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ENERGY EFFICIENCY IMPROVEMENT POTENCIAL AND ENERGY SAVING STRATEGIES IN GLOBAL INDUSTRIAL SECTOR

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Abstract. *People's awareness of the importance of energy consumption in the industrial sector is growing due to the fact that the industrial sector is responsible for about third of the world's energy supply. The main challenge of each energy sector is reflected in increasing efficiency in each of its parts, which is directly related to the positive effects on human health, the environment and the economy of a country. Energy efficiency is often referred to as the "fifth fuel" (after gas, coal, nuclear and renewable energy) and can play a key role in meeting global power demand and mobility. This paper focuses on possible approaches and measures that lead to the reduction of energy consumption and the improvement of energy efficiency of various sectors in industry. In addition to improving energy efficiency in energy processes and the use of energy efficient technologies to reduce energy consumption in the industrial sector, it is necessary to provide energy efficient strategies that improve the functioning of the industrial sector, especially for developing countries.*
Key words: *industrial sector; energy efficiency, energy savings by technology.*

1. INTRODUCTION

The industrial sector has always been the most energy-intensive sector in all countries, so it is one of the primary goals when exploring the potential for energy savings. Over the past decades, due to the increasing energy consumption associated with the harmful impact on the environment, there has been an increased awareness of scientists and researchers about the development of energy efficient techniques and systems in the industrial sector. A third of global energy use occurs in the industrial sector, which is also responsible for 35% of greenhouse gas emissions (Figure 1). Due to the increase in energy consumption in the industrial sector as a result of economic growth, global industrial energy demand is expected to increase by 76%, from 106 EJ in 2009 to 185 EJ in 2050, unless measures are introduced that can contribute to the reduction of final energy consumption [1], [2]. In addition, an increase in the price of energy contributes to an increase in the price of final products because the cost of the final product also includes the cost of energy. Improving energy efficiency is defined as reducing the specific energy consumption per product (eg GJ/t of crude cell, MWh/t of aluminum, etc.). Energy efficiency in the industrial sector, in addition to having significant potential to reduce greenhouse gas emissions – which directly affects climate change mitigation, is also a key factor in boosting a country's economic growth and development by reducing system costs.

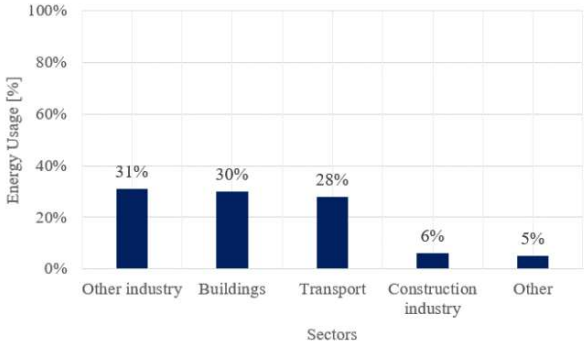

Figure 1. Globalfinal energy consumption in the energy sector

The implementation of measures to improve energy efficiency estimates that energy consumption in the industrial sector can be reduced from 185 EJ to 140 EJ by 2050, which is a reduction of 24% [2].

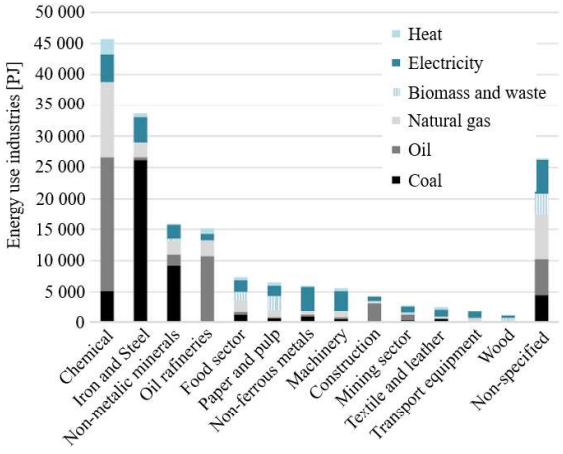

Figure 2. Global energy use in industries in 2016 (PJ)[3].

Rational energy consumption and rational use of energy resources along with ecological and safe infrastructure development also ensures sustainable development of society.

