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Original scientific paper

LIFECYCLE COSTS COMPARATION BETWEEN DISTRICT HEATING AND INDIVIDUAL GAS HEATING

Dame Dimitrovski, Dalibor Stojevski

Faculty of Mechanical Engineering, "Ss. Cyril and Methodius" University in Skopje, P.O. box 464, MK-1001, Skopje, Republic of North Macedonia
dame.dimitrovski@mf.edu.mk

A b s t r a c t: The purpose of this work is to define the economically more feasible solution to the air pollution problem in Skopje through use of district heating (DH) or individual gas heating. Suburb model is Lisiče in Skopje. Analyzed are the total lifecycle costs of entire city quarter through use of the mentioned heating types. The energy consumption and CO_2 emissions from different lifecycle phases depend on the properties of pipe material, type of technologies used (during manufacturing the pipe, installing equipment and pumping technologies) and the type of fluid. Four phases are considered in this lifecycle assessment, which are production and fabrication, transportation to job site, pipe installation and operation or service phase. As can be concluded, total lifecycle costs in DH system are lower than the costs for individual gas heating. The slightly higher operating costs are annulled by the costs for maintenance and CO_2, which are significantly larger by use of individual gas heating system. By use of DH system in the suburb of Lisiče, the emission of $PM_{10/2,5}$ will be practically extinguished as the DH system uses natural gas as only source. This will lead to improved air quality in this part of Skopje.

Key words: district heating, gas heating, air pollution, heating costs

СПОРЕДБА НА ТРОШОЦИТЕ ВО ТЕКОТ НА РАБОТНИОТ ВЕК НА СИСТЕМОТ ЗА ЦЕНТРАЛНО ГРЕЕЊЕ И ИНДИВИДУАЛНОТО ГРЕЕЊЕ СО ГАС

А п с т р а к т: Целта на овој труд е да се дефинираат економски исплатливи решенија на проблемот на загадувањето на воздухот во Скопје преку анализа на системи за централно греење со гас и индивидуално загревање на објектите со гас. Како модел е земена населбата Лисиче. Во трудот се анализирани параметрите од целиот работен век на производот (услугата) за двата вида греење. Анализирани се процесите: проектирање, производство и транспорт на материјалите, вградување и работа на системот. Поради долготрајноста на системот, управувањето со отпад по завршувањето на работниот век на услугата не е земено предвид. Како што може да се заклучи, трошоците за централното греење се пониски во споредба со индивидуалното загревање со гас. Повисоките трошоци кај централниот дистрибутивен систем за топла вода се компензираат со трошоците за одржување на индивидуалните системи. Со користење централен систем за снабдување со топла вода, погонуван со природен гас, во населбата Лисиче, емисиите од системите за загревање во овој дел на градот ќе бидат нула. Па така, за очекување е дека со тоа ќе се подобри квалитетот на амбиенталниот воздух во овој дел од Скопје.

Клучни зборови: централно греење; греење на гас; загадување на воздух; трошоци за греење

BACKGROUND

Skopje is at the top of most polluted cities in the world. The situation repeats every heating season [1]. Figure 1 shows the monthly distribution of PM_{10} and $PM_{2,5}$ in Skopje in 2017.

All relevant studies get to the conclusion that the air pollution is caused by burning wood which is most common heating by the individual households [2, 3].

The city quarter JI03 (Lisiče suburb) is characterized with dense structure of individual houses, which the highest percentage use wood in old stoves as heating source. Figure 2 shows the disposition of the Lisiče suburb. Figure 3 shows the fuels used for household heating in Skopje.

