 4 for the period before the implementation of ECMs (2009, 2010 and 2011) and for the period beyond implementation of ECMs (from November 2012 to the end of 2015) in the natural and financial terms were collected and processed. These data are presented in Table 1. Heat consumption during the project implementation (from September 2011 to April 2012) is not subject to this study.

Table 1. Energy consumption for heating of Blocks 1, 3 and 4 before and after ECMs implementation

Years	Month	I	II	III	IV	Total for I, II, III n IV	X	XI	XII	Total for X, XI n XII	Total for the year
2015	MWh	199	194	86	24	502	-	48	117	166	668
	BGN	18526	18024	7916	2036	46503	-	3948	9503	13451	59954
2014	MWh	182	138	58	-	378	32	125	105	263	640
	BGN	16426	12517	5173	-	34115	3007	11632	9736	24375	58490
2013	MWh	230	182	120	23	555	-	63	135	199	754
	BGN	21531	17034	11139	2005	51710	-	5259	12159	17419	69128
2012	MWh	-	-	-	-	-	-	63	161	224	-
	BGN	-	-	-	-	-	-	6250	16041	22291	-
2011	MWh	293	354	263	-	909	-	-	-	-	-
	BGN	29076	35251	26185	-	90512	-	-	-	-	-
2010	MWh	259	400	227	-	886	-	58	215	273	1159
	BGN	23128	35671	20136	-	78935	-	6053	22647	28701	107635
2009	MWh	214	276	246	-	736	-	149	242	390	1126
	BGN	22426	29160	25844	-	77430	-	12538	20386	32923	110353

The results of the Table 1 show that the total energy consumption for heating of Blocks 1, 3 and 4 is 1126.37 MWh for 2009 and 1159.51 MWh for

2010. The average thermal energy consumption for these 2 years is 1142.94MWh. The total energy for heating is 754 MWh for 2013, 640.4 MWh for 2014 and 667.61 MWh for 2015. The average consumption of thermal energy of these 3 years is 2061.04 MWh. The decrease in the heat energy consumed for heating after the ECMs implementation is 40.04%. The results of the Table 1 are presented in Fig. 1.

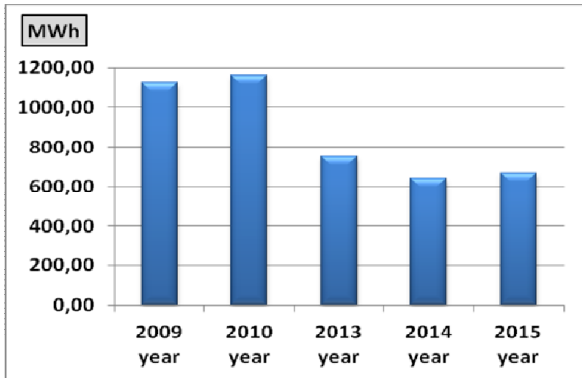


Fig.1. Energy consumption for heating of Blocks 1, 3 and 4 before and after ECMs implementation

The same data, but considered for the first half of years (months I, II, III and IV) show that the total consumption of energy for heating for I, II, III and IV months of 2009 is 735.75 MWh, 886.51 MWh for 2010, 909.3MWh for 2011, and the average of this three years for the same months is 843.7 MWh. The monthly energy consumption in total for the months I, II, III and IV is 555 MWh in 2013, respectively 377.53 MWh in 2014, 502.1 MWh in 2015 and the average of these 3 years for the same months is 477.9 MWh. The decrease in the energy consumed for heating after ECMs implementation is 43.36%. The results are presented in Fig.2.

