ENERGY EFFICIENCY OF HEATING SYSTEMS FOR RESIDENTIAL AND INDUSTRIAL BUILDINGS IN ROMANIA

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Although Romania has the largest oil and gas resources in Central Europe, the efficient use of energy along the entire energy chain, from production to consumption, has been a consistent feature of Romanian policy in recent years. There is an actual need in rehabilitation of heat supply systems in Romania. The heating of residential or large industrial enclosures is a complicated problem, because of the variety types of buildings, the complexity of the indoors activities and the necessity of choosing the economic solution, regarding both aspects: investment and maintenance. For industrial buildings, the radiating heating system can represent a better solution for large enclosures. For residential buildings could be applied several measures in their heating systems in order to obtain energy efficiency. The present article makes a comparison between different heating systems in order to recommend the most efficient ones.

Keywords: energy efficiency, radiant heating, small-scale cogeneration

1. Introduction

Romania's energy intensity is among the highest in the Central Europe and is about five to ten times higher than in UK, France, Germany or United States. Inefficient energy utilization exists in all sectors of the economy, notably in the industrial and residential sectors, which accounts for over 80% of energy consumption. In large part, such high intensity in Romania is due to aging equipments of antiquated technologies. So, energy efficiency measures have concentrated on the industrial and residential sectors, where there is the clearest scope for improvements. Private enterprises as well as restructured and/or privatized state enterprises are actively exploring cost reduction and efficiency improvement strategies as a consequence of steep increases in energy prices (gas, electricity and district heat) and with a view to improving competitiveness through energy efficient technologies. However, actual investments in energy efficiency are low. This is, in large part, due to the absence of appropriate funding mechanisms, coupled with a lack of expertise in identifying and developing commercially viable projects. A short "history" of consumptions in Romania show that in the year 2007, the sectors with the most important shares of the total

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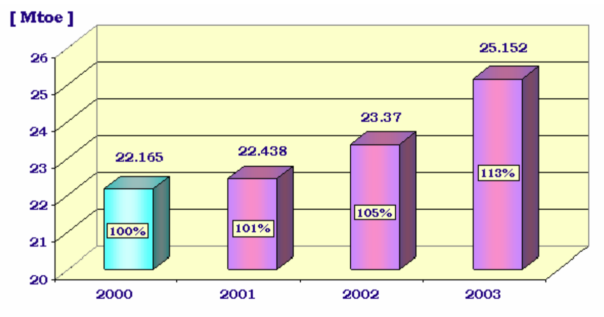
final energy consumption were industry (43.3%), residential (31.3%), and transport and communications (17.2%), as shown in Figure 1. The proportion maintains very close also in 2009. The graph in Figure 1 shows an increase of 13% of the total final energy consumption in 2003, compared to the year 2000. This increase is not uniform for all sectors and it results from the increases of energy consumption in industry (with 21%), transport and communications (with 23%) and other activities (with 125%). Between 2004-2009 the total energy consumption continued to grow. The sector of constructions registered an important development.

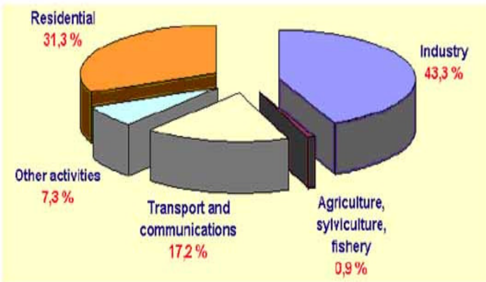


Source: National Institute of Statistics – "Romanian Statistical Yearbook 2004"

Figure 1. Evolution of the Total Final Energy Consumption

2. The actual situation

In the year 2007, the sectors with the most important shares of the total final energy consumption were industry (43.3%), residential (31.3%), and transport and communications (17.2%), as shown in Figure 2. The proportion maintains very close also in 2009.



Source: National Institute of Statistics – "Romanian Statistical Yearbook 2007"

Figure 2. Final energy consumption
in the year 2007, by sectors

The total final energy consumption in the industrial sector is distributed among the different industries as presented in Figure 3. Romanian industry, facing for a long time a deep restructuring process, particularly in the field of mining and quarrying, is still tributary to raw materials import, influenced at the same time by the lack of investments for production modernization and recovery. During 2005 - 2007, the turnover in industry, as well as the gross series of industrial production indices, with 2000 as base year, recorded however an upward trend, mainly in manufacturing sector.

