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SETTING ENERGY EFFICIENCY ENHANCEMENT OBJECTIVES FOR RUSSIAN ENERGY INTENSIVE INDUSTRIES*

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Abstract

This study is focused on the analysis of energy efficiency enhancement potential of Russian energy intensive industries and approaches to setting energy efficiency and greenhouse gas emissions national objectives. In 2019-2020, new legislation on regulating greenhouse gas emissions is expected to be passed in Russia. To set realistic, achievable but ambitious objectives, it is necessary to evaluate current energy consumption and greenhouse gas emissions related characteristics and opportunities to improve both technological processes and energy management practices of energy intensive industries.
This study considers opportunities for enhancing energy efficiency and reducing production greenhouse gas emissions of ammonia, cement, ceramic materials and ferrous metals processing industry in Russia. It is shown that the implementation of Best Available Techniques in Russian industry opens opportunities not only for reducing emissions of conventional pollutants, but also for enhancing resource efficiency of technological processes, using renewable energy sources as well as finding solutions for controlling process-related greenhouse gas emissions. Still, the Integrated Pollution Prevention and Control regulation (based on mandatory implementation of Best Available Techniques) and greenhouse gases regulation (based on applying market instruments) should act as independent regulatory constructions.

Keywords: Best Available Techniques, energy efficiency, greenhouse gas emissions

1. Introduction

In the Russian Federation (RF), new Integrated Pollution Prevention and Control (IPPC) legislation obliging larger industries (over 7,000 installations of more than 40 sectors)

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to implement Best Available Techniques (BAT) was adopted in 2014. In 2019, first installations began assessing their environmental performance and applying for the Integrated Environmental Permits (IEP), the conditions of which are based on BAT requirements (BAT-Associated Emission Levels, BAT-AELs). In Russia, the BAT concept considered not only as the basis for a new environmental regulation, but also as a means for the modernization of national industries. That is why the performance values of energy, raw materials and water consumption etc. are regarded as important as BAT-AELs. Though nowadays IEPs do not prescribe any requirements to the resource (and especially energy) efficiency, there is a hope that such parameters will be included in IEPs in future as recommendations, at least (Skobelev, 2019).

On the other hand, greenhouse gas (GHG) related legislation is expected to be passed in 2019-2020. Initially, there was an idea to describe GHG emissions in Russian Reference Documents on Best Available Techniques (BREF) and to include GHG obligations in IEPs. As the result of expert discussions, it was decided that Russian documents should contain energy efficiency (EE) related chapters similarly to European BREFs, but would not set any BAT-AELs covering GHG emissions (Skobelev, 2018).

In 2019-2020, the RF Law on Regulating Greenhouse gas emissions is expected to be passed in Russia. At the same time, a long-term strategy for the GHG emission reduction is being developed. It will present a vision to decrease emissions through a fair transition encompassing all sectors of the economy. The strategy will underline the opportunities that this transformation offers to Russian citizens and its economy, as well as identify challenges along the road. Industry wise, to set realistic, achievable but ambitious objectives, it is necessary to evaluate current energy consumption and GHG emission-related characteristics and ways to improve both technological processes and energy management practices of energy intensive industries.

2. Case studies

To evaluate EE enhancement and GHG emission reduction potential in Russian industry, four sectors (internationally recognized CO_2 emitters such as large volume cement and ammonia production) and sub-sectors (such as extremely energy intensive but low volume producer as technical ceramics and widely spread and diverse ferrous metal processing industries) were selected and studied. All these sectors and sub-sectors fall under the new Russian IPPC legislation.

2.1. Cement production

Traditional cement manufacture is a fuel intensive, electro-intensive and CO_2 intensive process. According to the State Report on the Status of Energy Saving and Energy Efficiency Improvement in the Russian Federation (RF Government, 2018), in 2016-2017, specific energy consumption in the production of cement reached 4.74 GJ per ton of clinker (Fig. 1). At the same time, in 2016, Russian cement sector contributed 20.34 mln tons CO_2-eq into the total GHG emission flow (2643.8 mln tons CO_2-eq) (Roshydromet, 2018).

The cement-making process can be divided into two basic steps. Firstly, clinker is made in a kiln, which heats raw materials such as limestone with small quantities of other materials to 1,450°C using fossil (and in some cases non-fossil) fuels. During this process, the CO_2 is disassociated from the limestone allowing the calcium oxide to react with alumina, silica and iron minerals; this aspect of clinker production is known as calcination. Secondly, clinker is ground with gypsum and other materials to produce cement powder.

