Energy and Environmental Analysis of the Current use of Heating and Recommendations for the most Suitable Energy and Environmental Heating Systems in the City of Korca

Ramadan Alushaj[1], Flamur Bidaj[2]

[1]Professor, Mechanical Engineering Faculty, PUT, Albania

[2]Energy Department of Mechanical Engineering Faculty, PUT, Albania

Abstract: ***The aim of this study is the analysis of the most used heating systems in the building sector of the city of Korca, using as criteria the cost of equipment, fuel type, energy efficiency, pollution impact on population health and climate change. Referring to one of the most touristic cities of Albania, with the lowest outdoor design temperatures during the winter season, with a relatively large number of individual buildings, combined with intensified touristic visits in the colder months, where heating requirements increases,while thermal comfort conditions and environmental pollution reduction from emissions of combustion products remains a problem for optimal solution. On the other hand, Albania's energy challenges until 2030 are summarized in the Energy Strategy,with the fulfillment of 3 main indicators: reduction of 11.5% of greenhouse gas emissions, increase of the contribution of renewable energies to at least with 48%, improvement of at least 15% of energy efficiency. In general, citizens of these cities are always inclined to buy low-cost heating appliances which have high operating and emission costs. Nowadays a variety of heating technologies are available, which have distinct advantages and disadvantages in capital cost and heat production efficiency in the emission potential, so it is necessary to consider different alternatives before choosing the most convenient one. service life higher than 10 years and that meets national energy criteria and degree of environmental pollution within the allowed norms. This study aims to assist and facilitate this selection of most suitable heating system for individual cities by analyzing and comparing decentralized energy efficient heating systems and district heating systems integrated with renewable energy, to identify their advantages and disadvantages and provide a classification based on the cost of operation, emission potential and their initial investment as a recommendation to users and local and national institutions strategies.***

Keywords: Energy, heating source,renewables, biomass, solar, energy efficiency, emissions, pollutions, environmental impact, health impacts, investmentcosts

1. Introduction

Generally, buildings in city of Korca,as worldwide, are one of the largest consumers of energy. Space heating represents about 69% of total energy consumption, including domestic hot water energy consumption by 11% for year 2015. Moreover, residential buildings are the fourth largest source of CO2 emissions in the EU and constitute up to 9.9 % of total emissions in 2007, while emissions from non-residential buildings are ranked as the fifth source and makes 3.9% of total CO_2 emissions.

For heating purposes, the total electricity consumption for 2017 was 484 Ktoe, while the total firewood consumption was 168 Ktoe. About 92% of this amount of energy is consumed in the housing sector and only a small amount in the buildings and industrial sector. Energy demands from the housing sector comprise a major challenge for our country as this sector consumes 60% of the total national electricity consumption, while in cold and rural areas continues mainly consumption of wood for heating and cooking. The city of Korca has a specific composition of individual residential buildings that use a lot of firewood for heating and cooking.

From the heating point of view, problems for the city of Korca have been and remain the lack of proper thermal comfort and gas emissions released by burning firewood for comfortable heating in the late autumn-spring season.

During this wood burning process, the combustion reactionsproduces heat and emissions in the form of water, organic vapors, gases, and particulatesthat are evidenced in the overall pollution of the city of Korcain level of the total TSP particles and the particulate matters PM_{10} with a 50 % efficiency cut-off at 10 μm aerodynamic diameter and fine $PM_{2.5}$ particles in accordance with EN 12341, as well as the carbon monoxide (CO), carbon dioxide (CO2), sulfur oxides (SOx), and nitrogen oxides (NOx).

2. The building typologies in city of Korça

The typology of individual residential buildings dwellings in Korça consists mainly of small one and two floorhouses that are located very close to each other. They are grouped into square blocks formed by the intersection of straight horizontal paths. Buildings of this construction period are usually combined systems with horizontal beams and reinforced columns and with non-insulated cladding. The walls are made of 20 cm thick clay blocks, plastered on both sides and the basement walls are made of 20 cm thick reinforced concrete and the roof of the building are usually without any thermal insulation.