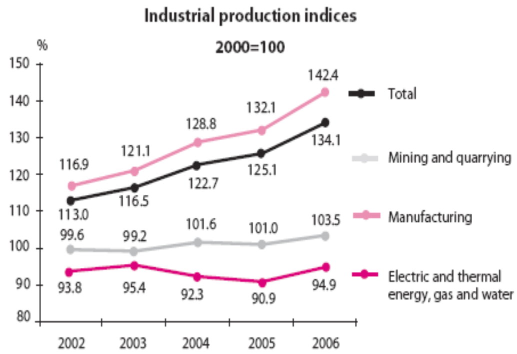


Figure 3. Industrial production indices

3. Industrial building

The heating of large industrial enclosures is a complicated problem, because of the variety types of buildings, the complexity of the indoor activities and the necessity of choosing the economic solution, regarding both aspects: investment and maintenance. For large enclosures, the heating systems and their maintenance suppose high costs and investments. The conclusions of this article can be extended for new buildings and their conception but also to old ones, inefficient, needed to be rehabilitated. The conception engineers must choose the heating system and its characteristics based on objective criteria. That means that, for the same building, several solutions can be adopted for the heating systems, less different between them from the economic and functional efficiency point of view. These selection criteria refer to:

- the specific of the activity and technological conditions inside the production enclosures,
- the geometrical and constructive characteristics of the building,
- the type of the energy utilized in the technological process
- economic considerations.

The economic criteria are related to costs needed for the equipment acquisition, mounting and maintenance costs. These costs reflect also the costs for the maintenance personnel, the fuel consumption and electric energy in order to realize the indoor thermal comfort. The highest rate for the maintenance costs is represented by the fuel costs. The efficiencies for the production, regulation and energy distribution in the building are almost the same. In these conditions the selection criteria for the solutions is represented by the electrical consumption. Sometimes, the less investments solutions are not the same with less costs maintenance solutions. The optimal solution is the one with minimal costs. Even that the heat demand calculus was based on SR 1907 methodology we consider that the results obtained with TRNSYS simulation in dynamic regimes are interesting. For the building with different heights regimes the calculus were made taking into consideration: the wall geometrical and thermo technical characteristics, their areas, the glass surfaces, variation of the heat or cooling supply temperatures diagram, internal heat sources etc. Based on these parameters and meteorological temperature variation for the second zone in Romania, the hourly heat demand was determined. The simulations were effectuated in the following hypothesis: one-hour time step, one-year simulation period of time, heating period from October to March. The indoor temperatures taken into consideration are: for the production large enclosure from 06:00 – 19:00 ti = 15°C and from 19:00 – 06:00 ti = 6°C. For the offices spaces from 08:00 – 19:00 and ti = 20°C and from 19:00 – 08:00 and ti = 15°C. The air exchange rate is n =0.5 1/hour, metallic walls insulated with 60mm polyurethane, the floor on the ground with a temperature tp = 10°C. For every hour of the heating season the indoor temperature and heat charge were calculated. For the classical heating system, one volume with variable night and day temperatures was taken into consideration for the simulation. The radiation system was simulated by dividing the volume of the building. The volume comprised between the radiation cone with t_1 = 150°C and the volume above the radiation cone with t_2 = 13°C. The data referring to the heat demand calculated with TRNSYS for the two systems compared are presented in Table 1.

Table 1

The level of calculated heat demand with different methods

	SR 1907		TRNSYS	
H	**Q_c [kW]**	**Qr [kW]**	**Qc [kW]**	**Qr [kW]**
12m	596.6	564.9	562.12	419,87
10m	548.0	517.0	499.66	369,55
8m	499.2	469.0	445.47	329,19
6m	450.3	420.9	396.17	285,15

where : Qc – heat demand for the classical heating system
Qr - heat demand for the radiating system

Figure 4. The heat demand and indoor temperature variation for a 12m height production large enclosure

While the simulation in the dynamic regime allowed obtaining also the monthly consumptions for the entire heating season, depending on the enclosure height and system heating type, the results for the gas consumption for the heating compared systems are presented in figures 5 and 6. The highest level for gas consumption was registered in January.