The chemical decomposition of limestone (calcination) generates up to approximately 60-65% of total CO_2 emissions. The remainder of emissions arise from combustion of fossil fuel and non-biomass waste fuel and indirect emissions from electricity consumption (JRC Reference Reports, 2013). On a global scale, about 638 kg of CO_2 were produced per ton of cement in 2015. Compared to 761 kg of CO_2 per ton of cementitious product being emitted in 1990, this represents a reduction of 16% (JRC Reference Reports, 2013). In Russia, this parameter varies from about 700 kg to 900 kg CO_2 per ton of cement produced (Rosstandart, 2015b).

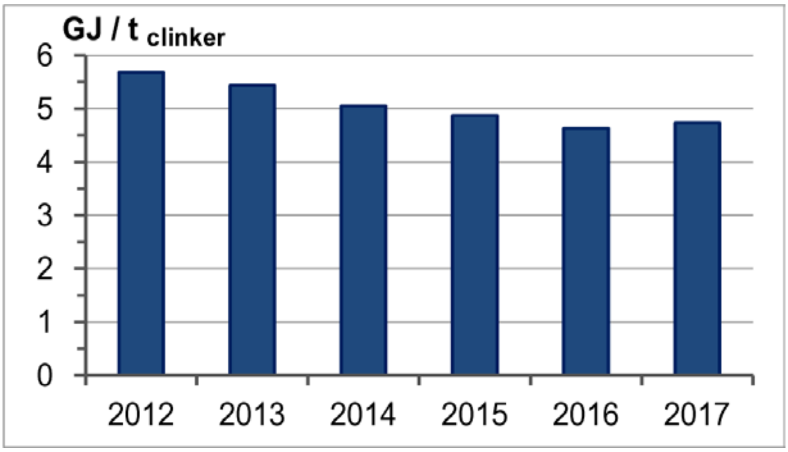

Fig. 1. Energy consumption in cement clinker production (RF Government, 2018)

Russian cement industries being IPPC installations and being obliged to apply for IEPs, expect also to fall under the new GHG regulation in 2020. They will have to not only report their CO_2 emissions, but to meet sector-related EE and GHG emission reduction objectives and pay emission fees. On the other hand, they anticipate that turning to burning non-fossil fuels may lead to increasing emissions of conventional pollutants. Thus, they suspect that burning biomass could lead to the emission growth for such pollutants as SO_2, NO_x, CO or dust, while burning waste-derived fuels could change dramatically the composition of stack gases and require additional treatment and complicated self-monitoring procedures.

Results of experiments and modelling prove that the use of wood chips, sunflower pellets, wood powder as fuel additives in amounts lesser than 15 % (by calorific value) will lead to decrease in total emissions of conventional pollutants by 0.5-1.1% (mass). As far as GHG emissions are concerned, the amount of CO_2 is reduced more significantly while using wood powder (0.76%) and wood chips (0.52%). It is important that for the reporting purposes, GHG emissions resulting from burning biomass, are not included in the total amount of CO_2 emitted by the installation. Thus, substituting 15% of natural gas by biomass, allows to reduce GHG emissions by 15.76 % (reporting wise) (Tikhonova et al., 2019).

Another opportunity allowing to reduce energy consumption and GHG emissions rises from using additives such as fly ash, mining or metallurgical slag. Russian operators report that the specific energy consumption level decreases down to 2.57 MJ per ton of clinker while substituting 25% of thermally pre-treated iron slag. EE improvement is achieved due to reduced energy consumption for decarbonization. On the other hand, process (non-energy) CO_2 emissions are also decreased since there are no carbonates in the slag. The installation does not report its GHG emissions, but it is possible to assume that they can decrease below 700 kg of CO_2 per ton of clinker. Still, most Russian industrialists are not ready to discuss these opportunities arguing that environmental authorities may introduce too stringent self-monitoring and reporting requirements and focus their attention on exploring fuel substitution options.

2.2. Ammonia production

The chemical and petrochemical sector is one of the largest industrial energy consumers. Ammonia is a chemical produced in very large volumes. In 2016, ammonia was produced in 66 countries. In descending order, the largest producers were: China (33%), Russia (8%), India (8%), and the United States (6%), cumulatively accounting for 55% of global production. Ammonia production is responsible for about 17% of the energy consumed in the chemical and petrochemical sector (Handbook, 2017).

In 2016, Russia ammonia industry produced 16.1 mln tons of ammonia (Market report, 2017) and contributed 34.69 mln tons of CO_2 towards the overall GHG flow (Roshydromet, 2018).