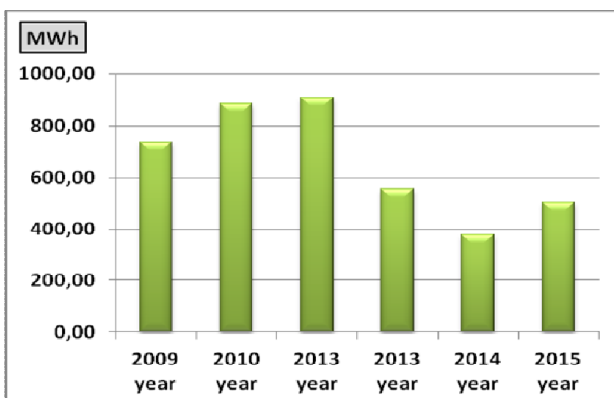


Fig.2. Average monthly energy consumption per years for months I, II, III and IV

For the period of the second half of years (months X, XI and XII) the total energy consumption after

ECMs implementation (2012, 2013, 2014 and 2015) is 851.4 MWh and the average annual energy consumption is 212.8 MWh. The total energy consumption before ECMs implementation (2010 and 2011) is 6636 MWh and the average annual energy consumption is 331.3MWh. The average annual decrease in the heat energy consumed after the ECMs implementation is 35.8%. The results are presented in Fig.3.

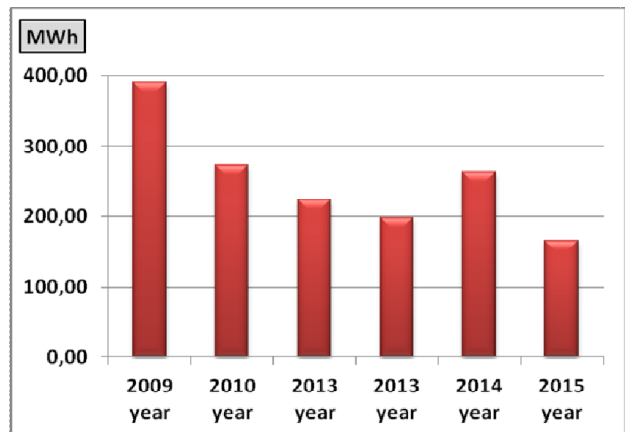


Fig.3. Average monthly energy consumption per year for month X, XI and XII

The data of energy consumption only for heating of Block 1 before and after implementation of the ECMs are presented in Table 2.

Table 2. Energy consumption for heating of Block 1 before and after ECM implementation

Years	Month										
		I	II	III	IV	Total for I, II, III n IV	X	XI	XII	Total for X, XI n XII	Total for the year
2015	MWh	122	123	83	14	342	-	33	71	104	445
	BGN	11067	11190	7519	1138	30913	-	2687	5882	8569	39482
2014	MWh	110	83	36	-	228	21	66	78	164	393
	BGN	9460	7194	3073	-	19727	1862	6003	7045	14910	34638
2013	MWh	145	112	80	16	353	-	39	82	121	475
	BGN	13200	10199	7302	1404	32105	-	3114	7102	10215	42320
2012	MWh	-	-	-	-	-	-	39	100	139	-
	BGN	-	-	-	-	-	-	3810	9661	13472	-
2011	MWh	151	184	135	-	470	-	-	-	-	-
	BGN	14983	18343	13418	-	46743	-	-	-	-	-
2010	MWh	134	215	114	-	463	-	-	115	115	578
	BGN	11971	19159	10129	-	41259	-	-	12085	12085	53344
2009	MWh	113	145	132	-	390	-	78	130	208	598
	BGN	11911	15370	13883	-	41164	-	6558	10988	17546	58710

The results of the Table 2 show that the total energy consumption for heating of Block 1 for the three full years after the ECMs implementation (2013, 2014 and 2015) is 1312.6 MWh and the average annual energy consumption for the same period is 437.5 MWh per year. The heating energy

consumption for the two full years before the ECMs implementation (2009 and 2010) is 1175.6 MWh and the average annual energy consumption for the same period is 587.8 MWh per year. The average annual decrease in heat energy consumption after the ECMs is 25.56%. The results in Table 2 are presented in Fig.4.

