

## THE EVOLUTION OF CO<sub>2</sub> EMISSIONS FROM THE HEATING SYSTEMS OF A LARGE CITY

Aura OSANU<sup>1</sup>, Liviu ENACACHE<sup>2</sup>, Marius BODOR<sup>1,\*</sup>

<sup>1</sup> "Dunarea de Jos" University of Galati, Romania

<sup>2</sup> S.C. CALORGAL S.A., Galati, Romania

e-mail: marius.bodor@ugal.ro

### ABSTRACT

*Different current reasons, like global warming due to greenhouse gases and high energy prices, creates the necessity to make the heating systems in large cities more efficient. The present paper presents a real situation for an urban agglomeration, regarding the transition from a centralized heating system to a decentralized one. Two types of decentralized possibilities are discussed and analyzed taking into account especially the CO<sub>2</sub> emissions, during several recent years. In this respect, a calculus of CO<sub>2</sub> emissions from the former heating system, compared to the present heating systems is also presented and discussed.*

KEYWORDS: heating systems, CO<sub>2</sub> emissions, pollution

### 1. Introduction

The world is moving towards the least favorable scenario estimated by the Intergovernmental Panel on Climate Change (IPCC), leading to a significant possibility of overheating by 4 °C by the end of this century. In order to meet the global carbon budget needed to limit global warming to 2 °C, the global economy needs to increase its decarbonization level to 6.2% per year by 2100, which would ensure that virtually the global energy system will have zero carbon emissions by the end of the century [1].

Also, it is expected that by 2050, national and international measures to reduce fossil fuel consumption will become a possibility and a necessity that is hard to ignore. The first phase of climate change will result in a 4 °C increase in global average temperature, which could happen in the next 30-50 years. Even if the measures discussed above were taken immediately, it would be very likely that this change in average temperature would take place in the next 50 years [2].

But a second phase of climate change, namely a 2 to 3 °C increase in average temperature, which would mean an increase of 4 to 6 °C in temperate climates and even greater changes in the polar regions - is an evolution on which the world will probably decide to at least postpone it as much as possible. Clearly, a small increase or stabilization in global fossil fuel consumption would slow down the global warming trend, which would greatly increase

humanity's chances of developing a sound policy to adapt to the effects of climate change [3].

We can therefore assume that this possible change in the Earth's climate would have detrimental effects in certain regions without, however, constituting a catastrophic evolution for all mankind. It could lead to changes in agricultural activity and trade balances, as well as in the way of life of many people, and eventually, in a few centuries, it would lead to the evacuation of lowland areas as a result of the considerable increase of ocean water level. Avoiding or at least postponing these adverse effects is an ideal based on the hope that the countries of the world will eventually launch a joint effort to limit the consumption of fossil fuels [4].

Carbon dioxide (CO<sub>2</sub>) is one of the most dangerous greenhouse gases because it can stay in the atmosphere for hundreds of years. This is due, among other things, to the burning of fossil fuels, on which we have become very dependent in industry, energy and transport. It is estimated that since the Industrial Revolution, the concentration of carbon dioxide in the atmosphere has increased by 43% [5].

Globally, warming in the Arctic is thought to be associated with less extreme cold weather in the northern hemisphere, and climate change will lead to moderate winters in Europe and the United States. Scientific results show that warming of 0.1 °C/decade is expected in the next two decades, even if the concentration of all greenhouse gases and aerosols remains constant in 2000 [6].

In response, local, national, regional and international initiatives are being developed and implemented to limit greenhouse gases (GHG) concentrations in the Earth's atmosphere. Such GHG initiatives are based on quantifying, monitoring, reporting and verifying GHG emissions. With regard to reducing the impact of climate change, the key factor is the policies to meet the EU's 2030 commitments to reduce GHG emissions by at least 40% from 1990 levels and a 27% improvement of energy efficiency [7].

Since wind and solar energy are variable resources and do not yet provide capacity commitments for peak load, increasing their penetration will require a complementary capacity for peak load [8].

In support of the goals described above, the energy efficiency of heat supply systems can be a real help. In the case of Romania, in order to rehabilitate the centralized heat supply systems of some localities, the works performed contributed to the increase of energy efficiency, by streamlining the centralized systems of production, transport and distribution of thermal energy and to increase the quality of the public heat supply service.