Natural gas is the most relevant feedstock in Russia. Stoichiometrically, CO_2 is formed as co-product at 0.97 tons CO_2 per ton of NH_3 produced. In reality, average direct CO_2 emissions of European ammonia plants amount to 1.33 tons of CO_2 per ton of NH_3 (compared to the global average of 2.87 tons CO_2 / ton NH_3) (Department for Energy and Climate Change (2015a). As long as hydrogen is supplied by the means of steam methane reformation (or by the help of other fossil sources) these feedstock-related CO_2 emissions are unavoidable.

Thus, CO_2 emissions occur during the production of synthetic ammonia, primarily through the use of natural gas or other fossil fuels. The natural gas processes produce CO_2 and H_2, the latter is used in the production of ammonia. At the advanced installations some amount of process CO_2, rather than being emitted to the atmosphere, is captured and used to manufacture urea. In 2016, Russian ‘complex’ installations had captured 5.30 mln tons of CO_2 to produce urea. Thus, Russian installations emit 2.15 tons of CO_2 per ton of NH_3 produced, while 0.33 tons of CO_2 are captured; this result in 1.82 tons of CO_2 per ton of NH_3.

Ammonia production will always consume large amounts of energy for high temperature and pressure processes. Still, the industry has become more energy efficient through improved design. Ammonia plants built after 1990 use some 30 % less energy per ton of nitrogen than those designed in the 1970s. A contemporary plant with natural gas as a main fuel in a methane reformation process can use less than 30 GJ per ton of NH_3, compared to 75 GJ per ton for the processes prevalent in the early 1960s. In 1995, the average for all plants in the EU industry was about 40 GJ per ton of NH_3 (IPPC, 2007). According to Chinese research, BAT implementation worldwide could further reduce energy consumption by 20-25%, and decrease GHG emissions by 30% (Zhou et al., 2010).

Russian ammonia producers believe that in order to contribute towards the decrease of GHG emissions in the sector, they can apply EE solutions and consider capturing more CO_2 in urea if there is an adequate market demand (Rosstandart, 2015a). On the other hand, they are not prepared to convert no non-fossil fuels arguing that natural gas remains to be not only affordable but the cleanest energy source for the chemical industry.

2.3. Technical ceramics manufacturing

Technical ceramics manufacturing is without any doubt the most energy- and resource-intensive sub-sector in ceramics production; specific (per ton of product) CO_2 emissions in this sector are 20 times higher than those in brick production or 6-7 times higher than specific GHG emissions in cement manufacturing (Rosstandart, 2015c). Technical ceramics embrace a broad range of materials with tailored properties for advanced applications in the aerospace and automotive industries, electronics, environmental protection, etc. and require the largest variety of raw materials, from high grade clays to rare-earth elements (oxides and non-oxide compounds), the highest firing temperatures (i.e., energy consumption), and the most sophisticated processing techniques. The picture is aggravated by a typically poor resource efficiency arising from small-scale production output and a substantial percent defective allowable.

Possible measures for EE enhancement are limited by strict requirements set both for technological process and product control. Practitioners in the field of advanced structural ceramics seek possible response to these challenges by employing advanced management systems, such as Lean Production approaches (Vartanyan et al., 2018).

The adjusted Lean Production program has been introduced at one of production sites in 2014, and the first step to be taken comprised drafting a Value Stream Mapping to analyze manufacturing process and determine possible sources of losses. As a numerical value to describe energy and resource efficiency enhancement a startup coefficient Ks is used, which equals started green bodies to product yield ratio. In 2015, this parameter comprised about 1.6, i.e. to obtain 100 non-defective items not less than 160 green bodies were necessary.

A detailed study of all technological stages and determination of operational Ks proved that most crucial stages to increase product yield were shaping and drying of green bodies. Thus, several process-integrated measures were suggested that included changing a slurry preparation technique; altering molds construction and methods of their use; and most importantly – re-design of dryers to provide uniform heating and avoid temperature gradients. Another important action taken towards Ks increase was aimed at better management of the most energy-intense stage, i.e. high-temperature firing. Since 2015 the operator has initiated a deep modernization of existing kilns and installed a number of newer ones, with improved heat insulation and automated firing regime controls.

Specific energy consumption decreased from 6.15 to 5.25 GJ per ton of product, while specific (direct and indirect) GHG emissions reduced from 5.22 to 4.46 kg of CO_2 per ton of technical ceramics produced. EE and environmental performance enhancement is achieved by reducing the amount of defective items entering heat treatment stages (drying and firing), this allows to reduce specific energy consumption and decrease specific gaseous emissions. Moreover, due to quality concerns, no backward material flow is possible, and lower amount of defective items at all technological stages means less solid waste generation.

