BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi" din Iaşi
Tomul LXI (LXV), Fasc. 3, 2015
Secţia
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ

THE ENERGY EFFICIENCY PROMOTION IN BUILDINGS

BY

MIHAI TÎRŞU*, SVEATOSLAV POSTORONCA and ION MARTNOS

Institute of Power Engineering of Academy of Sciences of Moldova, Chişinău

Received: October 16, 2015
Accepted for publication: October 30, 2015

Abstract. In the paper the solutions how to decrease the energy consumption for the most common types of buildings in urban areas of The Republic of Moldova using the modern practice of improving energy efficiency are shown. Here we mean modernization measures like thermal insulation and integration of renewable energy sources. A study has been made for the schedule of energy consumption and the losses of energy inside the buildings. Were described the technical possibilities of mounting of such sources as, solar collectors, photovoltaic panels, devices for recovery the waste heat. The optimal operating conditions of renewable and traditional energy sources with subsequent analysis of the effect gained from measures described are submitted.

Key words: building efficiency; heat recovery; PV; renewable sources; solar collectors.

1. Introduction

Moldova is a country with limited fossil energy resources. This fact imposes to the country that more than 95% of energy consumption to be provided by import. Being a country with limited energy resources, Moldova should use the widest available sources in territory such as renewables. This would help increase the level of energy security. On the other hand, it is necessary to use the innovative technical solutions (so called BAT – best available technologies) in order to have high energy efficiency. Unfortunately, the country's energy consumption is constantly rising and the level of energy

*Corresponding author: *e-mail*: tirsu.mihai@gmail.com

efficiency is very low. Today Moldova has energy intensity 2-3 times higher than the average of European countries. This means that for each unit of production is consumed 2-3 times more energy compared to other countries. The main cause is the use of obsolete technologies from the Soviet era and lack of investment for modernization.

In Moldova there are several crucial opportunities to increase energy efficiency. One of them is related to multi-storey buildings, which are important energy consumers. Over 60% of all dwellings are situated in (Alcaz *et al*.). The present work presents possibilities for efficient energy use in both existing buildings and new ones under construction or planned.

2. The General Characteristic of Energy Consumption in Moldova

Moldova consumes around 2,300 ktoe. Distribution by consumption category is shown in Fig. 1.

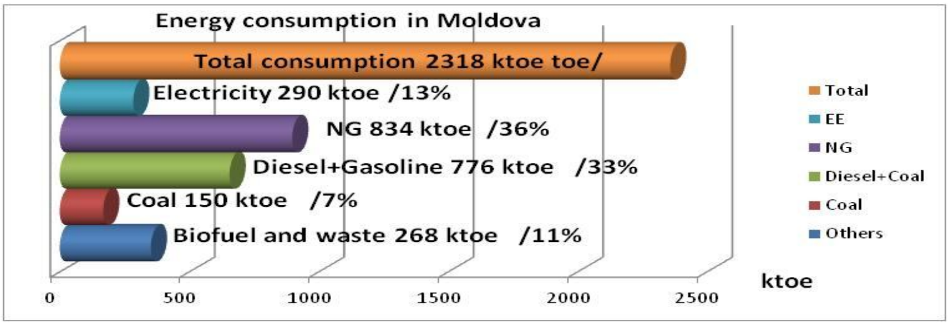

Fig. 1 – Energy consumption of Moldova for 2013. Source National Bureau of Statistics (NBS).

It should be mentioned that around 50% of all energy is consumed by the residential sector. Over 220 ktoe is used as heat supply by district heating, which constitutes 10% of total consumption in the country. The services provided to consumers via district heating systems are of low quality. As result a big part of consumers installed mural boilers. The new building constructed last 10 years also installed individual boilers, which results in a less efficient centralized system. Another important factor is the high level of heat losses in networks. It reaches 22%.

3. Building Characteristics of Chişinău Municipality

The current situation on buildings from Chişinău is presented in Table 1.

