Overview on heating systems energy efficiency in industrial and residential buildings from Romania

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Abstract: - 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. The study will plead for cogeneration systems in the spirit of Directive 2004/8 EC and for radiant heating systems for industrial sector.
Finally, the study will present some results if these types of systems are utilized in Romania.

Key-Words: - energy efficiency, radiant heating, cogeneration systems

1 Introduction

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 1. The proportion maintains very close also in 2009.

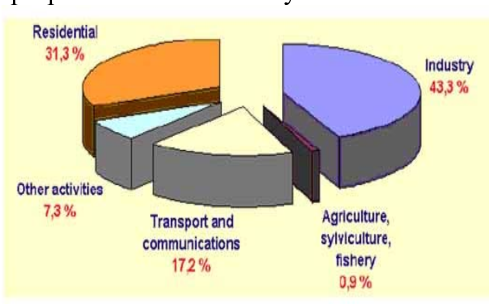

Figure 1. Final energy consumption in the year 2007, by sectors

The total final energy consumption in the industrial sector is distributed among the different industries as presented in Figure 2. The chemical, petrochemical and construction sectors are the principal industrial consumers. 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.

The industrial sector comes with a potential for

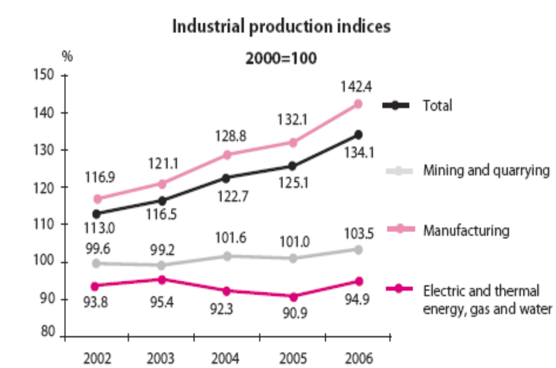

Figure 2. Industrial production indices

energy conservation of around maximum 17% of the total, equivalent of 1.590 Mtoe energy savings. The savings may be obtained mainly by the improvement of the energy management, investments in M&T systems, technological rehabilitation and modernization. The technical analyses revealed that the medium value of the specific investment is around €200/toe.

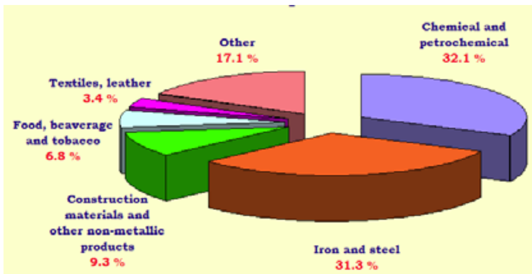

Figure 3. Total final consumption in industry

The transport sector comes with a potential for energy conservation, of around maximum 35% of the total, equivalent of 1.390 Mtoe energy savings. The technical analyses revealed that the me dium value of the specific investment is around €250/toe. The increase in final energy intensity after the year 2000 has been primarily determined by the increase in the population fuel consumption (that does not produce value added registered as such).

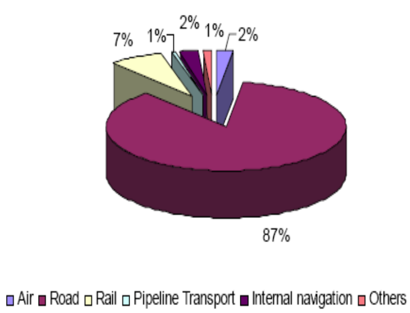

Figure 4. Final energy consumption in the transport sub-sectors
(Source: International Energy Agency)

2. The actual situation

For the present study, were selected five relevant cities with district heating systems, from different parts of Romania. In Table 1 are given some data regarding the number of the apartments connected to district heating system and heat prices, in €. It is very important to underline the fact that after 1989, a lot of industries was closed, so a big number of heat consumers disappeared from the market. The industries that resisted on the market and the commercial sector, are paying for thermal energy consumed, the price approved by ANRSC.