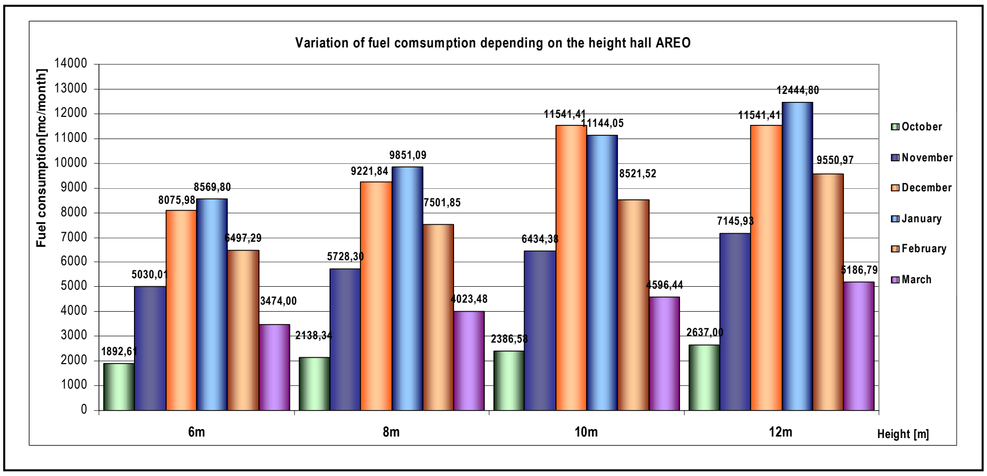


Figure 5. The variation of monthly gas consumption depending on enclosure for AREO system

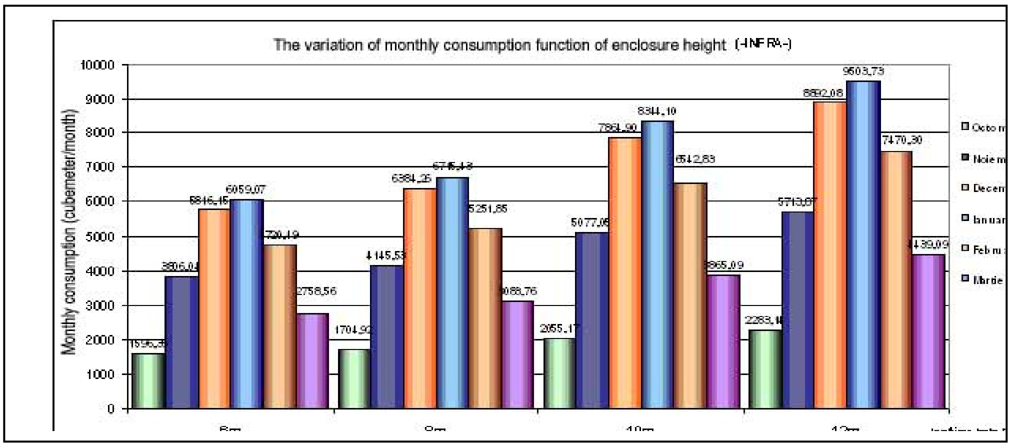


Figure 6. The variation of monthly gas consumption depending on enclosure for INFRA

4. Investment and maintenance costs for the heating systems

Depending on the adopted heating systems for the industrial large enclosure (classical system with boiler and hot-air fan coils and radiating system with INFRA tubes), depending on the enclosure different heights of 6m, 8m, 10m, 12m, depending on the type and fuel consumption, the results for the investment costs are presented in Table 2.

Table 2

Total costs of the investments for heating solution

System type	Acquisition costs for the equipment EURO	Mounting costs EURO	Price of the equipment EURO	Costs for the gas equipment EURO	Total price for the investment EURO
6 I	27899.48	4900	32799.48	4490	37289.48
6.A	20010	7201.2	27211.2	400	27611.2
8 I	30746.08	4368	35114.08	3055.5	38169.58
8.A	25300	7980.2	33280.2	400	33680.2
10 I	32667.71	4819.5	37487.21	3090.5	40577.71
10. A	26270	9519.32	35789.32	400	36189.32
12 I	34589.34	5859	40448.34	3125.5	43573.84
12.A	28110	9930.42	38040.42	400	38440.42

Based on the final results for the annual consumptions, the maintenance annual costs for every type of the system were calculated. The prices for gas taken into consideration were 0,25 Euro/Nmc for Romania and a medium price of 0,48Euro/Nmc for European Union. The results are presented in Table 3.