Table 1
Structure of Residential and Nonresidential Buildings by Story Category

Residential buildings	3,521	Nonresidential buildings	5,092
1-2 floors	2,207	General education school	168
3-4 floors	250		
5 floors	713	Preschool institutions	152
9 floors	248	Other education institutions	65
6,7,8,10, 15 floors	55		
12-14 floors	9	Cultural institutions	99
16 and higher floors	39	Medical institutions	436
		Commercial units	3,760
		Industrial factories	281

Analysis of the consumption data shows that over 150 ktoe or about 1,500 kGcal are consumed by these buildings from centralized heating networks (13) and nearly as much energy is consumed by individual heating systems powered by natural gas. The buildings in Chisinau are responsible for over 20% of total energy consumption in the country, which means a major potential for efficient energy consumption.

At the same time, the buildings have different periods, varying between 0 and 50 years. Building age distribution is shown in Fig. 2.

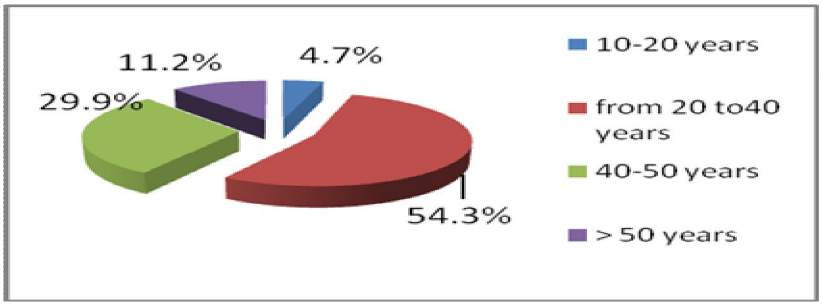

Fig. 2 – Buildings characteristics by age in Chişinău.

It should be noted that most of existing buildings are without thermal insulation and the windows allow large energy losses. In many apartments were installed new PVC windows by owners themselfs. Unfortunatelly they do not respect mounting technology, which resulted in thermal bridges and of course not very much improvement of energy efficiency.

4. Estimation of Energy Losses in Buildings

Much of the existing buildings in Moldova are between 20,…,60 years old and their thermal characteristics are low. On average 75% of energy is consumed for heating buildings. To estimate the energy losses in buildings we will focus on multi-storey buildings constructed of reinforced concrete, which constitutes over 30% of all buildings. We consider an apartment building with nine floors and two staircases. Such blocks have approximately 500 m^2 and 72 apartments. The energy consumption of these apartments is approximately 180 kWh/m^2 year, which is 3 times more than in EU countries (Bălăraş *et al.*, 2007).

For this type of building are characteristic energy losses through walls (U value) of 1.8 W (m^{2}K), through the windows of 3.3 W (m^{2}K), through roof of 0.73 W (m^{2}K).

Typical distribution of energy losses through the constructive elements of the building are shown on Fig. 3.

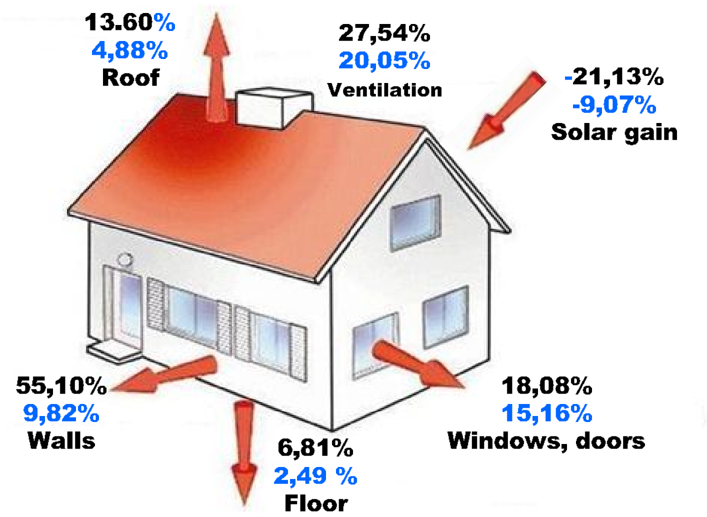

Fig. 3 – Typical distribution of energy losses through constructive elements of building.