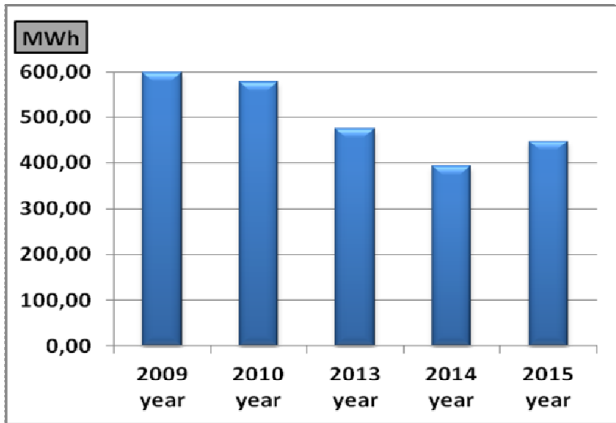


Fig.4. Energy consumption for heating of Block 1

The results in Table 2 show that the total consumption of thermal energy for heating of Block 1 for months I, II, III and IV is 390.4 MWh in 2009, 462.7 MWh in 2010 and 469.30 MWh in 2011. The average of these three years for the same months is 440.9 MWh. The monthly consumption of thermal energy for heating in the months I, II, III and IV of 2013 is 353.2 MWh, respectively for 2014 is 228.37 MWh, for 2015 is 341.63 MWh and the average of these 3 years for the same months is 307.73 MWh. The decrease in the heat energy consumption for heating after the implementation of ECMs is 30.6%. The results are presented in Fig.5.

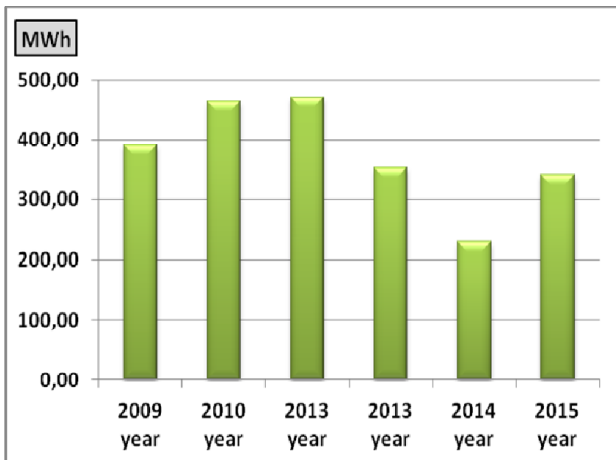


Fig.5. Average monthly energy consumption (Block 1) per years for month I, II, III and IV

Similarly the total consumption of thermal energy for heating of Block 1 during the months X, XI and XII of 2009 is 207.6 MWh, respectively for 2010 year is 114.9 MWh (as there was no heating for November this year) and the average of these 2 years is 132.16 MWh. The consumption of thermal energy for heating in total for the months X, XI and XII of 2012 is 139.2 MWh, respectively for 2013 is 121.44 MWh, for 2014 is 164.31 MWh, for 2015 is 103.71 MWh, and the average consumption of these 4 years for the same months is 132.16 MWh. The decrease in the heat energy consumed for heating after the ECMs implementation is 18%. The results are presented in Fig.6.

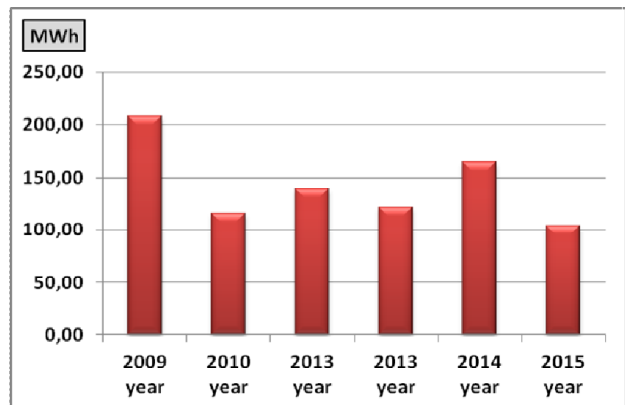


Fig.6. Average monthly energy consumption (Block 1) per years for month X, XI and XII

The data on energy consumption for heating of Block 3 before and after implementation of the ECMs are presented in Table 3.