Table 1.

City	No of apartments supplied	Supply price* with VAT (€/Gcal) **	Reference local price (€/Gcal)	Price paid by the population (€/Gcal)
Bucharest	570.537	65,88	28,00	28,00
Ploiesti	59.976	55,91	27,61	23,53
Iasi	61.937	61,61	41,18	41,18
Timisoara	88842	67,98	38,26	38,26
Cluj	47.905	81,66	39,76	39,76

** - price approved by ANRSC (Romanian Public Services Regulatory Authority); ** 1€=4,25 ROL*

It is presented in the Figure 5 the level of heat supply prices approved by ANRSC, in the last 3 years.

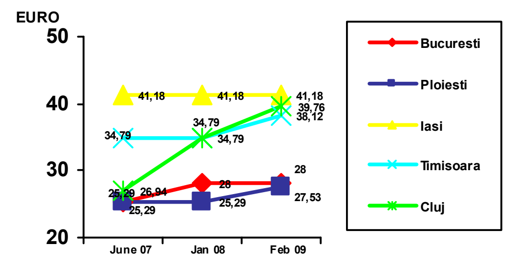

Figure 5. The level of heat supply prices

The general objective of the energy strategy is covering the necessary of energy in the present and in future (medium and long terms), at a lower price, proper to a modern economy on the market and to a standard level for life, in quality conditions, security in supply, and respecting the principles of sustainable development. Energy efficient improvement represents one of the most important strategic objectives for Romania, in situation of existing activities in industry which use energy resources as primary materials, special in petrochimistry and chemical fertiliser industry. General measures are given: •Improving the institutional and legal framework, •Improving the price policy for fuel, thermal energy and electricity, •Using the human potential, increasing of work efficiency and improving of work conditions, •Technological development in energy sector, •Foreign and internal financing in energy sector, •Developing competition market for electricity and natural gas. Taking into account the goal of this study, hereinafter are given some relevant specific measures of energy strategy:

Energy efficiency: • Using financial instruments for saving energy. •Acquisition of equipment and technologies with energy efficiency. •Improving of

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the execution process of energy audits at the industrial consumers, public and residential buildings, audits certificate by the skill bodies, followed by the reducing of de energy consumption measures.

Residential: • Thermal rehabilitation of the building, financial support scheme for the poor owners for building rehabilitation, •Thermal and lighting installation more efficient, • Compulsory implementing of directive's provisions and of european standards of efficiency in the new buildings.

Public sector: • Increasing efficiency and reducing consumption for public lighting, •Increasing efficiency and reducing consumption for water supply installations, • Improving energy efficiency in public buildings.

Cogeneration: •Promoting of high efficiency cogeneration, •Energy audit for cogeneration installations, • Rehabilitation and modernization of existing installations, for increasing efficiency and reducing impact on the environment.

Based on the estimations concerning the potential energy savings for the main energy consuming sectors and also based on the final energy consumption of those sectors, the National Strategy for Energy Efficiency included the values for the cost-effective savings of energy (Table 2).

Table2.

Sector	Estimated medium cost-effective potential energy savings	Maximum values for the potential annual energy savings
	[%]	[ktoe/year]
Industry	13.0 (10 – 17)	1590
Residential	41.5 (35 – 50)	3600
Transport and communications	31.5 (30 – 35)	1390
Tertiary sectors	14.0 (13 - 19)	243
TOTAL	**100**	**6823**

