Use of Solar Installations as a Way to Reduce Low Emissions

Tomasz Wyleciał, Robert Starczyk, Henryk Otwinowski and Dariusz Urbaniak

Abstract The paper presents the application of solar heating installation as an element contributing to the production of heat in a traditional coal heating plant. To reduce emissions from furnaces of individual households, it is advisable to opt out of this type of heating and, where possible, to connect to a central heating system fed from a heating plant. In this way, the fragmented heat generation, where control of the combustion process is ineffective, will be replaced by central heat generation where the local community's nuisance is limited and the combustion process is controlled. In addition, the use of solar installations reduces the amount of coal burned and thus reduces harmful emissions. Renewable energy sources are characterized by the randomness of their use. It is often the case that potential uses (wind, sun) do not coincide with the time of energy demand. A solar installation working as a auxiliary element of coal boilers seems to be a good way to address the above mentioned deficiency of renewable energy.

Keywords Heating plant · Solar installations · Coal boilers · Emission of pollution · Renewable energy sources

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1 Introduction

The growing awareness of human and economic development, causing an increase in the wealth of society, have led to increasing debate on the protection of the environment. These discussions are increasingly leading to the implementation of such activities, which significantly contribute to the improvement of air, water and soil quality.

One of the essential human activities, contributing to the pollution of the environment are coal combustion processes. In Poland, coal was and is the main source of meeting the needs of energy and district heating [1, 2]. Therefore, the state of the environment until the mid-nineties of the last century was not satisfactory.

Since the mid-nineties of the twentieth century, a lot of activities have been implemented in the field of energy, which have contributed to the significant improvement of the quality of nature. Exhaust gas desulphurization technologies have been introduced, with efficiencies of more than 90%, which significantly reduced sulphur oxide emissions to the atmosphere, thus significantly reducing the negative impact of this sector on the environment. Activities aimed at limiting the formation of nitrogen oxides have been introduced, this reduced the emission of these compounds into the atmosphere by about a half. Currently, the implementation of selective and non-selective catalytic methods for the capture of nitrogen oxides from flue gas is being carried out, which further reduces emissions. For a long time, the emission of dust into the atmosphere has been eliminated. The use of high efficiency electrostatic precipitators (over 99%) eliminates almost all this kind of pollution.

In the field of district heating similar trends are observed. The actions taken to reduce the harmful emissions are present to a lesser extent, but the situation is not the worst. The operation of the heating plant is covered by legislation regulating and controlling emissions.

The worst situation is in the area of family holdings. Wallet of the average inhabitant of the poor areas of the country is such that the heat generation is realized by combustion in outdated furnaces and boilers. Replacing these units on modern boilers with closed combustion chamber exceeds the financial capacity of most of these people. Outdated boiler units are incapable of controlling combustion. Such an implementation of this process, generates the emission of products of incomplete combustion. These units are characterized by low efficiency, which forces, in order to achieve the assumed amount of heat, greater amounts of badly burned fuel.

Low prosperity often involves the burning of the “cheapest” fuel, whose questionable quality is due to poor quality of combustion, and thus increased pollutant emissions.

Emissions in single-family holdings are particularly dangerous because they emit to the atmosphere from low chimneys. Heat generation happens frequently when the humidity is high. This is the reason for the persistence of pollutants in the area where people live every day. In effect the people are poisoning themselves.

2 Low Emissions

The environment is the air, soil, water. So talking about the pollution of nature, we need to analyze each of these elements. However, it seems that air pollution is of crucial importance in the process of polluting the entire ecosystem. Atmospheric pollutants affect other elements of the environment—soil and water. Among the pollutants of the atmosphere stands out:

- carbon dioxide (CO_2);
- carbon monoxide (CO);
- oxides of nitrogen (NO_x);
- sulphur dioxide (SO_2);
- hydrogen chloride (HCl);
- hydrogen fluoride (HF);
- persistent organic compounds (POPs), which include polycyclic aromatic hydrocarbons (PAHs), dioxins and furans (PCDDs and PCDFs), polychlorinated biphenyls;
- volatile organic compounds (VOCs);
- heavy metals, especially mercury (Hg) and its compounds, cadmium and thallium (Cd, Tl) and their compounds, antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), vanadium (V);
- total dust (TSP) and its fractions PM10, PM2.5.