Table 3. Energy consumption for heating of Block 3 before and after ECMs implementation

Years	M	I				II			III		IV		Total for I, II, III n IV			X			XI		XII		Total for X, XI n XII		Total for the year			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	X	XI	XII	I	II	III	IV	X	XI	XII	I	II	III	IV	
2015	MWh	48	49	33	5	134	-	13	28	41	175																	
	BGN	4355	4403	2958	447	12163	-	1057	2314	3371	15535																	
2014	MWh	43	33	14	-	90	8	26	31	65	155																	
	BGN	3722	2830	1209	-	7762	733	2772	2362	5867	13628																	
2013	MWh	57	44	32	6	139	-	15	32	48	187																	
	BGN	5194	4013	2873	553	12632	-	1225	2794	4020	16652																	
2012	MWh	-	-	-	-	-	-	16	40	56	-																	
	BGN	-	-	-	-	-	-	1499	3801	5301	-																	
2011	MWh	76	92	68	-	235	-	-	-	-	-																	
	BGN	7505	9188	6721	-	23415	-	-	-	-	-																	
2010	MWh	67	108	57	-	232	-	58	58	115	347																	
	BGN	5996	9597	5074	-	20667	-	6053	6053	12107	32774																	
2009	MWh	57	73	66	-	196	-	39	65	104	300																	
	BGN	5966	7699	6954	-	20620	-	3285	5504	8789	29409																	

The results in Table 3 show that the total energy consumption for heating of Block 3 for the three full years after the ECMs (2013, 2014 and 2015) is 516.5 MWh and the average annual energy

consumption for the same period is 172.2 MWh per year. The heating energy consumption for the two full years before the ECMs (2009 and 2010) is 646.5 MWh and the average annual energy consumption for the same period is 323.3 MWh per year. The average annual decrease in the heat energy consumed after the ECMs is 46.73%. The results in Table 3 are presented in Fig.7.

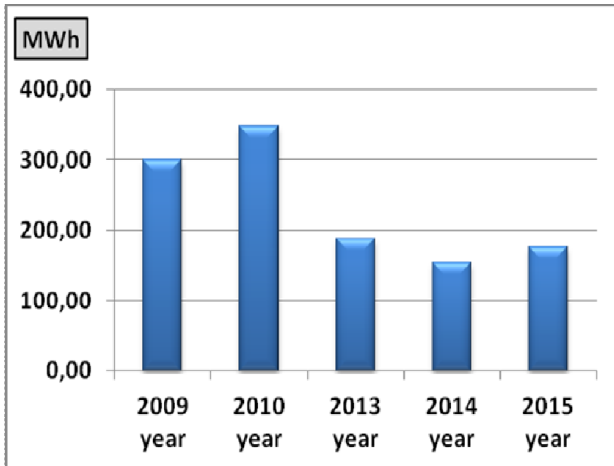


Fig.7. Energy consumption for heating of Block 3

The results in Table 3 show that the total consumption of thermal energy for heating of Block 3 for the months I, II, III and IV of 2009 is 195.5 MWh, for 2010 is 231.8 MWh and for 2011 is 235.3 MWh, and the average consumption of this three years for the same months is 220.7 MWh. The monthly consumption of thermal energy for heating in total for I, II, III and IV months of 2013 is 138.96 MWh, for 2014 – 89.9 MWh, for 2015 – 134.45 MWh and the average of these 3 years for the same months is 121.1 MWh. The decrease in the heat energy consumed for heating after the implementation of ECMs is 45.17%. The results are presented in Fig.8.