Source: National Strategy for Energy Efficiency

3. The industrial consumers

Enhancing the working environment is an important goal in industry sector. As a consequence, the thermal comfort is an important scientific issue especially in large enclosures. The radiant heating systems can be a better alternative in cases of large openings heated with classical systems (hot-air batteries or convective systems). The conventional heating systems cannot insure a constant indoor temperature, may cause unpleasant draughts and can have a low efficiency. Another inconvenient of traditional heating systems is a consequence in low humidity of air. The indoor air becomes dry, in the case of a reduced outdoor temperature. The main advantage of the radiant heating systems consists in insuring a fresher air and a lower content of dust then in classical heating system. The effect of radiation in large enclosures is determined by the proper thermal comfort, by keeping a low temperature of the indoor air and of the surfaces of walls. Also, it is important to mention the fact that heating radiation systems allow limitation of heating in the desired zones of enclosures. In fact, the directed radiation determines the heating of the floor, the corresponding absorption coefficient having a higher value. This contributes to the process of heating the air by convection and limits the losses of heat at the floor's level. The economies obtained with a radiation heating system are important. In the heating radiation systems, the study of the radiation surfaces efficiency is extremely important. In all cases, the main problem, beyond the heat radiation transfer modelisation difficulties, consist in obtaining a uniform heating flux on the receiver surface. The uniformity of a radiating flux can be achieved by a constant temperature of the radiation source or by a uniform distribution of the emitted radiations. In order to accomplish this demand, the radiating tubes are located in reflecting enclosures; an optimal geometry will ensure a uniform flux on the receiving surfaces. The optimization of the shape of the geometry enclosure or the position of the radiating tubes inside the enclosure and the distance between them, can be obtained only by trying different positions until the optimum position is found. This problem is enough expensive to solve it experimentally, and there are a few laboratories where this study is possible. Also, an analytical model is difficult to build because the integration of the equations which describes the system could not be realized. Until now, the problem was solved using a numerical method on a computer, taking into consideration any configuration and geometry. Recently studies show that the most appropriate solution from technical and economical point of view is to place the radiant tubes in a reflector half hexagonal enclosure.

The TUBRAD program, formulated in order to evaluate the radiation distribution emitted by the tube in the enclosure, it is flexible and easy to work with different geometry of the system. The program allows introducing attenuation coefficients of the radiation due to the imperfect reflections of the surfaces. The majority of the surfaces are characterized by a reflection coefficient equal with the unit.

In the figure 5 it is shown the model of radiation corresponding to a tube in "U" form with the burner and the collector both on the same side (which leads to a better uniformity of the temperature along the tube).

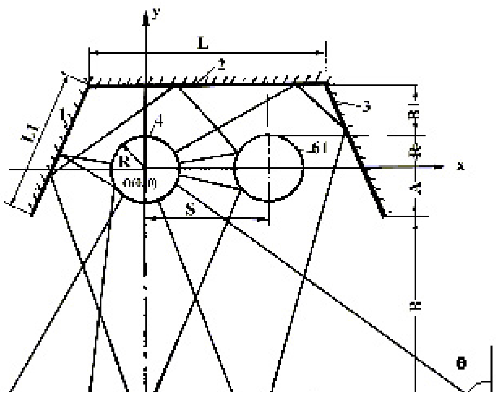


Figure 6. Radiant tube in "U" form with a reflecting half-hexagonal screen

Applying TUBRAD program we can obtain: •the distribution of the radiation in the receiving plan for different geometries of the reflector baffle as the result of varying angle inclination or lateral parts of the baffle, •the influence of radiant tubes position inside or outside the reflector baffle on radiation distribution in the receptor plan, •the effect of the depth of the baffle, of the distance variation between the tubes. The distribution of the radiation in the receiving plan for different heights of placement of the tubes in the heated enclosure. The values were integrated then using MATLAB program in order to determine the temperature fields at the receiving surface level. For example the form of this distribution is shown in Figure 7.

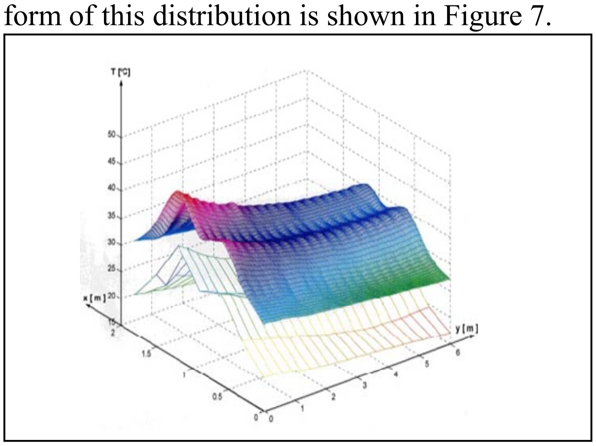


Figure 7. Calculated temperatures distribution on the reception surface. h=2.2m

In order to give a real image of the energy efficiency of different radiant systems we compared 2 heating systems: hot air system (classical model AREO and EOLO) and radiant systems (INFRA and OHA). The results give the level of annual exploitation costs (fuel and electrical energy) and investments costs. The monthly and annual fuel consumptions for each different case were established in dynamic regime simulation:

$$B_a = \frac{n_0}{P_{ci}\eta_g(t_i - t_{ec})} z(t_i - t_{em})Q_h \qquad (1)$$

with P_{ci} = inferior caloric power of the fuel; n_0 = number of daily hour utilization of the heat system; z = number of days in the heating season; t_i = indoor temperature; t_{em} =outdoor medium temperature in the heating season ; Q_h= the hourly heating charge of the enclosure[m^3].

The efficiency was calculated as:

$$\eta_g = \eta_p \cdot \eta_t \cdot \eta_r \cdot \eta_d \qquad (2)$$

η_g= the global efficiency of the heating system; η_p= the production efficiency; η_t= transportation of the heat efficiency ; η_r= regulation efficiency ; η_d= distribution efficiency . While the simulation in program TRNSYS was effectuated in dynamic regime, monthly gas consumptions for entire heating season function of the height of the enclosures were obtained. *Table 3.*

The height of the enclosure [m]	System OHA [Nmc/h]	System INFRA [Nmc/h]	System AREO [Nmc/h]	System EOLO [Nmc/h]
12	35679,11	38302,21	48506,9	47460,30
10	31437,86	33749,14	43461,39	42523,65
8	29291,78	27285,76	38464,9	37380,06
6	23010,18	24756,7	33539,69	32593,76

Two examples of the height of enclosure influence on the total gas consumption (for hot air and radiation system) are given in Figure 8 and 9.

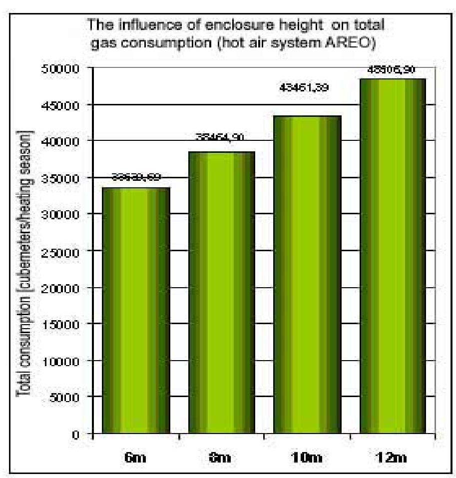


Figure 8. Height influence on gas consumption for system hot air AREO

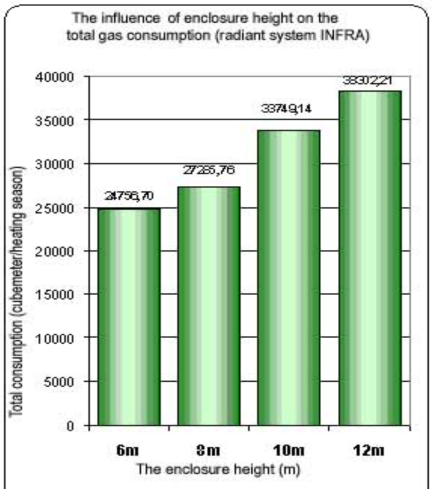


Figure 9. Height influence on gas consumption for radiant system INFRA

Based on the results for annual gas consumptions, the annual exploitation costs for every type of system were obtained. The price for gas in Romania is 0,25 Euro/Nmc while in UE is 0,48Euro/Nmc.

Table 4.