All these pollutants are extremely important from a human point of view, because in a relatively short time they cause a deterioration in human health, and in many cases even death.

In Poland, the main sources of pollution are considered the power industry, communal-living sector and road transport [3]—Fig. 1. According to the KOBiZE [3] report, professional power industry leads the field of emissions of sulfur dioxide and nitrogen oxides. The emission of sulphur oxides, suspended dust, non-methane volatile organic compounds, and nitric oxide from communal-living sector are not insignificant. Road transport, which is growing year by year, mainly produces nitrogen oxides and non-methane volatile organic compounds (NMLZO).

For the average person, the last two emission sources are of particular importance. They are responsible for so-called low emission (emission from sources with emitters not exceeding 40 m). Low emissions are particularly dangerous in the heating season in areas where people meet their living needs by burning the fuel of varying quality in outdated boilers or furnaces. It generates the emission of very dangerous toxic compounds, resulting from incomplete combustion.

Furthermore, low emission is extremely dangerous in large urban agglomerations where the influence of the factors mentioned above is enhanced by the impact of road transport. In large urban agglomerations are moving every day, growing from year to year, a significant number of cars, which operate in an urban environment is not ecological. A large number of traffic lights and car plugs cause

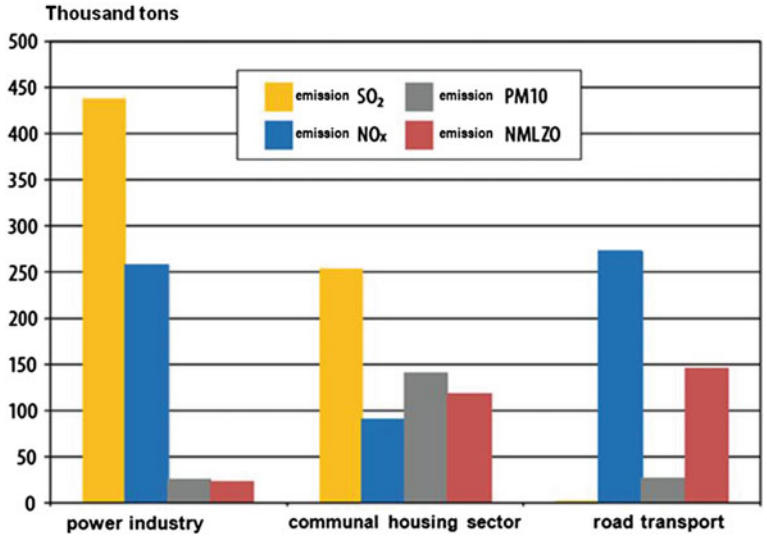

Fig. 1 The structure of emissions of main air pollutants in Poland in the year 2012 [3]

improper work of car engines. This is the cause of significant emissions of harmful gases, the concentration of which is very high and is maintained at this level for a long time. Often buildings in large urban areas make it difficult or even impossible natural ventilation of these areas.

High emission of pollutants in the communal-living sector (due to the low height of the chimneys—usually not exceeding 10 m) and road transport cause high concentration of air pollution at the ground level. This is very dangerous due to direct inhalation of contaminated air and consumption of contaminated food. Study of carcinogenicity "smoke" from the combustion of coal has shown that it is comparable to the emission of coke oven battery, and higher than cigarette smoke [4, 5]. Emissions of dioxins, one of the biggest poisons, have risen more than 100 times, if plastics, rubber or even inappropriately wood are burned with solid fuel at home [4, 5].

Among the pollutants emitted in the residential sector to particularly dangerous are dust, especially its sub fractions PM10 and PM2.5. They contain heavy metals and pollutants such as polycyclic aromatic hydrocarbons, dioxins and furans. As a result, PM10, PM2.5 are responsible for respiratory and cardiovascular diseases, various allergies, and as a consequence of population mortality in areas with high immittance ratios.

Particular attention is required to combustion of wood. Wood is considered one of the main components of biomass, which is particularly recommended by various EU documents [6, 7]. While the improper burning of wood can be much more dangerous than burning of coal. It has been shown that there is a correlation between exposures to wood burning smoke and chronic and acute respiratory

diseases. It is noticeable especially among children or older people [4, 5]. Studies conducted among Mexican women have shown that cooking in wood-fired kitchens causes heavier pulmonary diseases than nicotine addiction [5].