In Fig. 3 you can see that the biggest losses of energy are through walls (they can reach 50%) and windows (ranging between 15,…,30%).

Another source of energy loss is the domestic hot water. On average, each family consumes around 3 m^3 of hot water per month. In total per year a block of flats consumes around 2,592 m^3 of hot water. This means around 99 Gcal.

5. Efficiency Measures for Energy Consumption in Buildings

Recently was published the document entitled “Energy Efficiency – the first fuel for the EU Economy” (2015). It is an up to date roadmap on how to manage the investments in the situation of increasing energy efficiency requirements using the studies developed and obtained data resulted from the reach European practice over the last years. The Energy Community (EC), organization established in 2005 by the International Treaty, has developed the energy polices in regard to the energy efficiency treatment for countries in EU, South East Europe and Black Sea region, including Moldova (https://www.energy-community.org/portal/page/portal/ENC_HOME). Due to the appropriate specific of each country, the Ministerial Council of the EC, considering the recommendation from the Permanent High Level Group, has proposed implementation of Directive 2012/27/EU, in each Contracting Party, but with certain modifications (Council, 2013).

In this respect, in the Republic of Moldova the measures of energy efficiency to decarbonise and diversify the energy supply in the light of increasing energy consumption are the same with the EU ones. We have to reduce the high dependence on fossil fuels taking into account the Climate Change requirements. In the domain of Construction the Directives, 2010/31/EU and 2002/91/EC have been implemented the common general methodology for the calculation the energy efficiency of buildings. It was the Directive 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, so-called Energy Performance of Building Directive (EPBD), which required the EU Member States to ensure that by 31 December 2020 all new buildings are going to be classified as Nearly Zero Energy Buildings (NZEB). But the state of the art in Member States of EU is a significant deviation in EPBD implementation with big differences in impact, compliance and control. Many countries have already set up the necessary requirements and calculation methotds, but fail to establish the necessary follow up methods and support programs for a successful implementation (Directive 2010/31/EU, 2010). This adds to the relatively low requirements for energy efficiency and renewable energy still prevailing in most countries, leading to higher energy consumption that the cost-effective level (Directive 2002/91/EC). The main measures among the aforementioned onesare: renovation of residential and nonresidential buildings, integration of renewable energy sources and the installation of high efficiency equipment, utilization of modern appliances with low level of energy consumption. A special relevance has the basic building retrofit measures, like:

a) thermal insulation of the envelope (external walls, roof, eventually roof or ceiling below the lowest heated floor);

b) replacement of windows and doors;

c) regulation of the heating system (primarily measurement and the control systems, eventually on insulation of valves, pipe insulation or replacement of pumps);

d) installation of heat recovery units to reduce ventilation losses (including the distribution system).

Further was estimated a relative prices per square meter of floor space for each retrofit measure apart. An average unique price for all EC countries was considered suitable, as in the region there are similar construction standards, but not the same climate conditions.

Table 2
Prices of Building Retrofit Measures Concerning Heat Energy
(EUR/m^2 of floor area)

Measures		Price, [€/m^2]
Measures to reduce heating losses	Window replacement	31
	External insulation	28
	Insulation of the ground floor	16
	Roof insulation (slope)	15
	Roof insulation (flat)	6
	Ceiling insulation	5
	Floor to basement insulation	4
Regulation of a heating equipment		7

Focusing on the concrete measures in Moldova let's begin with organizational methods. On the top of importance we find the appropriate state legislation framework which facilitates the sustainable development of the domain. The important methodology for developing an energy review is an energy audit with the purpose to analyze the energy consumption, to work out the potential for energy saving and to define the proposals. In addition, an energy audit report on the impact of the CO_2 emissions must be elaborated. European practice shows us that it's not enough to possess modern methodologies for calculation of energy efficiency. We first have to collect large volumes of data during some periods of time in different locations. It will be very useful to share the experience of European countries in recruting the people who are knowledgeable more or less about energy and technology among rezidents to help in collecting the relevant data on building energy behavoir (consumption, losses etc) in the deal of elaboration and implementation of retrofit measures for energy efficiency of buildings (Heiskanen *et al*., 2015). Involving users has the advantage that they are usually at the forefront of adapting new trends and know how to use cutting-edge technology. Users exhibit relevant real-world experience, strongly benefit by enacting change and can provide accurate data about the matters at hand (E. von Hippel *et al*.,1988). In this regard we have to select individuals who fulfill the minimum screening criteria: they are open to technological and behavioral change, can provide a constructive criticism, are willing to discuss and participate, and have some understanding or experience in the field.