Socialist-era residential areas with collective multi apartment buildings are mostly located in the southern part of the city. They are characterized by large residential MAB's (4-5 floors) organized with limited green spaces, wide roads and wide common spaces with thermal non insulated building structures.Residential areas from the last socialistic period (1980-1990) are mainly located in the northeastern part of the city with 6-storey high-rise multi apartment residential blocks with the thermally non-insulated building structures.

Buildings structures constructed after 1990's period are characterized by the construction of multi-storey and very functional buildings (8-9 floors high) but still without thermal insulated building structures. They are located mainly in the former industrial area at the entrance of the city.

Based on the typology of buildings, as well as the data obtained from INSTAT (2011) presented, in Table 1, the city of Korça has the composition of buildings as follows. [1]

Table 1: Types of buildings in city of Korça

Municipality	Type of building					Number of inhabitants in the building			
	Total	Individual house	Partially detached house	House in order or terrace	Multi apartment	1	2	3 to 4	over 5
Korca	6792	4615	1014	429	734	4985	958	261	588

From the above table it is noticed that the buildings of the city of Korca both individual and those with several floors, buildings that were built until 2012 are not thermally insulated and as such they constitute more than 90% of the buildings of the city in Korca.

For the buildings without thermal insulation the average of specific heat losses for all types of the buildings, is about 125 (W / m2). While referring to the State DECISION no. 537, dated 8.7.2020, named "For the Approval of the Minimum Energy Performance Requirements of Buildings and Elements of Buildings", the total heat transmition coefficient, the rate of transfer of heat through a structure of the elements of existing buildings envelope, known also as U-value, should be:

a) external walls in contact with the external environment: U = 0.40 (W / m^2K), b) roof (sloping or terrace): U = 0.35 (W / m^2K), c) attic floor: U = 0.45 (W / m^2K), ç) ground floor: U = 0.5 (W /m^2K), d) glazed components (insulated aluminum frame windows, plastic, wood, etc.), in which the U value for transparent structures (windows) includes glass and frame overall value: U = 2.20 (W / m^2K).

Based on the minimum building energy performance requirements, by implementing above mentioned thermal insulation measures, the minimum value of average specific heat losses is about 55 (W /m^2).

3. Verification of energy costs and environmental impact on the use of current heating fuel

In close collaboration with relevant ministries we have used the document "Census for Population and Housing" of the city of Korça, from the survey conducted by INSTAT in 2011, from where we received specific information on the number of inhabitants and buildings of the city, the period of construction of the buildings, their area, number of floors, the number of members per apartments, the type of energy used and the heating methods in this city [1].

Below are presented tables 2 and 3 for the energy sourceused for heating and the main typeof heat, according to INSTAT statistics.

Table 2: The main types of the energy used for heating in city of Korça

The main type of energy used for heating	
	Urban Zone
Total	26,178
Wood	24,248
Electrical energy	548
Gas	964
Another type of energy	170
No heating	248

Table 3: The main types of heatings in city of Korça

The main type of heating	
	Urban Zone
Total	26,178
Central heating in the building	378
Individual central heating	251
Wooden Stove	24,306
Fireplace	206
Electric heating	361
Air conditating	136
Main type of heating	290
No heating	248

From the above table data analysis it is noticed that the use of heating systems with conventional equipment of wood stoves and less with open heating fireplacesin total constitutes about (90%) of users and as such these equipments represents the type of largest use of heating energy in the city of Korca. Moreover, from this mode of use of energy for heating purposes in the city of Korca has been identified an inconvenience and discomfort of the used fuels, due to the high cost of wood while the high presence of aair pollutions from the fuel burnings is noticed.

In table 4, below, for a living room model with area of 50 m^2 and without thermal insulation, based on the typology of heating equipment used in the Albanian market, apart of the unit price of each potetialfuel and price for electricity with tariff for household use (including taxes), the corresponding average calorific value of fuels, the efficiency of the heat production process for a heating operation time of 12 hours, are presented the overall costs of use.