3 Modern Coal Heating Plant Assisted by Solar System

For a long time, also in Poland, renewable sources of energy enjoy great interest [6–9]. Relatively low operating costs and environmental savings are their main advantages. The use of these sources of energy allows to reduce the emission of pollutants into the atmosphere resulting from the combustion of traditional fuels. Nevertheless, these sources are characterized by the randomness of occurrence and the need to store energy. The increased share of renewable energy sources in the entire power system of the country would also require a highly developed intelligent control and distribution system, which would have an impact on operating costs and would reduce the overall system security.

In addition, a rapid reduction in the share of conventional fuels in heat and power generation would lead to large changes in the employment structure, which could be a serious social problem—unemployment, employment restructuring, etc.

It seems that a good idea to solve the problem of poor air quality (low emission) is to combine the use of conventional and renewable sources in larger power generation units such as heating plants. Indeed, one of the recommended ways of reducing low emissions is, where possible, the abandonment of domestic boilers and the use of district heating systems.

Using renewable sources in heating plants would reduce the consumption of conventional fuels and save the environment, and the randomness of renewable sources could be correlated with the use of conventional fuels.

The advantage of solar energy is its beneficial effect on the environment, particularly as a result of the reduction of pollutant emissions into the atmosphere resulting from the process of generating energy from coal combustion. Reduction of CO2 emissions through solar thermal energy, according to forecasts, will amount to almost 2.8 million tons/year in 2020 and 4.8 million tons/year in 2030 [3].

The paper presents the interaction of these two types of energy sources on the example of a modern academic heating plant. The primary fuel burned in the heating plant is hard coal. Heating plant produces and provides heat for central heating (central heating) and preparation of domestic hot water (dhw) [10]. There are three water boilers with mechanical grate in the heating plant. All boilers are modern computer-controlled units.

Scheme water boiler is shown in Fig. 2.

In the heating plant solar heaters are also used, which are used to prepare the dhw—solar energy is used for pre-heating of network water, but the basic heating is carried out by the coal boiler. Such solution allows partial replacement of coal with solar energy, while the possibility of producing hot water is independent of the

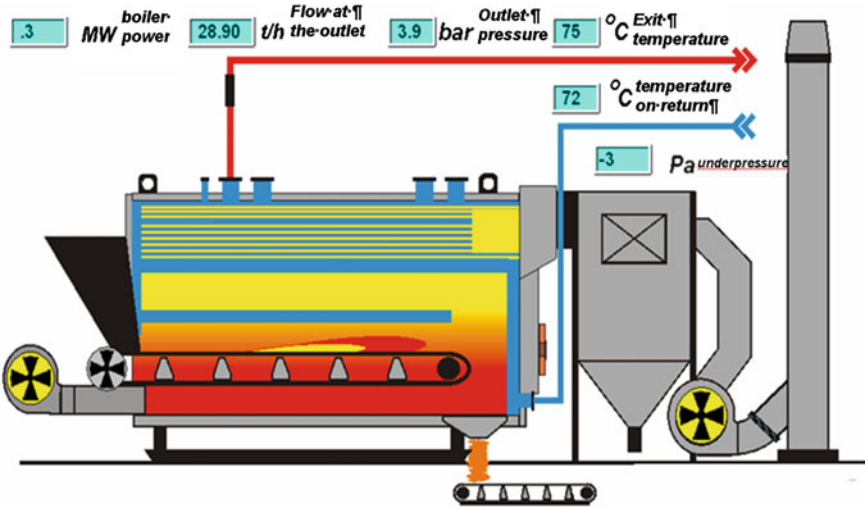

Fig. 2 Scheme of water boiler of type KRm-1,1; company SEFAKO S.A. [10]

randomness of solar energy. Limiting the amount of coal burned reduces emissions and reduces the cost of heat producing.

The solar installation, shown in Fig. 3, consists of 117 solar collectors. The number of collectors has been determined by the available surface of mounting and the specificity of everyday life of the heat consumer, which is an academic campus. The installation is divided into two sets. Technical data of the collector installed in the heating plant are presented in Table 1.