In order to support efforts to reduce greenhouse gas emissions and thus limit global warming, accurate information is needed on emission levels, developments and policies and measures to improve the situation. To this end, a sound framework for monitoring and reporting GHG emissions is needed, as well as reliable information on the changes that existing and planned policies and measures are expected to bring about in terms of emissions.

Regarding Romania, CO<sub>2</sub> emissions from different sectors of activity also highlight the major contribution of the energy sector and transport, which means that these are the areas on which it is necessary to implement measures and actions to reduce CO<sub>2</sub> emissions.

The case study in this paper is related to the centralized system for thermal energy supply (SACET) in the city of Galați, Romania. Currently this system supplies thermal energy to about 6000 apartments and 17 public institutions, economic agents and has the following main components: i) source of thermal energy production (natural gas boilers, installed in 24 thermal points); ii) the primary circuits that ensure the closed circuit of the thermal energy between the source, the hot water boilers and the heat exchangers from the thermal points; iii) the secondary thermal networks that ensure the distribution of thermal energy from the thermal points to the final consumers and iv) final consumers. GHG from this centralized system is compared with individual heating (IH) systems used by a large part of population of Galati municipality.

In 1990, the central heating system of Galati municipality was connected to approx. 90,000 apartments and the heating agent was procured from a now defunct Combined Heat and Power Unit (CHPU), located outside the city, on a nearby metallurgical complex platform. Taking into account the large number of disconnections and the technical-economic inefficiency of the former central heating system, the authorities of Galați municipality, started in 2017 two parallel programs aiming the following: i) installation of heating capacities in all schools and ii) providing the population with financial aid for alternative heating resources. These directions were in line with the idea, also stated in [9], that a particular heating system could be favored for its efficiency but mostly for its cost.

In March 2018, only a number of 18,366 apartments were still connected to the system, which led the local authorities to abandon the old centralized system and reorganize another one. Also, as a result of this decision, another 7,844 IH systems, on natural gas, of 24 kW, were installed, with a total power of 188.256 MW. The statistical data show that before this organized decentralization, there were already a number of about 29,000 IH systems installed in the city.

The priority given to the efficiency of the present SACET configuration results from the following advantages: i) fuel economy; ii) reduction of air pollution; iii) the promotion/expansion of modern, state-of-the-art systems meeting the general needs of increasing energy efficiency and environmental protection.

Based on historical data on the configuration of heating systems in the city of Galați, Romania and the method of calculating carbon dioxide emissions from these systems, this paper has managed to highlight the evolution over time of CO<sub>2</sub> emissions; the differences (regarding the CO<sub>2</sub> emissions) between the mentioned heating systems were identified and also, diminishing the impact on the environment by replacing and/or modifying the old heating system was emphasized.

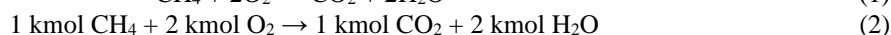
## 2. Methodology

The price trend of the heating agent is subject to continuous increase due to the exchange rate, the price of fuels and other factors that determine the price adjustment. To these factors are added the external environmental costs. In the face of inevitable increases, it is necessary for the thermal energy supplied from the centralized systems to enter into fair competition with other solutions.

The continuous increase in the rate of disconnection from the centralized system was determined, on the one hand, by the poor quality of the service provided and the high price, and on the

other hand by the low price of natural gas offered to captive consumers through subsidy mechanisms. Thus, reducing the phenomenon of disconnections and possibly the return of disconnected consumers to the centralized system will not be possible without adopting a viable alternative solution to IH systems, and this solution can only be the low price of the central heating system.

Knowledge regarding the combustion mechanisms of fuels is very important in the regulation and operation of thermal equipment, so that they work with complete combustion, in designed parameters and with maximum efficiency, essential elements in reducing energy consumption and, implicitly, with optimal results in terms of GHG emissions. In this sense, we can say that the combustion reaction of methane is the following:



Carbon dioxide emissions can be determined by direct measurements, with specific equipment, or by calculation. For optimal monitoring of GHG emissions it is necessary to define the calculation parameters, which can be implicit or determined by analysis [10]. The calculation of GHG emissions is made according to Regulation (EU) no. 601 of 21 June 2012 on the monitoring and reporting of GHG emissions in accordance with Directive 2003/87/EC [11].