2. ENERGY CONSUMPTION IN THE INDUSTRIAL SECTOR AND APPROACHES TO ENERGY EFFICIENCY

Figure 2 shows the global energy use in the industrial sector. The industrial sector with the highest energy consumption (up to 26%) is the chemical sector. After the chemical sector (which includes petrochemistry), the iron and steel sector has the highest energy use (19%), followed by the non-metallic minerals industry and the oil refinery (9%), with the cement industry having the highest energy consumption in the non-metallic minerals sector (between 70 and 80%). The industry most often uses coal with a share of 28%, followed by oil with 26%, natural gas with 19% and electricity with a share of 18%. Of the total coal consumption in industry, the largest share is occupied by the iron and steel sector (78%), followed by the non-metallic minerals sector (19%) and the chemicals industry (10%). Oil consumption is most widespread in the chemical industry (37%) and in the oil industry (24%). Consumption of natural gas in the industrial sector occurs most in the chemical industry (37%), and electricity consumption is most widespread in the chemical industry (14%), iron and steel industry (13%) and non-ferrous metals industry (12%) which is in mostly related to aluminum production [4]. The use of renewable energy sources in all these sectors (except biomass) is negligible. Taking into account all these sectors, the total energy consumption in the industrial sector in 2016 was 174 EJ, which represents 30% of the total primary energy consumption in the world of 576 EJ [3]. In addition, the use of these types of energy in the industrial sector is responsible for 35% of global greenhouse gas emissions. In the industrial sector, energy efficiency can be achieved through three different approaches, namely [5]:

1. Energy savings by management;
2. Energy savings by technologies;
3. Energy savings by policies/regulations.

In order to increase the efficient management of energy resources, increase energy savings and energy efficiency of the industrial sector, it is necessary to introduce technical innovations and energy strategies that improve the functioning of the industrial sector. The implementation of modern management mechanisms using the international standard for energy management ISO-50001 (EMS -Energy Management Standard), provides the possibility of a systematic approach to management and optimization of energy consumption [6]. This tool enables a successful strategy for the implementation of energy efficiency policy, and includes a set of measures needed to reduce energy costs, taking into account the reduction of negative impact on the environment. Also, the energy management system in the industrial sector via the Internet of Things (IoT) offers the possibility of saving energy, increasing productivity and improving various processes using data coming from a network of sensors and meters, using connected smart devices to automate processes, remote monitoring and predictive maintenance [7]. In addition to IoT, digital twins can be used in the energy sector to analyze and visualize data over time, optimizing system performance, connecting separate systems for improved process monitoring, analytical evaluation of production decisions, putting the machine into operation from remote service centers thus reducing maintenance costs, etc. [7]. Industrial energy policy is widely used in the industrial sector in order to to develop a strategic plan to increase energy efficiency and reduce greenhouse gas emissions. It includes legislation, international treaties, agreements, investment incentives, taxation, energy efficiency standards, conservation guidelines energy [8]. In addition to the above approaches, the reduction of harmful impact on the environment can be achieved at the same time by using energy efficient technologies that take into account economic and social factors. When planning or improving the production of a particular sector to save energy and reduce emissions, it is necessary to establish a database of best available, advanced and economically sustainable technologies, processes or operational methods (BAT - Best Available Technologies) [6]. BAT is determined on the basis of

modern achievements of science and in the industrial sector most often includes cogeneration, waste heat recovery, waste use, efficient engines, etc. The potentials of energy efficiency in this paper are based on the application of BAT. In addition to BAT, a very important measure to save energy in the industrial sector is the use of biomass energy. Developing countries continue to face barriers related to the adoption of energy efficient technologies and the use of renewable energy sources, even if they are environmentally and economically attractive and often easy to implement. This shortcoming is reflected in the lack of regulation and energy policy, limited awareness of people who create energy policy and lack of knowledge and trained staff, as well as lack of finances. The authors divided the barriers into 6 categories, as follows: 1. technical; 2. institutional; 3. financial; 4. managerial; 5. costs and 6. information [9].

3. ENERGY EFFICIENCY MEASURES IN THE INDUSTRIAL SECTORS WITH THE HIGHEST ENERGY CONSUMPTION

This section will describe energy saving measures in the main industrial sectors, namely: chemicals, iron and steel and cement. It includes the production of aluminum, which is the sector that consumes the most electricity, after chemicals and iron and steel.