Table 4: The average costs of different types of heatings in city of Korça

Apliances Residential heating	Room 50 m^2 -no isolatin -125 W/m^2								
	Thermal power (kw)	*Heating time (hours)*	*daily capacity, kW*	*Calorific capacity kWh / kg*	*Max. Consumation l.dj (kg/date)*	*Min. Consumation l.dj (kg/date)*	*Max. €/daily*	*min. €/daily*	*€/kg*
Open Fireplace COP=0.10-020	3.125	12	37.5	4.1	91.5	45.7	**11.1**	**5.5**	0.121
Party closed Fireplace COP=(0.5-0.80)	3.125	12	37.5	4.1	18.3	11.4	**274.4**	**1.4**	0.121
Convencional stoves COP=(0.4-0.5)	3.125	12	37.5	4.1	22.9	18.3	**343.0**	**2.2**	0.121
High -efficiency stoves COP=(0.55-0.75)	3.125	12	37.5	4.1	16.6	12.2	**249.4**	**1.5**	0.121
Advanced/ecolaboled stoves COP=(0.70)	3.125	12	37.5	4.1	13.1	13.1	**196.0**	**1.6**	0.121
Pelette stove and boilers COP=(0.88-92)	3.125	12	37.5	4.5	9.5	9.1	**284.1**	**2.2**	0.243
Electric heaters COP=1	3.125	12	37.5	1	37.5		**34.5**		0.92
Inverter Hi-wall AC SCOP=5.1	3.125	12	37.5	1	7.4		**6.8**		0.92

From the table it can be seen that the most expensive heating cost is the one with the open heating fireplace and the lowest heating cost is the one with inverter air conditioner (without considering the investment cost). The lowest cost in systems with biomass are identified using advanced wood- or pellet-burning appliances, when are properly sized for the space to be heated.

Fuel combustion is the process of oxidation ofthe fuel by means of atmospheric oxygen resultingin intense releasing of heat, which is, in turn, efficiently utilized and the main emissions that can be released from biomasscombustion in such heating equipments are:

Particulate Matter (PM), Nitrogen Oxides (NOx) including; nitric oxide (NO), nitrogen dioxide (NO2) and nitrous oxide (N_2O), Carbon oxides (COx) including; carbon monoxide (CO) and carbon dioxide (CO_2), sulfur oxides (SOx) including; sulfur dioxide (SO_2) and sulfur trioxide (SO_3).

PM products are considered to be one of the most important pollutants produced by biomass combustion (wood and pellets). PM size varies, with two categories usually identified when analyzing the impacts of PM on human health and the environment; PM_{10} and $PM_{2.5}$.). Based on EN 12341

'PM10' mean particulate matter which passes through asize-selective inlet as defined in the reference method for thesampling and measurement of PM_{10}, with a 50 %efficiency cut-off at 10 μm aerodynamic diameter;while $PM_{2.5}$, or fine particles, includes all particles having an aerodynamic diameter ≤2.5 micrometers.Total Suspended Particles (TSP) is the fraction sampled with high-volume samplers, approximately particle diameters <50-100 μm.

Along with PM, nitrogen oxides (NOx) are the pollutants that are most concerning when considering emissions from biomass combustion. NOx emissions important for biomass combustion includes nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O).
In the EU Air Quality Directive (2008 / EC / 50), are set two particulate limits (PM_{10}) for the protection of human health: The average daily value of PM_{10}can not exceed 50 micrograms per cubic meter (μg / m3) more than 35 times per year and the average annual value of PM_{10} can not exceed 40 micrograms per cubic meter (μg / m3).

In the following tables 5, are presented the pollutant emission factors of heating equipment with biomass and 6emission levels were identified by the European Monitoring and Evaluation Programme/European Environment Agency (EMEP/EEA) [2].

Table 5: The pollutant emission factors of different types of heatingequipments in city of Korça

Residential heating Appliances	*TSP (g/GJ)*	*PM_{10} (g/GJ)*	*$PM_{2.5}$(g/GJ)*	*NO_2(g/GJ)*	*CO (g/GJ)*
Open fireplaces burning wood at best 20% efficient	***880***	**840**	**820**	50	4000
Conventional stoves burning wood (usually >50%)	*800*	760	740	50	4000
High-efficiency stoves burning wood (55 % and 75 %)	400	380	370	80	4000
Conventional boilers < 50 kW burning wood	*500*	480	470	80	4000
Advanced / ecolabelled stoves and boilers burning wood(near 70 % at full load	***100***	**95**	**93**	**95**	**2000**
Pellet stoves and boilers burning wood pellets(between 80 % and 90 %)	***62***	**60**	**60**	**80**	**300**