In the present study, the calculations are based on the following variables:

- activity data, meaning the amount of fuel or materials consumed or produced by a process, relevant to the calculation-based monitoring methodology, expressed in terajoules, tones per mass or, for gases as normal volume in cubic meters (explanation of calculation: for example, the consumption of 479,594 m<sup>3</sup> of gas is converted from m<sup>3</sup> to Nmc according to the relation:  $479,594 \text{ m}^3 \times 273.15/288.15 = 454,628.15 \text{ Nmc}$ );

- net calorific value (NCV), meaning the specific amount of energy released in the form of heat when a fuel or material is subjected to a complete process of combustion with oxygen under standard conditions, without taking into account the heat water vaporization possibly formed (the value is considered a constant equal to 0.00003658 [TJ/Nmc]);

- emission factor (FE), meaning the average rate of emission of a GHG relative to the activity data of a source stream assuming complete oxidation in the case of combustion and full conversion for all other chemical reactions (the value is considered a constant equal to 55.61 [tCO<sub>2</sub>/TJ]);

- oxidation factor (OF), meaning the ratio of carbon oxidized to CO<sub>2</sub> as a result of combustion to the total carbon content of the fuel, expressed as a fraction, of carbon monoxide (CO) emitted into the atmosphere as the equivalent molar amount of CO<sub>2</sub> (the value is considered a constant without a measuring unit, equal to 1).

Thus, the formula used in CO<sub>2</sub> emissions calculation for this study is the following:

$$\text{CO}_2 \text{ emissions [tCO}_2\text{]} = \text{Gas consumption [Nmc]} \times \text{NCV [TJ/Nmc]} \times \text{FE [tCO}_2\text{/TJ]} \times \text{FO} \quad (3)$$

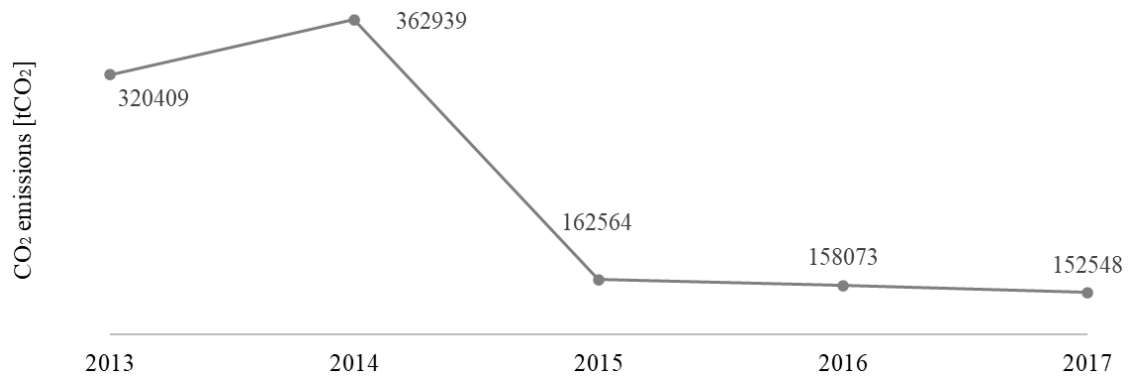
The NCV and FE values are taken from the List of national values of net emission factors and calorific values, specific to each fuel type and activity category, used to meet the requirements for monitoring and reporting carbon dioxide emissions. The values in this list apply to small combustion plants [12].

This calculation method shows that the total value of CO<sub>2</sub> emissions is directly proportional to the gas consumption of combustion plants. So, for the calculation of the quantities of CO<sub>2</sub> emitted, we need to highlight the natural gas consumption of all heating systems.

### 3. Results and discussions

#### 3.1. Evolution of CO<sub>2</sub> emission values of the former centralized heating system

Using the gas consumption data for the former CHPU during the 2013-2017 period, we can make an analysis based on calculation of the GHG emissions generated (Figure 1). Year 2017 was the last one with this former unit supplying thermal energy for SACET Galați.