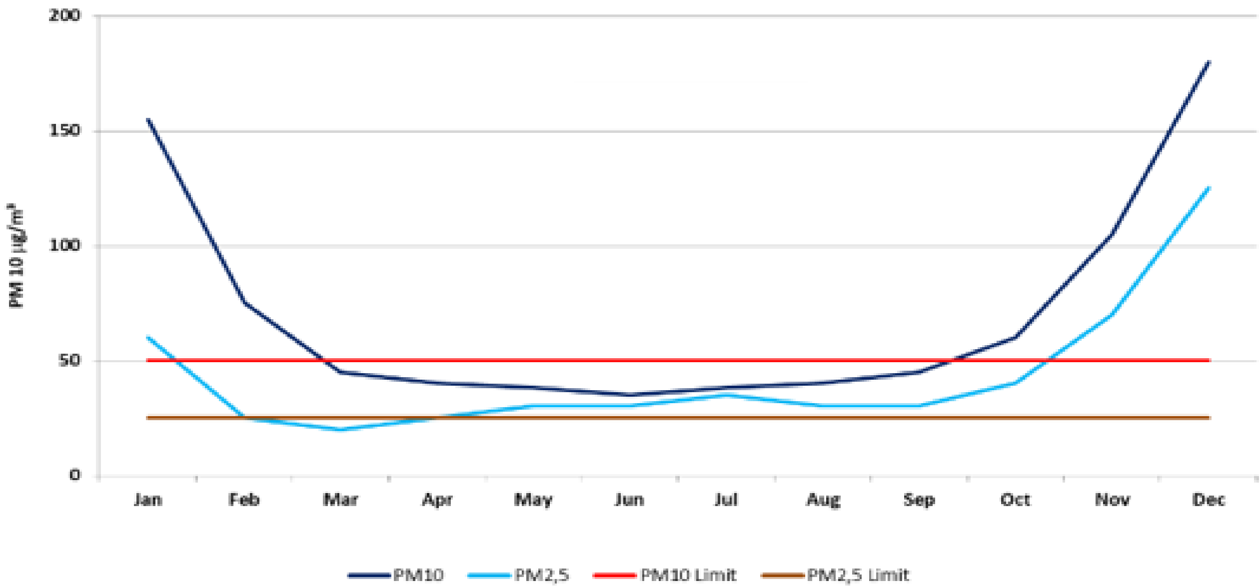

Fig. 1. Monthly distribution of $PM_{10/2,5}$ in Skopje in 2017

Fig. 2. Disposition of Lisiče suburb

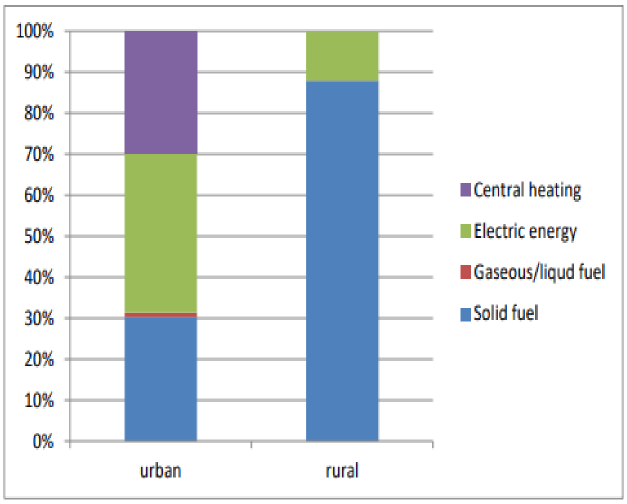

Fig. 3. Used type of heating in Skopje area

Detail analysis was made for the entire life-cycle costs of district heating and individual gas heating.

The following costs groups were taken into calculation:

- material costs,
- installation costs,
- exploitation and maintenance costs.

All costs were summarized as a whole for the entire quarter, in order to find solution which can be promptly initiated and can lead to the fastest solving of the air pollution problem.

EXPERIMENTAL

The Lisiče suburb is located in the eastern part of Skopje. Even though it's relative close to the city urban part, its conjuncture can be considered as rural. For getting info regarding number of objects and their heat consume, poll through the cadastre was made and the following type of objects were counted:

As can be viewed from the satellite view, predominantly the suburb is consisted of individual houses. According several polls, most widely used type of heating in areas with dominant individual houses is the wood heating in stoves [3]. Table 1 shows the number of objects considered in the study and the heat consume.

Table 1

Objects and heat consume

	1 story	2 story	3 story
Number of objects	321	93	2
Heat consume (kW)	3624	2789	76

The relative age of the houses in Lisiče suburb is > 40 years, with poor thermal insulation. In the recent years, the trend of improving the energy efficiency of the houses is obvious. Therefore, we take average thermal insulation in the calculation.

Taking into consideration the above mentioned, the following input parameters were taken into account for the heat type economic feasibility:

- Equipment is designed for heating of the whole house;
- Specific heat consume of the houses is taken as 115 W/m^2;
- Design room temperature is 20 ˚C;
- Design ambient temperature is –15 ˚C;
- Heating hours per year is 2745.

RESULTS AND DISCUSSION

Design of district heating system

This part of Skopje does not have district heating (DH) network. The main DH network under control of BEG AD is approximately 1000 m from the potential connection point with the conceptual secondary and connection line network in Lisiče. According design parameters (flow velocity, heat consume…), the main pipeline should be DN150. The secondary DH network should be 3 km′ DN80. Connection lines are 15 m′ at DN25. In Table 2, the prices of components used in central district heating system are shown.

Table 2

Prices of components used in DH system

	Pipes (EUR/m')	Control valves (EUR/piece)	Heat meter EUR/piece)	Inner installation (EUR/kW)
DN25	63	590	301	133
DN32	74	826	413	
DN40	86	1.062	578	
DN50	98	2.360	826	
DN65	113	3.340	826	
DN80	134	5.310	1.333	
DN100	181	/	/	
DN150	262	/	/	
DN200	378	/	/	

The heat station is designed as indirect, with installation of heat exchanger which separates the network medium from the indoor installation medium. Other necessary components and their costs (installation and VAT included) are:

Design of individual gas system

This part of Skopje does not have gas infrastructure. The main gas network is approximately 3000 m from the potential connection point with the conceptual secondary and connection line network in Lisiče.