The first measure urgently needed to be implemented is the thermal rehabilitation of buildings shell for both residential and nonresidential buildings. This measure requires huge investments (around 660 mln. EUR according to http://www.chisinau-projects.eu/media/content/ and it is clear that for the implementation of investment projects to succeed the Central or/and Local Public Authorities must be involved. If we implement the measures related to building insulation it is possible to cut energy losses by up to 40%.

Using Phase Change Materials (PCM) in order to have a passive building design, we can mount a solar heating system which works *versus* electricity with positive effect even in the winter. Term of passive solar building design is used for a house in which, windows, walls and floors are made to collect, store and distribute solar energy in the form of heat. One of the goals to use and design passive solar buildings is to take advantage of the local weather (Doerr *et al*.,2012).

Overall, for existing buildings energy losses can be reduced on average by at least 30% only by thermal rehabilitation of buildings shell. This value would be about 500 thousand Gcal.

Here we have to underline the assessment that has corroborated the difference between the energy performance of buildings calculated with the simulation software and their actual energy performance (Burman *et al*.,2014). As the practice of some EU countries like Italy, UK and Denmark showed, there are deviations of around 30% between the esteemed and really consumed energy quantities (Petersen *et al*.,2012). The phenomena results from the difficult complexity of behavior of users/consumers. It is not easy to predict accurately what indoor temperature will prefer the tenant to adjust, how long the consumer will be cooking, watching TV, staying in the bathroom, etc.

A second measure would be replacing of one-pipe internal thermal distribution system by two-pipe heating system, metering each apartment, ensuring the possibility of regulating the temperature in each room as needed and the financial strength of tenants.

As next measure it is necessary to implement individual thermal points (ITP) in every residential block. This would exclude transport losses which are around 20%.

Keeping the current tariff for heat, implementing efficiency measures will create a surplus of money that can be directed towards paying investments.

Another category of measures can include recovery of waste heat from canalization. To this end it is necessary to install waste heat recovery systems for sewer pipes that can be redirected back to the individual thermal points for domestic hot water (DHW).

5.1. Using of Renewable Energy Source in Energy Circuit of Buildings

One of the possibilities to reduce traditional energy consumption is using of renewable sources for both heat production and electricity. Well known Building Integrated Solar Thermal System (BISTS) can ensure the reduction of: overall primary energy demand for space heating and cooling purposes; building construction capital cost and land cost; overall building energy consumption (toward NZEB).

The results obtained by the energy and economic analysis highlight the promising feasibility of the adoption of building integrated photovoltaic thermal collectors (BIPVT) which involve high and satisfactory Primary Energy Saving (PES) (Bougiatioti *et al*., 2015). The highest thermal and electric efficiencies of the case when PVT system is mounted on the roof are observed. The calculated Simple Pay Back is still high, ranging from 12 to 15 years depending of the investigated cases.

As mentioned above, the roof surface of two staircase 9-story building is approximately 500 m^2. To estimate the amount of energy produced by solar collectors or photovoltaic panels we will use the information presented in Table 3.

Table 3
Level of Daily Insulation in Moldova According to Zones

Average indicators for last 22 years	Mounth											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Drochia, [kWh/m^2/day]	1.69	2.56	3.15	3.49	4.71	4.19	4.48	4.40	3.14	2.44	1.39	1.44
Bălţi, [kWh/m^2/day]	1.19	2.18	3.42	4.48	5.65	5.89	5.83	5.05	3.71	2.24	1.27	0.93
Taraclia, [kWh/m^2/day]	1.19	2.18	3.42	4.48	5.65	5.89	5.83	5.05	3.71	2.24	1.27	0.93
Chişinău, [kWh/m^2/day]	1.08	1.78	2.68	3.87	5.40	5.70	6.39	5.63	3.96	2.45	1.06	0.87

Based on the data of Table 3, the estimated amount of energy available monthly on the surface as 500 m^2 is given in Fig. 4.