**Fig. 1.** Evolution of calculated CO<sub>2</sub> emissions, during 2013-2017, from the Combined Heat and Power Unit responsible with the thermal energy supplied to SACET Galați

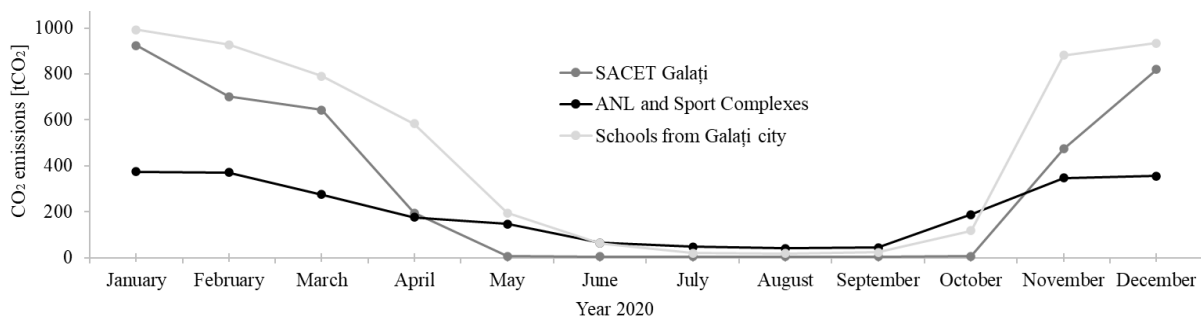
Thus, we observe a consistent decrease in gas consumption from 166,159,727 cubic meters of gas in 2013 to 79,762,203 cubic meters of gas in 2017 and, implicitly, in greenhouse gas emissions from 320,409 tons of CO<sub>2</sub> in 2013 to 152,548 tons of CO<sub>2</sub>, so a decrease of more than 50%. This decrease was generated starting with year 2105 by the decrease in heat demand and mass disconnection of consumers, that compelled the CHPU to function seasonally accordingly to the existing demand of thermal energy.

The age of heat transferring networks lead to massive losses, which were translated into additional costs to be covered by a decreasing number of consumers. Thus, the public district heating service became much too expensive compared to other technologies for supplying thermal energy. All these elements resulted in massive disconnections from the municipal district heating system. Thus, many citizens have installed IH systems. This transition

resulted in a drastic reduction of CO<sub>2</sub> emissions, as already stated, but unfortunately, also in transferring the remaining emissions from outside the city to the heavily populated areas.

### 3.2. Evolution of CO<sub>2</sub> emission values of the present heating systems

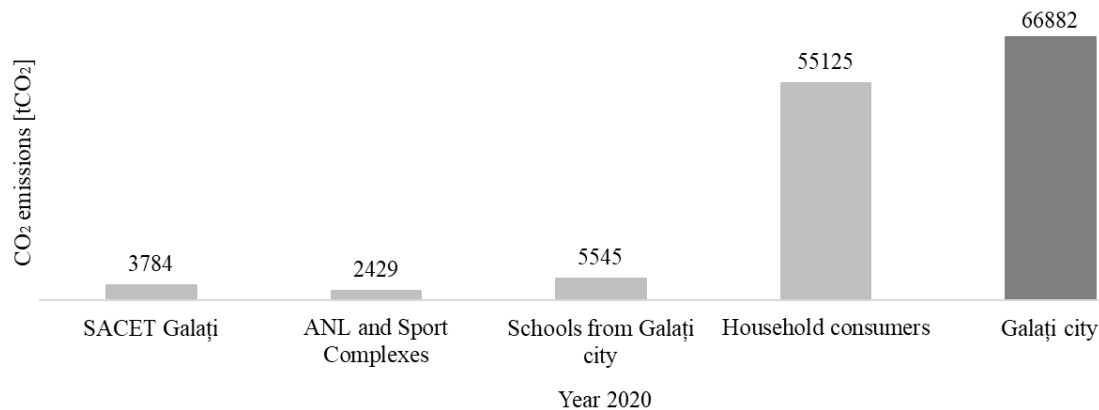
By adding up the CO<sub>2</sub> emissions generated by SACET, heating systems of new apartment buildings (ANL), sports complexes and schools, a clear view is possible regarding the evolution of CO<sub>2</sub> emissions throughout an entire year. Since most of the thermal power generation units operate seasonally, with a peak load during the cold season, it is noticed that the major share of CO<sub>2</sub> emissions is recorded in January, February, March, April, November, and December (Figure 2).