2.4. Ferrous metals processing

The Development Strategy for the Russian Iron and Steel Industry during 2014–2020 and until 2030 (RF Government, 2014) has a special section on energy efficiency issues. The Strategy states that specific energy intensity reduction should be achieved by developing and implementing innovative techniques and measures: advanced energy and resource saving technologies, including design for new equipment; the introduction of combined ferrous metals processing with simultaneous reduction in technological operations, etc.

The State Reports on Energy Saving and Energy Efficiency Improvement pay a very significant attention to ferrous metals processing: information is provided on the specific fuel and energy consumption for rolled metal (until 2015) and steel pipes (until in 2016) (Fig. 2) (RF Government, 2018).

The ferrous processing uses various types of energy carriers for production (natural gas, coke and blast furnace gases, electricity, oxygen, compressed air, etc.). In order to bring these energy carriers to the equivalent fuel and calculate the energy intensity, they establish conversion factors for mean heat capacities of the energy sources used. Rolling is the final step in ferrous metals processing. Rolling mills of metallurgical integrated plants consume up to 20% primary energy sources of their total costs for an enterprise, the electric consumption is slightly less than the 20%.

High-grade heat is consumed by heating furnaces during various technological stages of process: heating the metal before deformation and heat treating. Its main energy sources are blast furnace, coke and natural gases and fuel oil. The consumption of this type of energy on average is 3-5 MJ fuel per ton of product.

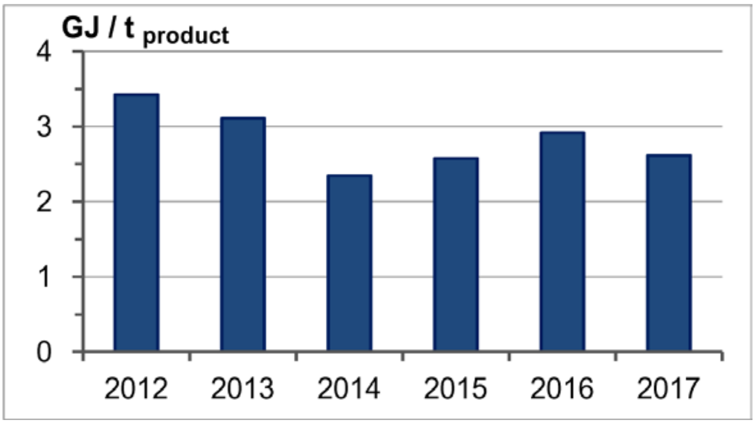

Fig. 2. Energy consumption in the production of steel pipes (RF Government, 2018)

Russian BREF for ferrous metals processing industry (Rosstandart, 2017b) emphasizes that over 75 % of BATs identified directly point out the importance of resource and energy efficiency. These techniques range from organizational measures like Energy Management Systems (IPPC, 2009) to fundamental improvements in process technology (applying automated continuous rolling mills, establishing heat recovery and regeneration systems, applying multi-strand rolling and drawing and using highly efficient automated drive systems for main and auxiliary equipment based on the use of electric motor).

The specific fuel and energy consumption statistics for steel pipe production in the Russian Federation for the period 2012-2017 have total decrease by 23.5%. At the same time, the dynamics were ambiguous: the declining trend of 2015 was replaced by growth till the end of 2017 when there was another decrease by 10.2% compared to the previous year. In the 2014–2016, Reports indicated that the specific fuel and energy consumption for rolled metal in Russia was decreasing systematically from 2012 to 2015 by 10-11 % to achieve 2.87 MJ per ton of product. The best installations show as low specific energy consumption as 1.1-1.5 MJ fuel per ton of product.

Practitioners argue, that since the sector is diverse, and many installations that have been reconstructed in 2015-2018, sector-related objectives can be set at the level of leading industries while taking into consideration peculiarities of the technological processes.

3. Results and discussion

For 2030, the Russian Federation Government sets the national goal of not increasing GHG emissions above 70 % of the 1990 level. Currently, two thirds of industrial emissions come from the following energy-intensive sectors: metallurgy, oil refining, chemicals, cement, pulp and paper, food and drinks, metal processing, and ceramics. These sectors use the greatest amount of energy and produce the most CO_2 emissions among other industrial sectors.

Internationally, pathways to decarbonization of the industry sectors studied in this article had been developed in 2014-2017; one of the most advanced documents was published in the United Kingdom in 2015 (Department for Energy and Climate Change, 2015b). The following decarbonization solutions are recommended:

- Cement: oxy-combustion; alternative cements based on non-traditional processes or raw materials; CO_2 capture technology and storage or use; use of hydrogen fuel.
- Chemicals (for the whole sector): carbon capture technology (including urea production); hydrogen production by electrolysis; recycled plastics to syngas; membrane separation technology.
- Ceramics (in general, for the whole sector): electric kilns, gasification of biomass to fuel kilns, reduced number of firings, lower temperature processes, lower product weight
- Ferrous metals processing: advanced (automated) technologies; carbon capture.
- At the same time, for each sector, Energy and Environmental Management Systems are described as universal solutions applicable to reduce energy demand and improve environmental performance of industrial installations.