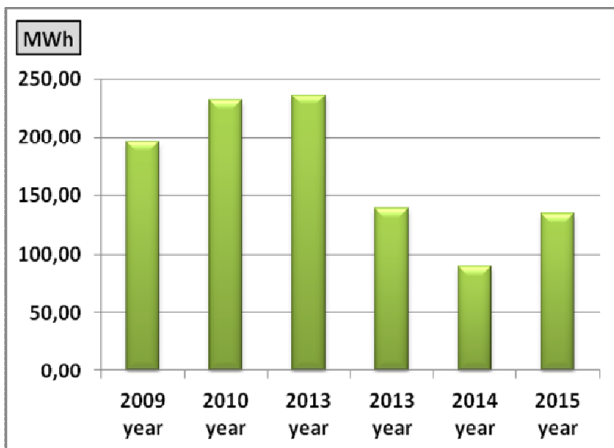


Fig.8. Average monthly energy consumption (Block 3) per years for months I, II, III and IV

Similarly the total energy consumption during X, XI and XII months of 2009 is 104.0 MWh, for 2010 – 115.2 MWh and the average of these 2 years – 109.8 MWh. The energy consumption for X, XI and XII months of 2012 is 55.6 MWh, for 2013 – 47.8 MWh, for 2014 – 64.6 MWh, for 2015 – 40.81 MWh, and the average consumption for these 4 years for the same months is 52.2 MWh. The decrease in the heat energy consumption after the ECMs is 52%. The results are presented in Fig.9.

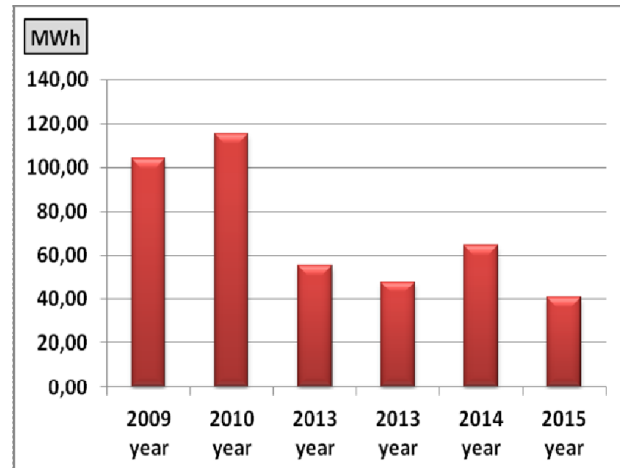


Fig.9. Average monthly energy consumption (Block 3) per years for month X, XI and XII

The data on energy consumption of Block 4 before and after the ECMs are presented in Table 4.

Table 4. Energy consumption of Block 4

Years	Month	I				II				III				IV				Total for I, II, III and IV				X				XI				XII				Total for X, XI and XII				Total for the year			
		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN		Nm ³ .10 ³	MWh	BGN					
2015	Nm ³ .10 ³	3,087	2,418	1,874	0,495	7,874	0,001	0,305	1,951	2,257	10,131																														
	MWh	28,7	22,5	17,4	4,6	73,2	0,0	2,8	18,2	21,0	94,2																														
	BGN	3104	2432	1885	7	7871	1	204	1307	1511	9383																														
2014	Nm ³ .10 ³	3,113	2,400	0,858	-	6,371	0,419	1,845	1,395	3,659	10,03																														
	MWh	29,0	22,3	8,0	-	59,3	3,8	17,2	13,0	33,9	93,3																														
	BGN	3243	2493	893	-	6629	411	1815	1371	3598	10224																														
2013	Nm ³ .10 ³	3,015	2,711	0,926	0,048	6,700	-	0,912	2,243	3,155	9,855																														
	MWh	28,1	25,2	8,6	0,4	62,3	-	8,5	20,9	29,3	91,7																														
	BGN	3138	2822	964	48	6972		920	2263	3184	10156																														
2012	Nm ³ .10 ³	-	-	-	-	-	-	0,834	2,287	3,121	-																														
	MWh	-	-	-	-	-	-	7,8	21,3	29,0	-																														
	BGN	-	-	-	-	-	-	940	2578	3518	-																														
2011	Nm ³ .10 ³	66,1	77,5	60,7	-	204,3	-	-	-	-	-																														
	MWh	6588	7720	6047	-	20355	-	-	-	-	-																														
	BGN	6588	7720	6047	-	20355	-	-	-	-	-																														
2010	Nm ³ .10 ³	57,8	77,5	56,3	-	191,5	-	-	42,9	42,9	234,4																														
	MWh	5161	6914	4933	-	17008	-	-	4509	4509	21517																														
	BGN	5161	6914	4933	-	17008	-	-	4509	4509	21517																														
2009	Nm ³ .10 ³	44,0	57,6	48,3	-	150,0	-	32,2	46,8	79,5	229,5																														
	MWh	4549	6092	5006	-	15647	-	2694	3894	6588	22235																														
	BGN	4549	6092	5006	-	15647	-	2694	3894	6588	22235																														