The above tables and and following Figure 1, shows clearly levels of the emission potentials from the use of biomass as heating fuel. The classic open heating fireplace has the highest emission potential TSP, PM_{10}, $Pm_{2.5}$, and CO as well. This appliance is followed by conventional heaters, while the lowest emissions have the use of biomass in advanced heaters with automatic controland pellet boilers (PM_{10} = 60, $PM_{2.5}$ = 60).

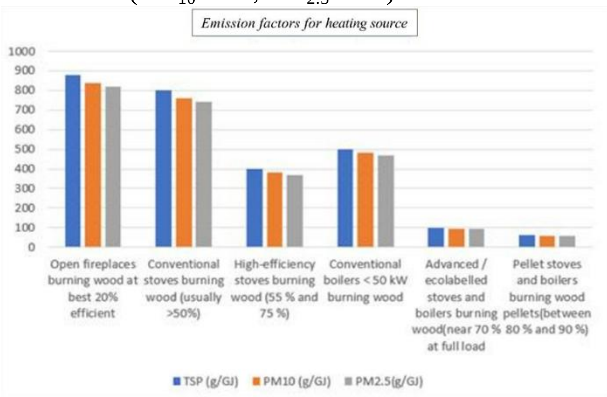

Figure 1: Emission factors for different heating system with biomass sources

Based on the above data we can conclude that the most appropriate heating system solution lies in between of the 2 main scenarios as follows;
- District heating system (DH)
- Decentralized heating system (DCH)

The comparison of investment costs will be realized for following 4 sub-scenarios:
1) Investmentsin buildings EE measures through building envelope thermal insulation associated with EE and low carbon emission heating system installations as DCH.
2) Investmentsin buildings EE measures through building envelope thermal insulation associated with district heating system (DH).
3) Implementation of decentralized heating systems with high EE coefficient and low emissions of pollutants (DCH)
4) Implementation of the district heating system (DH) for the city of Korca.

4. Investment analysis of the most suitable heating systems

Case scenario using the district heating system (DH)

District heating systems, also known as heat networks, generate heat in a centralised location and distribute it amongst multiple different buildings. They can be used to provide space or water heating for residential or commercial requirements and DHW as well. The idea is to provide low-carbon energy cheaply. If the central heating generator is a renewable technology, and 'waste' heat is incorporated from other sources, it can be a highly efficient and green heating option.

In this analysis we consider the stock of 6792 buildings with 20 328 apartments which are divided as follows in Table 6 in dwelling area in m^2.

Table 6: The building stck used for case study with DH in city of Korça

Living area, m2	*Number of apartments*	*Total area, m2*
<=40 (40)	7995	319,800
41-69 (55)	7373.85	405,562
70-99 (80)	3180.575	254,446
> 100 (120)	1258.7	151,044
Total area of all dwellings		1,130,852

The capacity of the heating plant can be determined by the following expression:

$$K_h = A_{mes}(H_p(1+R_e+H_{tr}))N_p$$

where is
- K_h- Heating capacity (Wh)
- A_{mes} – Total space area for heating
- H_p- Specific heat losses per m^2 (W/m^2)
- R_e – Correction factor for distribution network (%), recommended as sufficient 8%
- H_{tr} – Network thermal losses in DH system, 15%
- N_p – number of apartments to be connected in DH system
  Based on above expression for the estimated total area for heating 1,130,852 m^2, the DH system required capacity for scenarios 2 and 4 will be respectively:
- $DH\text{-}_{s2}$ will be 76.5 MW while estimated energy consumption 90.95 MWh
- $DH\text{-}_{s4}$ will be 173.87 MW while estimated energy consumption 206.7 MWh

Taking into account above calculated capacities of the foreseen thermal plant for DH, we have selected the most suitable combination of the renewable energy sources as below:

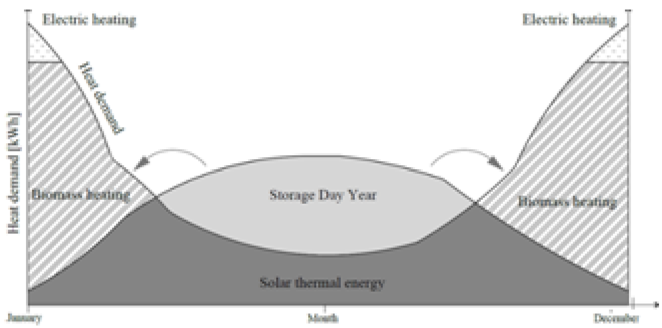

Figure 2: Combination of most suitable renewable energy sources for DH- biomass, solar energy and photovoltaics

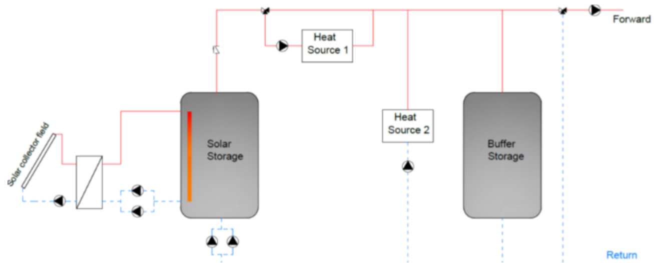

Figure 3: Proposed technical scheme: Biomass boiler+Solarheater+Electrical heater

The analysis of reference costs of energy sources for DH are presented in Table below:

Table 7: Reference investment costs based on heating source technology

Heat source technology	Investimi M (€)/MW	Varible O&M (E/MWH)	Fixed O&M (kE/MW)	Fuel eff./ COP
Biomass boiler	0.40		12	1
Solar energy + solar storage	0.213	0.5		1
Electric boiler + PHV	1.03	0.5	1	

In the combination of energy sources based on the fulfillment of the 3 main indicators (reduction of greenhouse gas emissions for 11.5%, increase of the contribution of renewable energy sources to at least 48%, improvement of at least 15% of energy efficiency) achieved results will be as follows:

- 45% solar energy + solar storage, [7]
- 50% biomass boiler and
- 5% electric heating and PHV

Study case with DH distribution network

In general the cost of the DH distribution network depends very much on the ratio of the density of buildings in the DH area and the level of heat energy demand. Referring to the Swidish District Heating Association, the DH distribution network area is divided into 2 dependent areas if they pass to "Inner City, Outer city or park area". In case of the city of Korca, individual buildings covers the largest area of multi-apartment buildings, reflecting that the reference density values for individual buildings are very low. Referring to the above mentioned Swidish District Heating Association [3], [4], the linear network density is>5 (Gj/m /y) and the reference costs for an individual apartmentis presented in below Table :

Table 8: The cost of distribution network for case study with DH in city of Korça

Type of transition zone	Linear grid density (GJ/m/y)	Investment cost in the green area (€)/house)	Investment cost in the prefabrication area (€)/house)
Individual building	<5	2,300	2,650

Study case with investments in buildings EE measures through building envelope thermal insulation

For buildings with thermally insulated envelope the average of specific heat losses is about 55 (W/m2). The energy saving costs for the analysed6792 buildings stock, based on the thermal insulation costs of the building envelope elements are presented in Table 9 below:

Table 9: The relative cost of thermal insulation of building envelope elements in city of Korça

Elements of the building envelope	Thermal insulation investment (€/m²)
Outer walls	28
Ceilings	18
Floors	27
Windows	15
Total investments (€/m²)	88

Table 10: The investment for the DH scenarioin city of Korça

Scenario	Equipment investment €/m²	Isolation investment €	Total investment €
DH_{s2}	85	0	85
DH_{s4}	54	88	142

Calculation of heating capacities for the case study scenarios for apartment heating with DCH that have a smallest living area from 40-50 m^{2}and the largest up to 150 m^{2}are as follow:

- DCH_{s2} heating capacity is from 2.5 kW to 6.6 kW respectively, with a total capacity of 64.22 MW, and with estimated energy consumption of 76.35 MWh
- The heating capacity of DCH_{s4} is from 5 kW to 15 kW with a total capacity of 145.97 MW, and withestimated energy consumption of 173.53 MWh.