According design parameters (flow velocity, heat consume, etc.), the main pipeline should be DN100. The secondary gas network should be HDPE DN65, while the gas connections should be G3-G10, depending of heat consume. Table 3 shows the prices of components used in individual gas system for heating.

Table 3

Prices of components used in gas system

Capacity (kW)	Boiler (€)	Connecting line with GMS (€)
24	770	1.036
28	803	1.036
33	1.306	1.036
55	2.033	1.569
85	3.084	2.369

Other necessary components and their costs (installation and VAT included) are:

– ***Exploitation and maintenance costs of DH system.***

Final yearly heat need of the Lisiče suburb at 6.5 MW heat consume are 7.137 MWh. The costs towards the DH operator are as follows [5]:

- engaged heat consume – 17.863 EUR/MW/year;
- heat energy price – 35 EUR/MWh.

There is no maintenance costs in this system.

– ***Exploitation and maintenance costs of individual gas system.***

Gas boiler efficiency is taken at 92% according low heating value [4]. This requires 814.216 Nm^3/year gas consumption.

The costs for the gas consumption are as follows:

- gas border price – 354 USD/1000 Nm^3;
- import costs – 2% of border price;
- trading margin – 47 EUR/1000 Nm^3;
- gas transmission tariff [6] – 27 EUR/1000 Nm^3;
- gas distribution tariff [7] – 52 EUR/1000 Nm^3.

Maintenance costs are costs for inspection of the gas boiler and inner installation and cleaning of chimneys, total 60 EUR/house.

***– CO_2 footprint in production and installation phase of DH system* [8].**

The energy consumption and CO_2 emissions from different lifecycle phases depend on the properties of pipe material, type of technologies used (during manufacturing the pipe, installing equipment and pumping technologies) and the type of fluid. Four phases are considered in this lifecycle assessment, which are production and fabrication, transportation to job site, pipe installation and operation or service phase. The working period of this heating is 40 years.

– CO_2 footprint in production and installation phase of individual gas system.

The working period of specific components of this heating varies between 10 (boilers) and 40 (pipes) years. CO_2 emissions from the DH and gas system in the early phase are given in Table 4 and Table 5.

Table 4

Emission of CO_2 in early phase of DH system

	DN25	DN150
Pipes production		
Weight (kg/m')	7,06	12.480
Total length (m)	40,66	6.000
CO_2 in production (t)	585	1620
Pipes transport		
Distance between site and plant (km)	4000	4000
Max pipe sections per truck	165	29
Total truck sessions	6	17
Total fuel consumption (l)	10.070	27.881
CO_2 per fuel (CO_2/l)	3	3
Total CO_2 for transport (t)	27	74
Pipes installation		
Necessary excavation/fill hours (h)	5.200	5.000
Fuel consumption (l/h)	10	10
Total fuel consumption (l)	52.000	50.000
CO_2 per fuel (CO_2/l)	3	3
Total CO_2 for installation (t)	154	148

Total CO_2 emission of DH system in early phase is 2608 t.

Table 5

Emission of CO_2 in early phase of gas system

	DN20	DN65	DN100
Pipes production			
Weight (kg/m')	0,12	1,05	3,13
Total length (m)	6240	3000	3000
CO_2 in production (t)	11	45	134
Pipes transport			
Distance between site and plant (km)	360	360	360
Max pipe sections per truck	4.000	378	176
Total truck sessions	1	1	2
Total fuel consumption (l)	144	144	288
CO_2 per fuel (CO_2/l)	3	3	3
Total CO_2 for transport (t)	0,4	0,4	1
Pipes installation			
Necessary excavation/fill hours (h)	1.560	1.000	1.250
Fuel consumption (l/h)	10	10	10
Total fuel consumption (l)	15.600	10.000	12.500
CO_2 per fuel (CO_2/l)	3	3	3
Total CO_2 for installation (t)	46	30	37

Total CO_2 emission of individual gas system in early phase is 303 t.

CONCLUSION

Comparation of costs of different heating types and CO_2 emissions is given in Table 6.

T a b l e 6

Lifecycle CO_2 emission and cost comparison

	DH	Gas
Total CO_2 emission in early phase (t_{CO_2})	2608	303
Total CO_2 emission in exploitation (t_{CO_2})	16.869	48.623
Total CO_2 emission (t_{CO_2})	19.477	48.926
CO_2 price (EUR/t)	22	22
Total CO_2 costs (EUR)	428.500	1.076.362
Total investment costs (EUR)	2.743.463	3.664.730
Total operating costs (EUR)	18.399.652	18.151.475
Total maintenance costs (EUR)	–	1.250.000
Total costs (EUR)	21.571.615	24.142.567

As can be concluded, total lifecycle costs in DH system are lower than the costs for individual gas heating. The slightly higher operating costs are annulled by the costs for maintenance and CO_2, which are significantly larger by use of individual gas heating system.

By use of DH system in the suburb of Lisiče, the emission of $PM_{10/2,5}$ will be practically extinguished as the DH system uses natural gas as only source. This will lead to improved air quality in this part of Skopje.

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