**Fig. 2.** Evolution throughout year 2020 of CO<sub>2</sub> emissions from SACET, heating systems of new apartment buildings (ANL), sports complexes and schools in Galați city

For this study, it was not possible to accurately quantify the consumption of each apartment. Nevertheless, by using the data from the natural gas distribution operator for the municipality of Galați, in 2020, strictly for household consumers, a natural gas consumption of 28,585,000 m<sup>3</sup> was registered. This

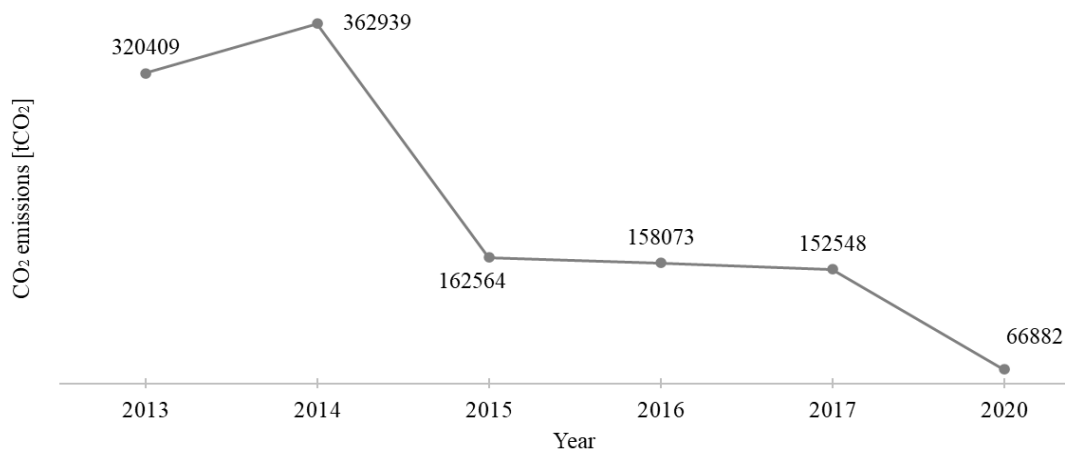
data was then used to obtain the CO<sub>2</sub> emissions resulted from IH systems utilization in Galați city. In this respect, Figure 3 presents these CO<sub>2</sub> emissions compared to the above values of other CO<sub>2</sub> emission sources and also the cumulated CO<sub>2</sub> emitted in Galați city in 2020 from all types of heating systems.



**Fig. 3.** Evolution of CO<sub>2</sub> emissions from all types of heating systems in Galați city during the year 2020

The cumulated CO<sub>2</sub> emissions in 2020 in Galați city from all heating sources present the largest contribution from the household consumers (55,125 m<sup>3</sup>). However, this amount is less than half the

quantity registered for the last year (2017) of CHPU operation, totaling 152,548 m<sup>3</sup> of CO<sub>2</sub> emissions for this unit alone.



**Fig. 4.** Evolution of CO<sub>2</sub> emissions from CHPU during the 2013-2017 period compared to CO<sub>2</sub> emissions from all heating systems in Galați city during the year 2020

This comparison is better placed in perspective by completing Figure 1 with the latest data presented earlier. Thus, Figure 4 presents the evolution of CO<sub>2</sub> emissions from CHPU during the 2013-2017 period, compared with CO<sub>2</sub> emissions from all heating systems in Galați city in 2020. This big difference of CO<sub>2</sub> emission values throughout these years is based on multiple reasons, the most influential being supposed to be the increase in gas price and replacing outdated heating systems with new ones.

#### 4. Conclusions

Reiterating the formula for calculating CO<sub>2</sub> emissions, in order to reduce emissions, one can

intervene on a single variable, namely the consumption of natural gas. In some cases, the transmission networks of the thermal agent operate with low efficiency, high specific consumptions, a situation that is due primarily to the advanced physical and moral wear of the existing pipes. The average heat loss was sometimes nearly 28%, especially for the old heating system in Galați city. All this is reflected in high consumption of natural gas and electricity, which leads to unreasonable production costs for heating systems. Apart from the state of the thermal networks, another element that leads to increased natural gas consumption is the improper operation of the systems.