The power of a single solar collector is 910 W/m^2 [10]. The total absorption surface is 249.21 m^2, which, assuming 60% efficiency of the entire system, allows

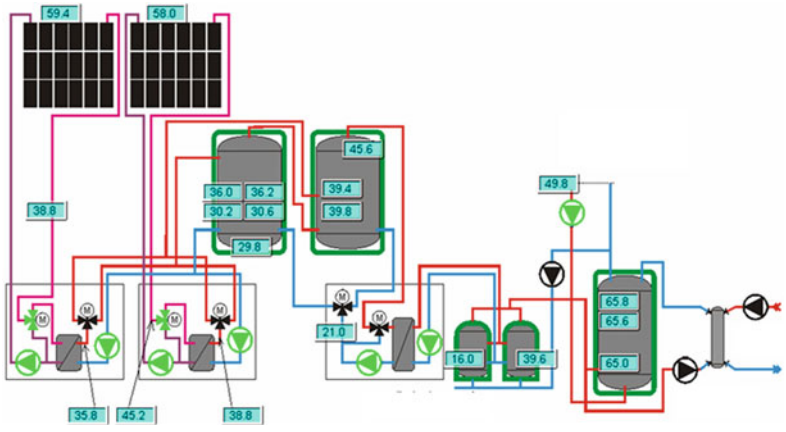

Fig. 3 Solar system installed in the analyzed heating plant [10]

Table 1 Technical data collector [10]

The dimensions of the collector	2036 × 1138 × 79 mm
The surface of the collector	2.32 m^2
The weight of the collector	46.9 kg
The nominal thermal output	910 W/m^2
The absorber surface	2.13 m^2
The absorber surface	2.13 m^2

for a maximum heat output of about 136.07 kW [10]. The total capacity of the trays of hot water in the solar system is 12,000 dm^3 [10].

4 Effects of Work of the Academic Heating Plant and Their Analysis

As mentioned at the outset, low emissions are complex phenomenon, which generally involves the excessive emissions of a large number of pollutants. Coal combustion, which is not always of a good quality, has a strong influence on its occurrence.

The paper presents the possibility of limiting the phenomenon of low emission by replacing in the process of energy production the process of burning coal using the solar system. Solar installation permits replace the specified amount of coal and thus does not emit pollutants.

The total amount of generated heat from a solar installation in individual months of 2014, 2015 and 2016 is shown in Fig. 4.

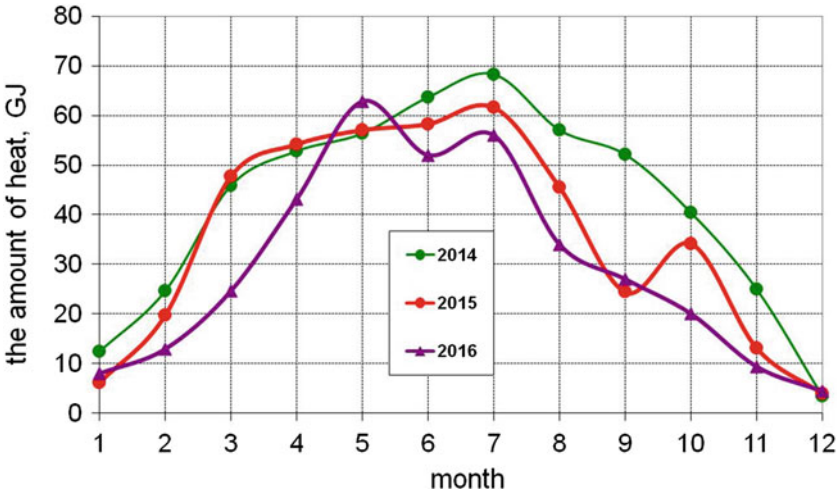

Fig. 4 The amount of heat absorbed by the solar installation in 2014, 2015 and 2016