In the decentralized heating system scenario we have analysed the most suitable technical solutions combining heating systems, DHW systems, using renewable energy sources with lowest emissions $PM_{2.5}$ and PM_{10}. This solution is presented in below Figure 4:

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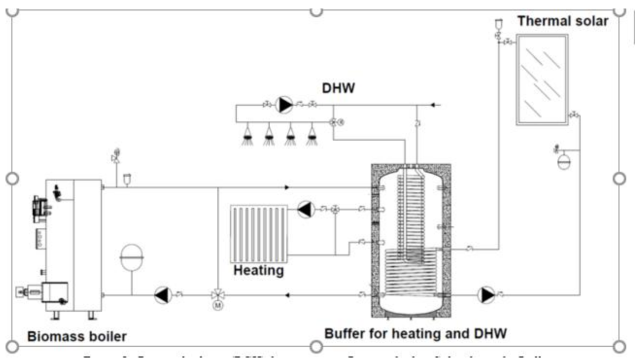

Figure 4: Proposed for DCH scenarios for apartments heating in city of Korça

The calculated investments costs for both DCH scenarios are presented in two following Tables.In study case DCH_{s1} annual cost savings are 47% for requirements of 64% yearly for DHW and 41% yearly for heating requirements. In both cases factor of thermal response is adopted as f=1.8.

Table 11: The investment cost per m^2 of apartments for the DCH_{s1} scenario in city of Korça

6.250 kW *1,8 = 11.25 kW – DCH-0						
Flat area ,m2	*Apliances Residential heating*	*Equipment investment €*	*Buffer investment €*	*Thermal solar investment €*	*Total investment €*	*Investimi total €/ m2*
100	Pelette stove and boilers COP=(0.88-92)	2,620	2,270	3,210	8,100	**81**

In study case $DCHs_3$ annual cost savings are 50% for requirements of 66% yearly for DHW and 41% yearly for heating requirements.

3.550 kW *1,8 = 6.4 kW						
Residential Heating Appliances	*Equipment investment €*	*Buffer investment €*	*Thermal solar investment €*	*Total investment €*	*Investimi total €*	*Total investment Equipment €/ m2*
100	High -efficiency stoves COP=(0.75)	1,290	1,925	2,490	5,705	57.05
				Isolation investment		88
				Total investment €/m2		**145**

In following Figure 5 are presented graphically comparative costs for heating systems for all 4 sub scenarios.

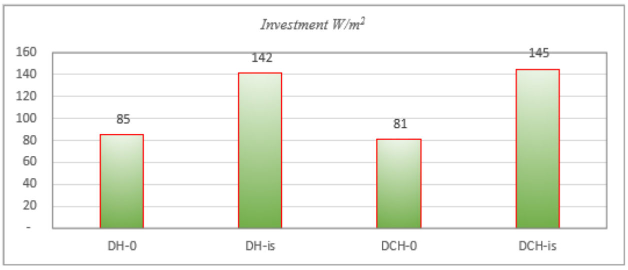

Figure 5: The comparative costs for all 4 scenarios for apartments heating in city of Korça

5. Conclusions

A comparative analysis of different heating systems and sub scenarios for decentalized and district heating systems for city of Korça are presented. Below are presented case study findings:

- The highest heating cost per m^2 of aparyments is identified using open wood fireplace
- The lowest cost in systems with biomass are identified.
- The lowest cost in systems with use of heat pumps, when thermal insulation is applied and apartments are properly sized for the space to be heated.
- The highest emission potentials of TSP, PM_{10}, $PM_{2.5}$, and CO has identified using classic open wood fireplace.
- The lowest particular matter emissions are identified using advanced pellet-burning appliances, when are properly sized for the space to be heated (PM_{10}=60, $PM_{2.5}$=60)
- The lowest investment costs are calculated in sub-scenarios DH_{s2} and DCH_{s3}
- The highest investment costs are identified for sub-scenarios DHs_4 and $DCHs_2$, with very low emission of PM and CO.
- Comparative analysis has shown that both main scenarios, DH and DCH, using renewable energy sosrces are applicable as heating solutions for city of Korça.

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