3.1 Chemicals and petrochemicals

About 80% of fuel consumption in this sector is used to produce ethylene, propylene, methanol, ammonia, benzene, toluene and xylene. Cracking, as the main chemical industry method in which saturated hydrocarbons decompose to produce unsaturated hydrocarbons, eg olefins (ethylene or propylene) or aromatics, accounts for about 20% of energy consumption in the chemical and petrochemical industries. In the process of cracking, temperatures increase from 815 °Cto 870 °C, while the pressures are around 15-20 bar, so thermal energy is the most used energy in this sector [1]. For example, the proportion of ethylene cracked from oil is 45%, 35% of ethylene is cracked from ethane, 12% from LPG and 5% from gas-oil. In addition, the production of one ton of ethylene from ethane requires 15-25 GJ of energy, 25-40 GJ of oil and 40-50 GJ of gas oil [10]. The petrochemical cracking process has the greatest potential to reduce energy use in this sector. By introducing energy efficient measures and technologies in the cracking process, energy efficiency can be improved by 37% by the end of 2050. [2]. Ammonia and mealol production accounts for about 32% of total energy consumption in this sector. By introducing energy efficient technologies for the production of ammonia based on natural gas, oil and coal, the current energy efficiency could be improved by 50% by the end of 2050. [2]. The total fuel saving potentials in the chemical and petrochemical sectors range between 8 and 50%. About 65% of electricity consumption in the chemical sector is used for motor systems (compressors, fans, pumps), 13% is used for the production of chlorine and sodium hydroxide and 22% is used for other processes and lighting. By using highly efficient motors with adjustable speed, energy savings of 20-30% can be achieved. In addition to improving energy efficiency in energy processes and the use of energy efficient technologies to reduce energy consumption in this sector, great potential for savings can be realized through energy integration of processes, combined heat and power production and through recycling and energy recovery. The estimated shares of each type of BPT in energy savings in the petrochemical industry are given in Figure 3.

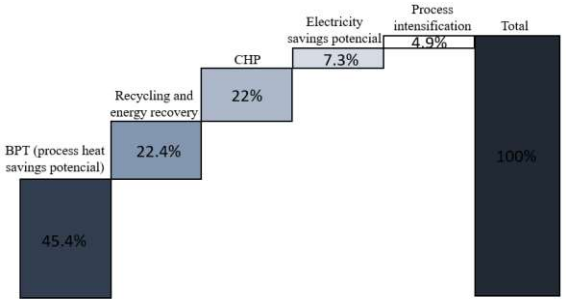

Figure 3. Energy efficiency improvent potecial of the global petrochemical industry (BAT scenario)

3.2 Iron and Steel

As one of the largest consumers of energy, the iron and steel industry is greatly contributing to the increase in greenhouse gas emissions. Demand for steel is expected to double by the end of 2050. due to its growing use in the construction, infrastructure, transport and manufacturing sectors. In the traditional steel industry based on iron ore and limestone, the most energy-intensive processes come from blast furnace equipment (about 70%). Replacement of fossil fuels or replacement of coke in blast furnaces can be achieved by the potential use of hydrogen as a fuel, which would accelerate the decarbonization of the steel industry and reduce CO_2 emissions in this sector [3].

Energy efficient energy saving methods in the iron and steel sector are essential. The greatest energy savings in this sector (up to 50%) can be contributed by coal moisture control, dry coke quenching (CDQ),

cogeneration by heat recovery and pulverized coal injection [1]. Additional energy savings can be achieved by reducing the need for hot rolling using a thin slab casting system [11]. The use of recycled steel in secondary production with pre-heating and process control can contribute to great energy savings. It is estimated that in 2050. the production of steel from scrap will increase from 36% in 2009. to 45% in 2050. [2]. In addition, the production of steel from scrap, in relation to the primary production of steel is less energy-intensive process, which leads to additional energy savings. With the adoption of these measures, it is estimated that energy use in the steel and iron industry will be reduced by 31% by 2050. (from 17 GJ/t of pig iron, which represents the world average to 11.8 GJ/t of pig iron) [2]. The shares of potential for energy savings in this sector according to the BAT scenario are presented in Figure 4 [1].

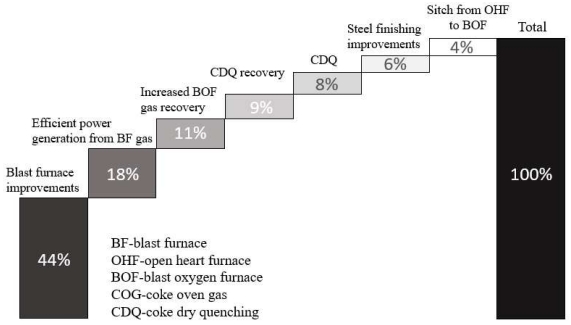

Figure 4. Energy efficiency improvent potecial of the global iron and steel industry (BAT scenario)