The results of the Table 4 show that the total energy consumption for heating of Blocks 4 for the

three full years after the ECMs (2013, 2014 and 2015) is 279.22 MWh and the average annual energy consumption for the same period is 93.1 MWh per year. The heating energy consumption for the two full years before the ECMs (2009 and 2010) is 463.9 MWh and the average annual energy consumption for the same period is 231.2 MWh per year. The decrease in the heat energy consumed after the ECMs is 60%. The results of the Table 4 are presented in Fig.10.

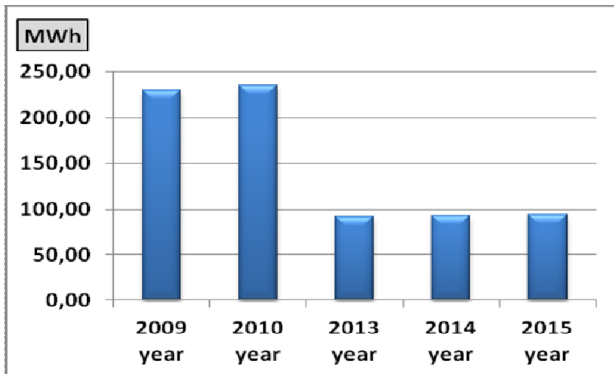


Fig.10. Energy consumption for heating of Block 4

The results of the Table 4 show that the total consumption of thermal energy for heating of Block 4 for I, II, III and IV months of 2009 is 149.95 MWh, for 2010 year – 191.51 MWh and for 2011 – 204.3 MWh. The average of these three years for the same months is 181.92 MWh. The monthly consumption of thermal energy for heating in total for I, II, III and IV months of 2013 is 62.33 MWh, for 2014 – 59.26 MWh, for 2015 – 73.24 MWh and the average of these 3 years for the same months is 65.1 MWh. The decrease in the energy consumed for heating after the implementation of ECMs is 64.27%. The results are presented in Fig.11.

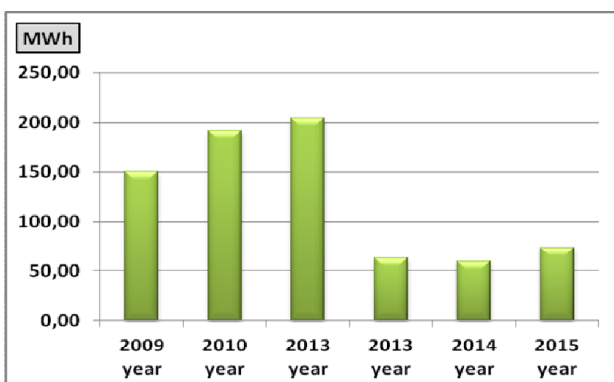


Fig.11. Average monthly energy consumption (Block 4) per years for months I, II, III and IV

Similarly the total consumption of thermal energy for heating of Block 4 during the months X, XI and XII of 2009 is 79.54 MWh, for 2010 year –

42.9 MWh (as there was no heating for November this year) and the average of these 2 years – 61.22 MWh. The consumption of thermal energy for heating in total for months X, XI and XII of 2012 is 29.02 MWh, for 2013 – 29.34 MWh, for 2014 – 33.94 MWh, for 2015 – 20.99 MWh, and the average consumption of these 4 years for the same months is 28.32 MWh. The decrease in the heat energy consumed for heating after the ECMs implementation is 53.74%. The results are presented in Fig.12.