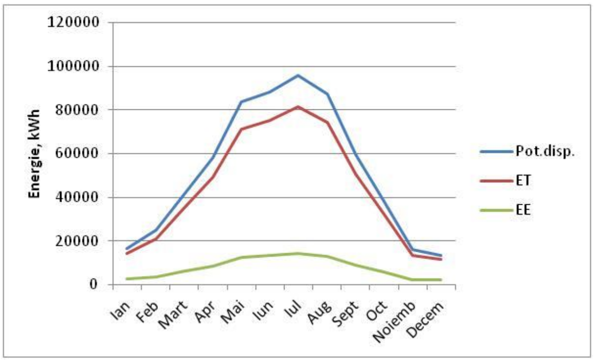

Fig. 4 – Available energy potential on surface of 500 m^2.
ET – thermal energy; EE – electrical energy.

From Fig. 4 it is evident that the use of solar collectors with an efficiency of 85% in July we can get an amount of 81,000 kWh of thermal energy and 14,400 kWh of electricity by using photovoltaic panels. Since maximum heat produced from this area is 70 Gcal in July, while house consumption is 99 Gcal/year or about 10 Gcal/month, it is obvious that the rational solution is using only an area of the roof for heat production and the rest for electricity. It should be noted that the location of solar collectors on the roof needs to be establish in combination with heat-insulated water tanks. In this case it is possible to produce more hot water than is neceesary. The extra quantity of hot water should be stored in tanks and used when we have cloudy days without sunshine. On the other hand, the size of the tanks could be calculated to provide tenants with hot water during the spring-autumn season.

The overall area of solar collectors must be calculated not to exceed the energy consumption for hot water by tenants. Otherwise it is necessary to implement additional solutions for the storage or use of the water. Remaining available surface may be covered with photovoltaic panels. Also available side surfaces can be used for installing the panels and connecting them to the electricity supply system.

For new constructed buildings it is required by law the implementation and use of renewable energy in the building's heating circuit. Under the new requirements, new buildings are built with insulation and double-glazed windows, which raises their energy efficiency compared to the old model, at least 30%. For new buildings it is possible to use also geothermal energy. The thermal load which can be obtained by horizontal collectors can be considered to be 25 W.m^2. So, the area of 500 m^2 can provide a heat source of 12.5 kW. Thus, during one year from this surface is possible to get around 82,000 kW.h by using heat pump with COP at least 4. This energy is equivalent to 70 Gcal/year or 71% of total consumption of thermal energy for DHW. In this case, it is necessary to use this energy for the heating season, and during the warm period geothermal plant can use the element of air conditioning. This application would essentially reduce electricity consumption.

6. Conclusions

By implementation of efficiency measures to existing buildings both residential and non residential we would reduce energy consumption by at least 30% or 300 ktoe. On the other hand, the use of renewable energy for existing buildings could replace around 35% (45% in new built homes) of conventional energy.

Acronymes and abréviations

BAT – Best available technologies;
NBS – National Bureau of Statistics;
EC – Energy Community;
EPBD – Energy Performance of Building Directive;
NZEB – Nearly Zero Energy Building;
PCM – Phase Change Material;
ITP – Individual Thermal Point;
RES – Renewable Energy Source;
DHW – Domestic Hot Water;
BISTS – Building Individual Solar Thermal System;
BIPVT – Building Integrated PV Thermal Collector;
PES –Primary Energy Saving.

Part of research from this article was presented at the International Conference on Electromechanical and Power Systems, SIELMEN 2015, a joint event organized by the Faculty of Power Engineering - Technical University of Moldova, Faculty of Electrical Engineering - "Gheorghe Asachi" Technical University of Iasi and Faculty of Electrical Engineering - University of Craiova.