3.3 Cement

After the iron and steel industry, the cement industry has the highest energy consumption in the industrial sector with a share of 7% and a share of 6% of global CO_2 emissions. Preparation of raw materials, clinker production and cement grinding are the main processes in cement production. The most energy-intensive process is clinker production. The production of clinker in a dry kiln with a precalciner and 5 to 6 preheater stages is currently considered the best technology for saving heat [12]. Electricity in the cement industry is mostly used for cement grinding, preparation of raw materials, fuels and additives and exhaust fan drive. Great savings in electricity consumption can be achieved if the efficiency of rolling machines in the process of clinker grinding is improved, then by introducing high-frequency motors and improving lighting efficiency. In addition to energy efficient technologies in the preparation of raw materials, clinker production and cement grinding, the reduction of energy consumption in the cement industry is mostly reflected in the reduction of clinker content in cement or merging clinker with other materials with similar properties (mixed cements) [13]. This reduces the demand for clinker, and thus reduces the use of heat for clinker production. Clinker can also be replaced by industrial by-products (blast furnace slag, volcanic materials or coal ash). Reducing energy consumption and increasing energy efficiency in this sector can be achieved by introducing energy management and control systems, reducing heat loss in furnaces and preheaters, heat recovery for electricity production, increasing preheating, improving furnace combustion systems, etc. By introducing energy efficient measures and technologies that contribute to reducing the heat required for clinker production and saving electricity in cement production due to the lower ratio of clinker and cement, it is assumed that energy consumption for cement production can be reduced from 2.9 to 2.1 GJ/t of cement by 2050. and energy efficiency could be improved by 27% [2]. Figure 5 shows the shares of energy saving potential in this sector according to the BAT scenario [1].

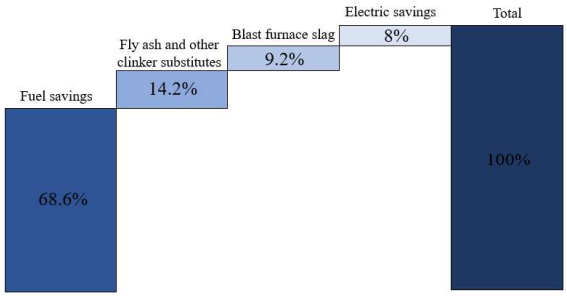

Figure 5. Energy efficiency improvent potecial of the global cement industry (BAT scenario)

3.4 Aluminium

The aluminum industry is one of the largest consumers of electricity in the industrial sector with a share of about 8% , because very large amounts of electricity in the form of direct current are used for the production of primary aluminum from alumina. The production of primary aluminum from alumina, ie the melting of primary aluminum is the most intensive energy process whose energy consumption is 70%. Also, if quality alumina refined in alumina through a more efficient Bayer process were used, energy consumption would be significantly reduced. In addition to energy efficient technologies for alumina processing and melting, cogeneration of heat and electricity and the use of waste heat from waste gases can play an important role in saving energy in this sector [3]. In addition to the mentioned energy saving measures, it is important to note that the recycling of aluminum, ie secondary production of aluminum in 2017, contributed to a 32% reduction in aluminum production. By adopting energy efficient

technologies, energy savings for the production of primary aluminum can achieve a reduction of 22% [14].

3.5 Other industries

The energy efficiency of other industries should also not be neglected because this industrial sector consists of a large number of small and medium enterprises with great potential for energy savings, even greater potential than these industrial sectors. The introduction of energy efficient motor systems can save 20-30%. [15]

Reducing end-use energy in addition to energy saving measures in industrial final energy consumption, can also be achieved by improving energy efficiency in primary energy use. The savings will be reflected in increasing the global average conversion efficiency for energy production from different energy sources. In addition, the use of primary energy can be further reduced by improving efficiency during electricity production.

4. CONCLUSION

The focus of this paper is the importance of energy efficiency issues in the industrial sector as the sector responsible for about third of global final energy consumption and about 35% of global greenhouse gas emissions. The industrial sectors that have the highest energy consumption are the chemical industry, the iron and steel industry and the cement industry. The importance of energy efficiency of energy systems is reflected in the more rational use of energy, the introduction of energy efficient and advanced technologies, while providing the principles for sustainable development of society. However, there are certain barriers and obstacles that make it impossible to improve energy efficiency. For this reason, the paper outlines various energy saving strategies in the global industrial sector, such as savings through energy management, supported by a well-designed and efficient energy policy and the implementation of comprehensive energy management standards. The application of these strategies reduces the use of energy and greenhouse gas emissions, and also improves the economic strength of a country. The energy savings of a particular sector depend on the characteristics of production and the current level of energy efficiency and usually range from 20-40%. A very important factor in reducing energy consumption are broader energy saving measures such as material recycling, limiting the use of materials with new product designs, replacing materials and also replacing fossil fuels using renewable energy sources or hydrogen.

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