For cement industry, GHG emissions can be reduced not only by ‘traditional’ energy efficiency measures but also by turning to partial use of alternative fuels and adding fly ash, blast furnace slag, iron slag etc. to raw materials. It is known, that European cement industry recovers a substantial amount of waste-derived fuels, which replace fossil fuels up to a level of more than 80% in some plants. This enables the cement industry to contribute to the reduction of GHG emissions and to the use of fewer natural resources. In Russia, biomass could be a good start for using waste as a source of energy, since burning used tyres or unpretreated waste leads not only to the substantial negative environmental impact but also to conflicts with local stakeholders. For 2030, the dry process rotary kilns, objectives of consuming less than 3GJ per ton of clinker may well be set along with less than 700 kg of CO_2 emitted per ton of clinker. This would mean somewhat 25 % EE improvement and GHG emissions reduction.

For ammonia production, energy efficiency enhancement and partial CO_2 capture seem to be quite realistic solutions, while hydrogen production by electrolysis is discussed rarely. Specific energy consumption wise, Russian industries could well target at 28-32 GJ per ton of product (somewhat 15-20%, relative to 2015 level). During the revision of national BREF (in progress in 2019), such a target could be included in the list of recommended environmental performance parameters. Depending on the market demand, it could be suggested that more CO_2 is absorbed to produce urea. Thus, CO_2 emissions could be reduced to 1.5 tons per ton of product reaching the level of advanced European installations.

In ceramic manufacturing industry, EE enhancement measures including those based on modern Energy Management Systems and Lean Production approaches, can help achieving 15-20 % reduction of energy consumption levels. The more energy intensive the ceramic sub-sector is, the more dramatic results can be obtained. In 2011-2012, national standards on EE enhancement in the production of brick and ceramic tiles were developed to form a basis for working-out respective chapters of the national BREF (Rosstandart, 2015c). Technical ceramics manufacturing is a sub-sector for which similar standards could be developed to motivate responsible companies to further improve their energy efficiency and environmental performance. It is likely, that due to relatively low production rates, these companies will not fall under the Russian GHG regulation and remain monitoring and reporting energy consumption on the voluntary basis.

As it follows from the case studies, Russian ferrous metals industry has a significant potential to improve its resource and energy efficiency, even though operators of advanced metallurgical and metal processing installations reconstructed in 2015-2018 claim that they can’t imagine reducing energy consumption more than by 8-10 %. Still, there are many installations with much poorer energy performance (Rosstandart, 2017b).

As it can be seen, installations of each industrial sector can explore (1) general (managerial) approaches, (2) BAT-based technological and technical solutions for EE enhancement (Rosstandart, (2017a) and GHG emissions reduction, and finally (3) specific means, developed for the industrial decarbonization purposes and focused on greening fuel pattern and capturing CO_2.

4. Concluding remarks

The aim of this study has been to analyze EE enhancement potential of Russian energy intensive industries and approaches to setting energy efficiency and GHG emissions national objectives. Four sectors and sub-sectors have been selected, including production of cement, ammonia, technical ceramics and ferrous metals processing. It has been demonstrated that at all industries organizational approaches such as Energy and Environmental Management Systems need to be implemented to identify EE enhancement opportunities, set short- and long-term targets and monitor their achievement.

In each sector, there are specific technological approaches aimed at improving resource and energy efficiency of the production processes, most of them are described both in the European and Russian Reference Documents on Best Available Techniques. These approaches can well be used both to meet objectives of the national Integrated Pollution Prevention and Control legislation and to reduce emissions of greenhouse gases.

For energy intensive sectors characterized with large production volumes (such metallurgy, production of ammonia and cement), there are internationally recognized solutions (including those aimed at capturing CO_2). So far, Russian operators do not seem to be prepared to go beyond BAT and applying carbon capture techniques unless it is required by their international partners/investors. Considering Russian national CO_2 emission targets, one can assume that new GHG regulation will not be stringent, and for the coming 7-10 years, carbon capture measures will not become wider spread in the country.

The Integrated Pollution Prevention and Control regulation based on mandatory implementation of Best Available Techniques, and greenhouse gases regulation applying market instruments should act as independent regulatory constructions.

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