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# The aspect of environmental effectiveness of renewable energy sources utilization

**Abstract**
This article concerns using renewable energy resources. It contains an analysis of pollution emissions created by combustion of conventional and unconventional energy resources. It provides examples of cogeneration systems. In particular, it focuses on a system correlated with a gas turbine and a system correlated with a piston combustion engine. Attention is paid to the issue of applying innovative solutions in heating technology.

**Keywords**: emission of pollutants, ecological safety, cogeneration systems, renewable resources.

## 1. Introduction

The demand for energy is a direct derivative of economic growth, and therefore the consumption of energy is bound to increase within the next dozen years or so (Suszyński, 2011; the Act of 10 April 1997 Energy Law). Modern economies have to face the problem of fossil fuel depletion and increasingly higher prices of this resource. This creates a need for taking action to look for alternative, renewable energy resources so as to ensure energy security (Ropińska, 2011).

The issue of renewable energy resources is dealt with in many provisions of the Polish law. The fundamental one is the Constitution of the Republic of Poland, and Article 74 thereof reads: *the public authorities shall ensure ecological security for the contemporary and future generations, and environmental protection is an obligation of public authorities who shall support the actions of citizens for preservation and improvement of the environment* (Gołębiowska, 2010; Constitution of the Republic of Poland, 2 April 1997).

## 2. Energy from renewable resources

Energy coming from renewable resources may take a directly usable form (wind energy, water energy, solar energy, geothermal energy) or a form which allows storing it (biomass, biofuels). The latter, if reasonably used, bring less pollution to the environment (Organista 2002). Obtaining energy from renewable resources is one of the main solutions for reducing the current dependency on fossil fuels, and satisfies the constantly growing global demand for energy. The interest in implementing technologies using renewable energy keeps growing. The extent to which they are adopted depends on the cost of energy from renewable resources compared to the cost of energy from conventional sources. Regulating the environmental protection policies combined with respective fiscal policies may influence the development of production and use of renewable energy resources (Jasiulewicz, 2008).

It is possible to utilise renewable energy resources for power generation purposes. This issue comprises utilisation of biomass or straw, whose production exceeds the demand in agriculture. Straw combustion, however, could cover 5 per cent of the country`s energy demand.

The comparison between pollution emissions from a straw-heated “Pilewang Gizex — PM” boiler and those created by a standard coal boiler has shown that the negative impact of straw combustion on air clarity is lower (Reszkowski, 1995). Table 1 presents pollution emission values concerning coal and air combustion.

Table 1. Daily emissions of pollution resulting from coal and straw combustion

| No. | Type of emission | Straw boiler [kg/day] | Coal boiler [kg/day] | Comparison 4:3 [%] |
|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* |
| 1. | Sulphur dioxide | 0,152 | 4,104 | 3,70 |
| 2. | Nitrogen dioxide | 0,083 | 0,210 | 39,52 |
| 3. | Carbon oxide | 0,245 | 11,544 | 2,12 |
| 4. | Dust | 0,312 | 2,141 | 14,57 |

Source: own work based on Odnawialne źródła energii — nadzieja czy utopia, E. Reszkowski, 1995, *Ekopartner, 6 (28)*, 12–15.

The analysis of the data concerning daily emissions caused by coal and straw combustion presented in Table 1 has demonstrated that sulphur dioxide emissions from straw combustion are lower by 3.95 kg per day, i.e. by 96.3%, than the emissions from coal combustion, and by 0.13 kg per day, i.e. by 60.5%, with regard to nitrogen dioxide. Carbon oxide emissions resulting from straw combustion are lower by 11.3 kg per day, i.e. by 97.9%, in comparison with coal combustion. In addition, straw combustion produces less dust: the emissions are lower by 1.83 kg per day, i.e. by 85.4%, in relation to coal combustion.

## 3. Cogeneration systems

Cogeneration systems enable simultaneous production of heat and electric power. Optimal performance of power conversion is achieved with minimum pollution of the environment, which makes these systems effective power converters. Cogeneration solutions have economic, operational and ecological advantages, to name a few.

In order to meet heating demands, the production of heat in cogeneration systems may be supplemented by energy from stationary boilers. An example of such a solution is a system correlated with a gas turbine (Fig. 1) and a system correlated with a piston combustion engine (Fig. 2).