4. Residential buildings

The existent house building stock in Romania comprises approximately 8 million dwellings in 4.6 million buildings. The heating systems are generally based on technologies corresponding to the period before the 1972 energy crisis. The primary fluid is boiled water (150^{0}C and 80^{0}C return) and the secondary fluid is hot water (95^{0}C and 75^{0}C return).However, almost all the existing District Heating (DH) system in the country are technologically obsolete, the heat losses are high and the energy efficiency is low.

Table 3.

Annual exploitation costs

The height of the enclosure [m]	Type of the system	Static regime		Dynamic regime	
		Gas costs RO	Gas costs UE	Gas costs RO	Gas costs UE
		EURO/year	EURO/year	EURO/year	EURO/year
12	INFRA	7383,8	14184	9874	18942
	AREO	10193	19578	13599	26088
10	INFRA	6754,6	12973	8700,2	16690,5
	AREO	9066,9	17417	12217,2	23438
8	INFRA	6115,2	11745	7551,4	14486
	AREO	7921,8	15215	10015,8	19214
6	INFRA	5484,6	10534	6368	12216
	AREO	6784	13031	8292,3	15908

The performances of the DH systems are poor, partly because of insufficient insulation of pipes, fuel shortages and excessive corrosion leading to hot water loss. But perhaps the most important factor leading to poor performance is the uncontrolled expansion of networks in the past. In buildings, the two main problems still are: the lack of meters and controls for each apartment, and poor insulation and sealing. The solution problem could be small-scale cogeneration. These systems may appear as very interesting for Romania. Cogeneration also has the added advantage of diversifying electrical energy production, thus potentially improving security of energy supply in the event of problems occurring with the main electricity grid. As residential scale cogeneration technologies are still in their infancy, the potential for residential cogeneration energy and emissions savings is yet to be firmly established, and the emissions savings are determined by the emissions of the displaced fuels. Cogeneration applications in residential buildings can be designed to: - satisfy both, the electrical and thermal demands, - satisfy the thermal demand and part of the electrical demand, - satisfy the electrical demand and part of the thermal demand -or, most commonly satisfy part of the electrical demand and part of the thermal demand. In addition, cogeneration in buildings can be designed for peak shaving applications, i.e. the cogeneration plant is used to reduce either the peak electrical demand or thermal demand.

5. Conclusion

• The reduced fuel consumptions for the radiating systems lead to less costs for maintenance. The maintenance costs for these systems are proportional with the enclosure height from 19% to 32%.

• No matter what calculus method is utilized, for the enclosures heigher than 6m, the radiating system is more economic than the hot air system. In addition, from the maintenance point of view, the system with a boiler and hot-air fan-coiles is much more expensive.

• Even the gas consumptions are different depending on the calculus method, the economies for the gas consumptions (taking into consideration as reference the consumption for the classical system with boiler and fan-coils), are almost identical by increasing the height of the building. For the enclosure of 6m height, even that the values for the hot air system are identical, in the case of the radiating system the economy for the gas varies with 4%. That means that the calculus is correct by all the three methods.

• Even for smaller heights, such as 6 m, the payback time for INFRA radiating system is around 5 years, which represent a very good term.

• The economic viability of cogeneration systems for residential buildings is critically dependent on the installed cost of each system, system maintenance costs and retail prices for the cogeneration system fuel and centrally generated electricity as well as the electricity exportation price if electricity is exported to the grid.

• To meet the full electrical or thermal demand of a building using cogeneration it is usually necessary to install cogeneration systems which are oversized in both their electrical and thermal outputs. Unless there is a use outside the building for the surplus heat and power, this usually has the unwanted consequence that the unit's running time will decrease due to an insufficient load being available. This reduction in functioning hours will affect the economic efficiency of the system. For this reason, cogeneration devices are usually sized to meet only a part of the electrical and thermal need.

R E F E R E N C E S

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