The enclosure heigt [m]	Heating system	Static regime		Dynamic regime	
		Gas cost for Romania	Gas cost for UE	Cost comb. RO	Cost comb. UE
		EURO/year	EURO/year	EURO/year	EURO/year
12	OHA	6883,8	13216	9200	18037
	INFRA	7383,8	14184	9874	18942
	AREO	10193	19578	13599	26088
	EOLO	9662,3	18559	12891,2	24730
10	OHA	6293	12087	8106,3	15551
	INFRA	6754,6	12973	8700,2	16690,5
	AREO	9066,9	17417	12217,2	23438
	EOLO	8687,7	16686	11304,3	21686
8	OHA	5697,7	10943	7035,4	13497
	INFRA	6115,2	11745	7551,4	14486
	AREO	7921,8	15215	10015,8	19214
	EOLO	7695,5	14781	9729,9	18666
6	OHA	5109,7	9815	5932,9	11382
	INFRA	5484,6	10534	6368	12216
	AREO	6784	13031	8292,3	15908
	EOLO	6663,5	12798	8144,5	15623,5

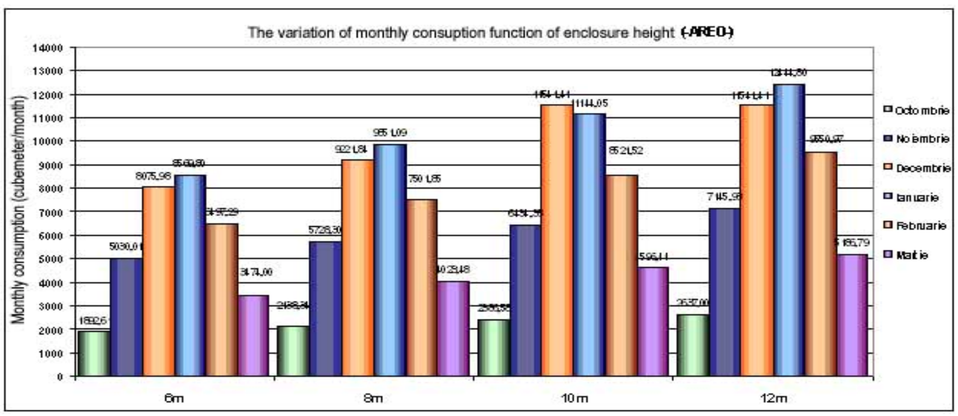


Figure 10. The variation of monthly gas consumption depending on enclosure for AREO system

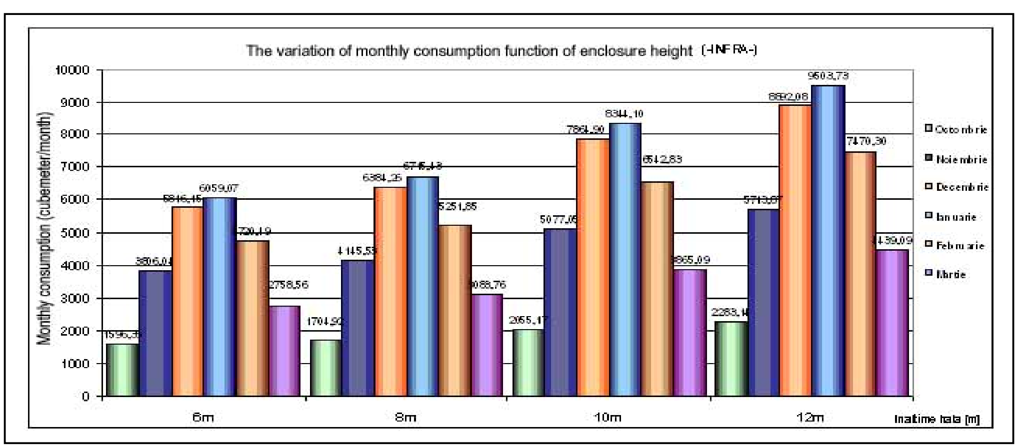


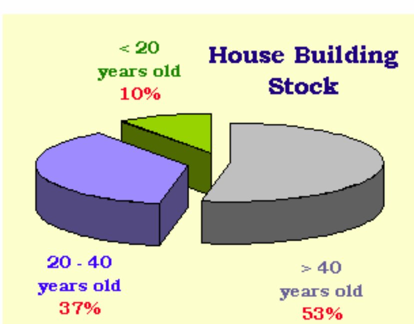
Figure 11. The variation of monthly gas consumption depending on enclosure for INFRA system