REFERENCES

Alcaz V., Isicico E., Ghinsari V., *Riscul seismic în teritoriul Chişinău*. http://www.akademos.asm.md/files/ Chisinau.pdf .

Bălăraş C., Garlia A., Georgopoulou E., Mirasgedis S., Sarafidis Y., Lalas D., *European Residential Buildings and Empirical Assessment of the Hellenic Building Stock*. Energy Consumption, Emissions and Potential Energy Savings. **42**, *3*, March 2007, 1298-1314, http://www.sciencedirect.com/science/article/pii/S0360132305004 671.

Bougiatioti F., Michael A., *The Architectural Integration of Active Solar Systems. Building Applications in the Eastern Mediterranean Region*. Renewable and Sustainable Energy Reviews, 2015. 47(0): p. 966-982.

Burman E., Mumovic D., Kimpian J., *Towards Measurement and Verification of Energy Performance Under the Framework of the European Directive for Energy Performance of Buildings*. Energy, **77**, 153-163 (2014).

Doerr T., *Passive Solar Simplified: Easily Design a Truly Green Home for Colorado and the West*. 1st. ed ed. 2012: Lexington, KY, Alitheia Press, c2012.

E. von Hippel, *Predicting the Source of Innovation: Lead Users in The Sources of Innovation*. E. von Hippel (Ed.), Oxford: Oxford University Press, 1988, 102-116.

Heiskanen E., Matschoss K., Repo P., *Engaging consumers and citizens in the creation of low-carbon energy markets*. In ECEEE 2015 Summer Study Proc., 2015, 2123-2132.

Petersen S., Hviid C., *The European Energy Performance of Buildings Directive: Comparison of Calculated and Actual Energy Use in a Danish Office Building*. IBPSA England first building simulation and optimization conference (BSO 2012), Loughborough, 2012.

* * * The European Parliament and the Council of the EU. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, Official Journal of the European Union, L315/1-56, 2012.

* * * UNION, T.E.P.A.T.C.O.T.E., Directive 2010/31/EU on the Energy Performance of Buildings (recast), 2010.

* * * *Cu privire la caracteristicile energetice ale clădirilor. Caracteristicile energetice ale clădirilor.* Conferința Finală 29.01.2013RO M.pdf http://www.chisinau-projects.eu/media/content/

* * * E. Community, "Energy Community," [Online]. Available: https://www.energy-community.org/portal/page/portal/ENC_HOME. [Accessed 09 2015].

* * * Group, E.E.F.I., Energy Efficiency – the first fuel for the EU Economy, 2015.

* * * M. Council, Recommendation of the Ministerial Council, R/2013/01/MC-EnC on Energy Efficiency, ANNEX 17/11 MC/25-06-2013.," Energy Community, 2013.

* * * Raport de activitate pentru anul 2014. ANRE. www.anre.md.

* * * The European Parliament and the Council of the EU, Directive 2002/91/EC of the European parliament of the council of 16 December 2002 on the energy performance of buildings, Official Journal of the European Union, L1/65-71, 2003.

* * * The European Parliament and the Council of the EU, Directive 2010/31/ of the European parliament and of the council of 19 May 2010 on the energy performance of buildings (recast), Official Journal of the European Union, L153/13-35, 2010.

PROMOVAREA EFICIENȚEI ENERGETICE ÎN CLĂDIRI

(Rezumat)

Sunt prezintate soluții de reducere a consumului de energie pentru majoritatea tipurilor de clădiri din zona urbană a Republicii Moldova, care constau în utilizarea practicilor moderne de îmbunătățire a eficienței acestora. Măsurile de modernizare propuse constau în izolarea termică a clădirilor şi integrarea surselor regenerabile de energie. S-a cercetat schema de consum a energiei şi pierderile ce au loc în clădiri. Sunt descrise posibilități tehnice de montare a astfel de surse precum colectoarele solare, panouri fotovoltaice, instalații de recuperare a căldurii reziduale. Sunt prezentate condițiile optimale de funcționare a surselor regenerabile în combinație cu cele tradiționale şi este efectuată analiza beneficilor de la introducerea măsurilor propuse.