Some proposed measures to increase the energy efficiency of the district heating system and thus to reduce energy consumption and CO<sub>2</sub> emissions are the following: i) resizing and replacement of secondary thermal energy transmission networks with pre-insulated steel pipes. The need to resize the networks results from the fact that these thermal power plants serve a smaller number of consumers than originally proposed; ii) rehabilitation of non-modernized thermal points; iii) reduction of the massive losses of the addition water by counting the final consumers on the heating circuits; iv) automation and monitoring of all heating systems.

In order for heating systems to produce thermal energy to operate in optimal parameters, with low gas and electricity consumption, another element is the quality of natural gas. Thus, in July 2020, an analysis laboratory with national accreditation was requested to perform chromatographic analyzes on the quality and chemical composition of the gas used by SACET.

Another measure that is recommended to reduce natural gas consumption is thermal insulation of all buildings that benefit from any heating system reliant on natural gas.

The adoption of the above-mentioned measures would lead to a significant increase in the efficiency of the systems and a reduction of about 25% in natural gas consumption and, implicitly, in CO<sub>2</sub> emissions.

Until all GHG emissions will fall towards targeted values, their monitoring will have to be maintained or even made more effective in the future. These data will continue to offer important information regarding the necessity to optimize all types of heating systems, with direct impact on the

overall emissions and also the price of heating commodities.

## References

- [1]. \*\*\*, [https://ec.europa.eu/clima/change/causes\\_roș](https://ec.europa.eu/clima/change/causes_roș).
- [2]. **Umid Abuzarli, Laman Mammadzada**, *Opțiuni strategice pentru reducerea emisiilor de gaze cu efect de seră în diferite sectoare ale activității economice*, ASE București, 2014.
- [3]. **Ardelean F., Colda I.**, *Cauzele schimbărilor climatice - un subiect controversat*, Conferința a XV-a Eficiență, Confort, Conservarea Energiei și Protecția Mediului, Facultatea de Instalații, București, 2008.
- [4]. \*\*\*, <https://documentar25.wordpress.com/2016/04/13/omul-si-clima-efectul-de-sera/>.
- [5]. \*\*\*, *Climate Adapt – Platforma europeană pentru adaptarea la schimbările climatice pentru România*, <http://climateadapt.eea.europa.eu/countries/romania>.
- [6]. \*\*\*, *Schimbările climatice și mediul construit din România*, [http://www.ecceengineers.eu/news/files/Climate\\_change\\_romania](http://www.ecceengineers.eu/news/files/Climate_change_romania).
- [7]. \*\*\*, MEWT, *Cea de-a treia comunicare a României privind schimbările climatice în cadrul Convenției cadru a Organizației Națiunilor Unite asupra schimbărilor climatice*, 2005.
- [8]. \*\*\*, *Starea Actuala a Sistemelor Centralizate de Termoficare – Propuneri pentru Reabilitarea și Dezvoltarea Acestora*, Cogen România, 2011.
- [9]. **Taeyeon Yoon, Yongsun Ma, Charles Rhodes**, *Individual heating systems vs. district heating systems: what will consumers pay for convenience?*, Energy Policy, 86, p. 73-81, 2015.
- [10]. \*\*\*, SR EN ISO 14064-1:2019, *Gaze cu efect de seră. Partea 1: Specificații și ghid, la nivel de organizație, pentru cuantificarea și raportarea emisiilor și a cantităților îndepărtate de gaze cu efect de seră*.
- [11]. \*\*\*, *Regulamentul (UE) nr. 601/2012 al Comisiei din 21 iunie 2012 privind monitorizarea și raportarea emisiilor de gaze cu efect de seră în conformitate cu Directiva 2003/87/CE a Parlamentului European și a Consiliului*.
- [12]. \*\*\*, *Lista privind valorile naționale ale factorilor de emisie și ale puterilor calorifice nete, specifice fiecărui tip de combustibil și categorie de activitate*.