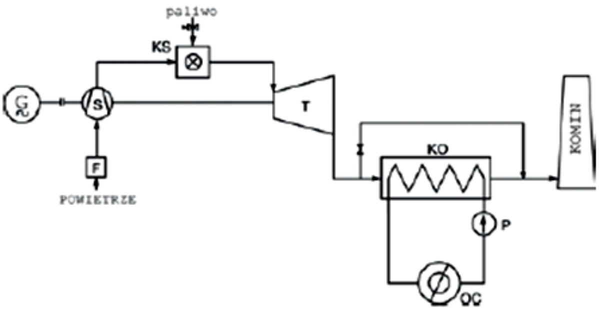


Fig. 1. A system correlated with a gas turbine: G — generator; KS — combustion chamber; T — turbine; S — compressor; KO — recovery boiler; P — heat receiver; F — filter

Source: Oszczędność energii chemicznej paliw wynikająca ze stosowania gazowych układów kogeneracyjnych i trójgeneracyjnych, J. Kalina, 2002, *Gospodarka Paliwami i Energią, 10.*

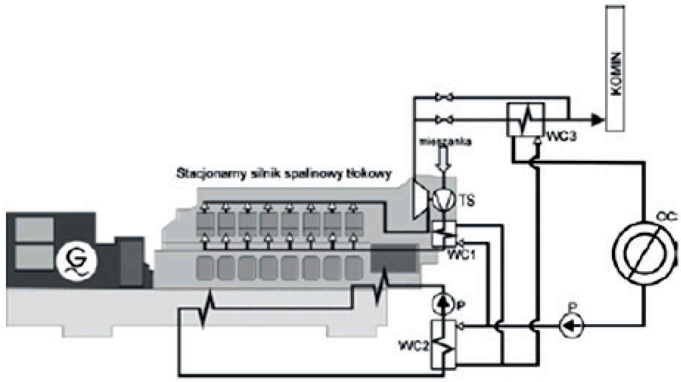


Fig. 2. A system correlated with a piston combustion engine: G — generator; P — pump; TS — turbo compressor; OC — heat receiver; WC1 — inlet air cooling heat exchanger; WC2 — water curtain and oil pan heat exchanger

Source: Oszczędność energii chemicznej paliw wynikająca ze stosowania gazowych układów kogeneracyjnych i trójgeneracyjnych, J. Kalina, 2002, *Gospodarka Paliwami i Energią, 10.*

In correlated systems demonstrated in Figures 1 and 2, the turbine or engine powers the generator. The heat, often called waste heat, is partly recovered in heat exchangers. In the case of turbine, there is one fumes-water exchanger (also called a recovery boiler), where hot fumes leaving the turbine are directed. The situation is more complex if the system is based on a piston combustion engine. The exchanger system is extended in this case, as there are a few sources of heat with different temperatures in the engine. These are:

– water curtain cooling heat,
– oil pan cooling heat,
– charge mixture cooling heat,
– enthalpy of fumes.

Variations in heat demand make technological diagrams of small heat power plants usually more complex. In the majority of cases, the engine or the turbine cooperates with peak load and reserve boilers and/or with heat reservoirs. Peak load and reserve boilers may be powered by fuels other than gas systems, which leads to creating multi-fuel heat power plants. In addition, in the case of engines (in particular of greater power), the system is usually fitted with an emergency fan cooler (Kalina, 2002).

System configuration and temporary load changes influence the annual value of parameters expressed by the formulae (1) and (2). This concerns the quantity of primary fuel chemical energy which can be saved. If a given process is carried out on a global scale, this value is one of the most significant comparative coefficients in the analysis of correlated usable energy carriers production (Horlock, 1987; Huang, 1996; Szargut, & Ziębik, 1998; 2000). This saving is demonstrated by the following formula:

$$-\Delta E_{ch} = \left(E_{ch}\right)_R - \left(E_{ch}\right)_S > 0 \qquad (1)$$

where: $(E_{ch})_R$, $(E_{ch})_S$ — chemical energy consumption in the system in the case of a separate and correlated usable energy carriers production.

The obtained value may be compared against power consumption before carrying out a given process (in separate production), and in this way a relative saving ratio may be obtained:

$$FESR = \frac{-\Delta E_{ch}}{\left(E_{ch}\right)_R} \qquad (2)$$

where FESR — Fuel Energy Saving Ratio.

## 4. Conclusion

Correlated heat and power management, as well as heat, power and cooling management are innovative heating technology solutions. High potential energy carriers should be used to generate mechanical (electrical) power. In turn, the waste heat generated during cogeneration processes may be used for heating or cooling purposes.

Using unconventional heat and energy sources may be classified in the group of renewable energy resources, such as, among others:
– clean electric power sources (photoelectric cells, water and wind power plants),
– clean heat sources (solar collectors, waste heat, geothermal waters, heat pumps),
– clean sources of heat generated by combustion (biogas, biomass, wood, straw),
– sources of heat generated by combustion (litter, waste).

Using renewable sources of energy for power generation purposes is particularly important for energy economy.

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