4. The residential consumers

The existent house building stock in Romania comprises approximately 8million dwellings in 4.6 million buildings. The following graphs (Figure 12) show both the house building stock by age, the percentage by type of dwellings and the evolution of the dwelling stock. 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 system in the country are technologically obsolete, the heat losses are high and the energy efficiency is low. The performances of the district heating 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. Sometimes, due to the lack of maintenance and operators of district heating systems it is impossible to maintain adequate levels of service to residential consumers. In buildings, the two main problems still are: the lack of meters and controls for each apartment, and poor insulation and sealing. At present moment the heat meters are mounted to the level of each staircase from the blocks of flats. 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.

As for the industrial consumers 2 systems were compared, 2 solutions for the residential consumers will be also analyzed. A consumer with heat demand of 21 077 MWh/year and an electrical demand of 5 900 MWh/year will be taken into consideration. As a first solution will be considered that the electricity will be taken from the national grid and the heat will be produced in a individual plant on gas. The second solution will consider a cogeneration unit EG 230 (Deutz Power Systems). The electricity cost for the national grid is considered as 0,074 €/kWh.
So, the annual cost for the electricity and gas in the first solution will be:
- 5900000 • 0,074 =436600 €/year for electricity
- 21077000•0,0238/0,8=627041 Euro/year for heat (considering a medium efficiency of the plant of 80%).

The total annual costs will be than 1 063 640,75 €/year. For the unit cogeneration:
-Module EG 230 – 450 000 €
-Peak consumption boiler– 4000 €
-Total investment= 450 000 + 4000 =454 000 €
-Life time – 15 years
-Finance rate –3,5 % (variable in time and Bank)
-Heat mounting equipment – 200 €
-Boiler – 2000 €
-Electric mounting equipment – 1000 €
Total costs =200+2000+10000=3200 €
-Other accessories needed = 3,5% •3200 = 112 €/year
-Total finance rate = 3,5%•454000 =15890 €/year
Total amount =112+15 890=16 002 €/year
-Maintenance costs (0,007€/kWhelectric)–12880 €/year
-Revision costs (0,008€/kWh electric)–14720 €/year
-Fuel costs for 8000hours/year-12357 €/year
Total amount for functioning =
=12 880+14 720+12 357=39 957 €/year
-Annual costs =39 957+16 002 = 55 959 €/year
-Electricity produced from the Module EG:
P_e •Annual number of functioning hours=
=1840MWh/year