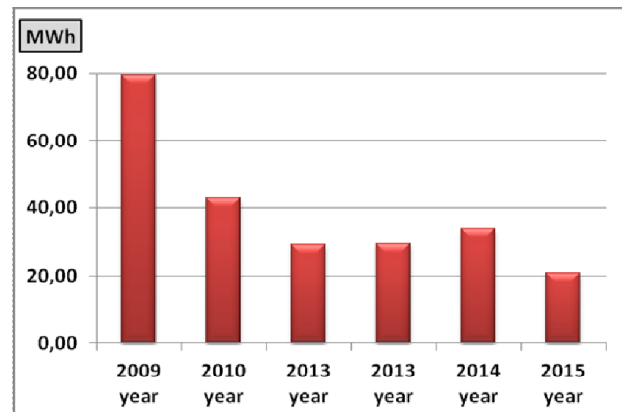


Fig.12. Average monthly energy consumption (Block 4) per years for month X, XI and XII

This paper presents data on energy savings compared to the actual energy consumption before implementation of the ECMs.

ECONOMIC ANALYSIS OF THE ECMs

Economic analysis of the rehabilitation must be performed in comparison to the baseline energy consumption, which ensures living comfort of the building (according to the legislation in this field). The baseline energy consumption in Block 1 is 918 034 kWh/y, in Block 3 - 595 222 kWh/y; in Block 4 - 600 734 kWh/y and in all three Blocks of UFT is 2 113 990 kWh/y.

The average energy consumption for heating of the three Blocks after ECMs implementation is 687 330 kWh/y, while the average annual energy savings are 1 426 660 kWh/y.

Investments for the ECMs implementation are: for Block 1 - 330 560 BGN, for Block 3 - 350 207 BGN, for Block 4 - 374 409 BGN and total for all 3 Blocks are 1 055 176 BGN.

Under these conditions, the payback period (PB) of all ECMs is 8.9 years, the inner return ratio (IRR) is 11.1% and the net present value (NPV) is 3 586 323 BGN. Therefore the ECMs are cost effective. The economic analysis has been performed with software ENSI Economy.

CONCLUSIONS

1. University of Food Technologies (UFT) in Plovdiv implemented the project “Energy efficiency, improving access for people with disabilities at the University of Food Technologies - Plovdiv and modernization of information services”, BG161PO001/1.1-07/2009/010 within which being implemented the prescribed energy saving measures.

2. The data on energy consumption for heating of 3 educational buildings of UFT before and after the implementation of ECMs were collected and processed on the basis of energy invoices.

3. As result of project ECMs implementation in Blocks 1, 3 and 4 the heat energy consumption has been reduced with 40.04% yearly. The really saved energy for the whole studied period is 1571.3 MWh compared to the average consumption for 2009 and 2010. The saved CO₂ emissions, emitted in the environment represent 456 tons.

4. Reduction of heat energy consumption for Block 1 is 25.56% per year. The saved heat energy for the whole studied period is 515.87 MWh and the saved CO₂ emissions are 149.60 tons.

5. Reduction of heat energy consumption for Block 3 is 46.73% per year. The saved heat energy for the whole studied period is 528.88 MWh and the saved CO₂ emissions are 153.38 tons.

6. Reduction of heat energy consumption for Block 4 is 60.0% per year. The saved heat energy for the whole studied period is 482.39 MWh and the saved CO₂ emissions are 139.89 tons.

7. The economic analysis shows that the performed ECMs are cost effective with a PB of 8.9

years, a IRR of 11.1% and a NPV of 3 586 323 BGN.

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