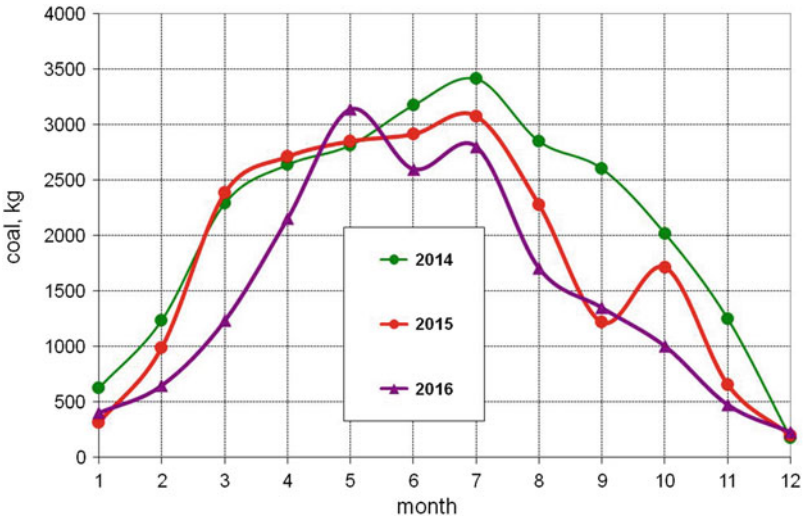

Fig. 5 The mass of unburned coal as a result of work of solar installation

It may be noted that the most effective solar installation work is the summer months—May, June and July. While in the winter months—October, November, December, January, February—solar installations are characterized by negligible amounts of produced heat. This is of course related to the geographical conditions of Poland.

If we assume that the calorific value of the average quality of coal is 20,000 kJ/kg, then the amount of generated heat by the solar system can be converted into the amount of unburned and thus saved coal. The calculation results are shown in the Fig. 5.

It is obvious that the nature of the curves in Fig. 5 above is identical to Fig. 4. The greatest amount of coal can be saved in the summer, which is not, unfortunately, the happiest observation. Low emissions are particularly vexatious in winter during the heating season. According to Fig. 5, solar installations are not the best alternative to coal in this period. However, it should be stressed that the operating costs of solar systems are negligible and thus the current costs of heat generation in the summer are reduced accordingly.

One of the pollutants of combustion of coal is CO_2. It is excessive amounts in the atmosphere are perceived negatively. Therefore, the amount of unburned coal was converted into the quantity not emitted CO_2. The results are shown in Fig. 6.

It can be seen that in this case the nature of curvature variations in particular months of the year is similar as before. The solar system is most beneficial for the environment in summer. In the winter its advantages are heavily restricted.

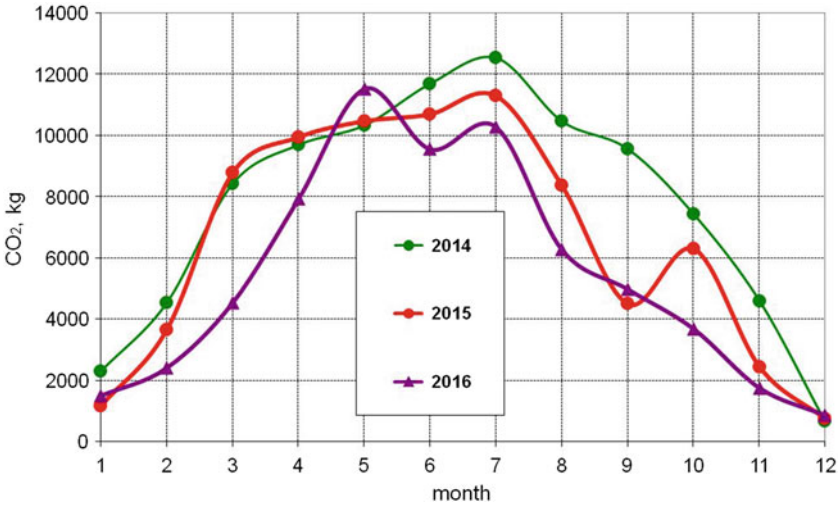

Fig. 6 The mass of CO_2 not emitted by working of the solar system

5 Conclusions

The cost of generating heat from hard coal is growing year by year. Therefore any amount of spared unburned coal is valuable. Unburned coal is a concern for the environment—it means less emissions of toxic pollutants. This is especially important for heavily urbanized areas, where compact housing hampers the natural ventilation of these areas and often causes low emissions.

Effective work of solar collectors depends on the time of the year. In the case of Poland, higher amounts of heat are consumed in winter, and then the efficiency of solar radiation is, unfortunately, the lowest. During summer the heat consumption decreases, accompanied by intense solar radiation. In the case of improper selection of solar power in relation to the amount of received heat, it can lead to excessive heating of installation, which in turn may result in its failure.

It must be remembered that a very important aspect of the potential use of solar collectors is the cost of installation, which in many cases is subsidized by environmental programs. This type of activity has a beneficial effect for the area, because it improves the environmental conditions, thus improving the health of inhabitants. If potentially saved money for public health improvements would be included in the total economic cost of solar installations, then perhaps these investments have become more profitable.

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