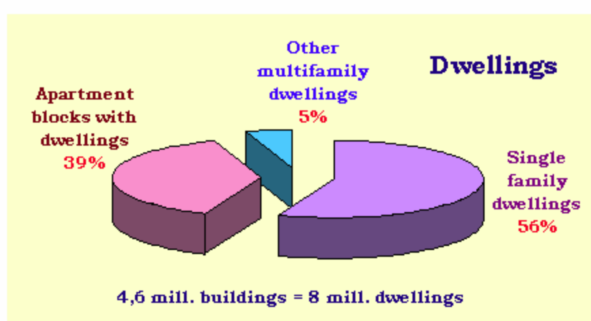


Figure 12. Housing building stock by age and dwellings by type

Heat produced from the Module EG:
P_t• Annual number of functioning hours=
=2 808 MWh/year
Total energy = 4 648 000 kWh/year
Cost per kWh = 55 959/4 648 000= 0, 012 €/ kWh
Energy costs :
Solution 1:
Electricity costs = 5900000•0,074=436 600 €/year
Heat costs = 21077000•0,0298 =627 041€/an
Total costs = 1063640,75 €/year
Solution 2 :
Investement costs = 457200 €
Annual costs = 55959 €/year
Electricity produced – 1840MWh/year
Heat produced from the Module-2808M Wh/year
Heat from the peak plant=
=21077-2808 =18269 MWh/year
Total energy from the module =
=1840 +2808 =4648 kWh/year
Electricity cost from the module:
1840000 kWh•0,0120 €/kWh=22152 €/year
Electricity cost from the national grid:
4060000 kWh•0,0740 €/kWh=300440 €/year
Total 322592 €/year
Heat costs:
Classic plant- 18269000 kWh •0,0298€/kWh=
= 543.503 €/year
Module -2808000kWh•0,0120€/kWh =
=33807 €/year
Total 577309 €/year
Costs for module 899.902 €/year
Annual economy with module EG:
1063640,75-899902 ≈163.739 €/year
Return time investment =
= 454000/163739=2,8 years
Emisssions reduction CO_2=
1840000•0,65=1196000 kg/year

4 Conclusion

•Romania is facing also to energy challenges. The safe, reliable and efficient functioning of the energy sector is crucial for the Romanian economy. In developing a competitive domestic energy market, Romania is closely observing the energy policy of the European Union with a view to establishing an integrated European market. Romania's energy intensity is among the highest in the region. Such high intensity in Romania is due to aging equipments of antiquated technologies. So, energy efficiency measures had and have to concentrate on the industrial and residential sectors, where there is the clearest scope for improvements.

•The sectors with the most important shares of the total final energy consumption are industry (43.3%), residential (31.3%), and transport and communications (17.2%). That is why energy efficient improvement represents one of the most important strategic objectives for Romania, in situation of existing activities in industry which use energy resources as primary materials. Residential sector is on the second place from the consumption point of view.

•The National Energy Strategy foresees an annual reduction of the energy intensity of the national economy of approximately 3% per year. The Strategy considers energy efficiency as an important option, in particular in the medium and long term.

•For industrial consumers radiating heating systems represent an alternative to classic systems (hot air system). For hot air systems the gas consumptions are insignificant depending of the enclosure height (1%). Radiant systems utilization lead to gas consumption economies depending on the enclosure height. The higher economy is obtained for 12 m enclosure height and system OHA (5716 Euro/year).In the same time, the investments are recuperated in 5 years which is a very acceptable return term. INFRA system costs can be recuperated faster than OHA radiant tubes but the connections and accessories for gas are more expensive.

•The exploitation costs for radiant systems are more reduced proportional with the enclosure height (between 19% and 32%).

• 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.

• With each of these potential system designs there are constraints on the practical and economic viability: - for a cogeneration unit designed to fully meet the electrical demand of the building; if the heat demand is below than the thermal output from the cogeneration plant, the plant unit will either throttle back to operate under part load conditions, or will switch on and off, or will require that the surplus heat is dumped to atmosphere/stored in a thermal storage device (such as the heat distribution system, the building structure or in water) [5]. On the other hand, if the heat demand of the building is higher than the cogeneration capacity, a secondary heat raising system such a boiler is often used to "increase" the heat output. - for a cogeneration unit designed to fully meet the thermal demand of the building; if the electrical demand of the building is inferior to the electrical output from the cogeneration plant, the cogeneration unit can either be throttled back, or the surplus electricity produced can be exported to the utility grid or possibly stored in an electrical storage device such as batteries or capacitors. On the other hand, if the electrical demand of the building is higher than the output of the cogeneration plant, the lack of electricity is usually covered by importing electricity from the utility grid.

- The economic viability of such systems is critically dependent on the installed cost of each system, system maintenance costs and retail prices (see example) 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.
- Romania has created an institutional and legal framework in conformity with the EU acquis in order to promote energy efficiency.
- The National Strategy for Energy Efficiency, which is the most important document concerning the energy efficiency policy in Romania, was approved by the Government in 2004 and the Action Plan included is in progress of implementation. The National Energy Strategy foresees an annual reduction of the energy intensity of the national economy of approximately 3% per year. The Strategy considers energy efficiency as an important option, in particular in the medium and long term.

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