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Green Technology and Renewable Energy in the System of the Steel Industry in Europe

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ABSTRACT

The purpose of this article is to review the potential applicability of the environmentally friendly metallurgical production technologies and potential replacement of traditional energy sources with renewable energy sources in this sector. The materials presented in this article lead to the following conclusions: (i) The metallurgical production in Europe can be considered as one of the most important sectors forming a high added value. Simultaneously, the metallurgical production is characterized by relatively high energy consumption and generates a significant contribution to carbon dioxide emissions, (ii) the metallurgical enterprises have to compete not only among themselves but also with other companies engaged in production of the substitute products (e.g. plastic pipes); therefore, the production and technological modernization and environmental optimization of the activity of the metallurgical enterprises in Europe is one of the ways to increase the competitiveness and to reduce the expense content, (iii) the use of technologies that virtually eliminate the generation of carbon dioxide in the processing of iron ore allows to reduce the average level of greenhouse gas emissions by an average of 20-25%, (iv) the integration of production technology characterized by very low CO_2 emissions with the use of solar thermal energy technologies to provide the energy needs of the metallurgical production can significantly reduce the level of energy consumption of the metallurgical plants by an average of 18-31%.

Keywords: Metallurgy, Renewable Energy, Green Technology, The Greening of Production, Europe
JEL Classifications: O10, Q40, Q42, Q43

1. INTRODUCTION

The ongoing political transformations in the European Union, as well as, probably, the imminent UK's departure from the European Union, will have an impact not only on the geopolitical, but also on the economic processes (Protopopov and Feyler, 2015; Popescu and Mursa, 2016; Central Intelligence Agency, 2016). The changing of the boundaries of the united Europe will result in the emergence of new challenges for the enterprises of the industrial, service and commercial sectors. First of all, it is necessary to take into account the emergence of the risks in the sphere of European logistics, since the political transformation and the reforming of the borders of the European Union will change significantly both the institutional and the cooperative component of the logistic flows. Also, it should be kept in mind, that there were some disparities between the production and the marketing specialization of the world markets in the past few decades (Popescu and Mursa, 2016).

In the European Union, the metallurgical industry is one of the main trends ensuring the economic growth (Central Intelligence Agency, 2016). At the same time, many European countries were able (and currently are able) to accommodate partially the demand of the steel industry for the raw material with its own ore deposits. However, as recent events have shown, the European steel industry ceases to be economically and investment attractive business, despite the fact that the manufactured products are in demand in the economy and in the social and domestic segment.

The problem here is that the existing stocks of own raw materials required for steel production are not only insufficient, but unable to completely meet all the demands for raw materials. In particular, the high costs, associated with the import of lacking raw materials, became the key cause of financial instability of some European companies in the steel industry (World Steel Association, 2016).

The second important reason is the replacement of the European-American global vector of development of the global metallurgical industry with the Asian one, followed by the changes in the structure of the raw material and sales markets. This led to the manifold growth of the logistic and other costs, related to supply and sales (World Steel Association, 2016; Janovská et al., 2012).

The third reason is that the metallurgical industry is the sector characterized by potentially high levels of environmental damage (Janovská et al., 2012; Jacobson, 2009; Wang et al., 2016; Li et al., 2016) to the atmosphere, water, flora and ability to reduce the biodiversity. Moreover, the environmentally harmful byproducts of the metallurgical production can affect adversely the quality of life of the population and the morbidity rate, and thus can increase the national burden of disease.

Despite the fact that the European Union as a whole can be regarded as the ecologically stable world region, it is worth noting that the further development of the metallurgical industry requires transition to the "green" technology. The "green" technology should be implemented, first, in the metallurgical production and, secondly, in the energy supply of the metallurgical plants.

2. LITERATURE AND METHODOLOGY

In this article, the researches in the field of international economics, technological shifts and environmental security of the various industries in the globalizing world (The Centre for Energy Policy of the Institute of Europe, n.d.; Dudin et al., 2015; Dudin et al., 2017; World Energy Council, 2013; Deutsche Energie-Agentur GmbH, 2015; United States Department of Energy, 2016; Schwass, 2011; World Energy Council, 2016; International Energy Agency, 2015; Branker et al., 2011) are used as the methodological basis. Moreover, two key trends, defining the greening of the metallurgical production, which can be used by the business entities of other industries geographically localized not only in the European Union but also in other countries (Kalogirou, 2013; Scarlat et al., 2015; Gross et al., 2005; Mysachenko, 2008), are studied.

The first key trend is the "green" technology of metallurgical production. Here, the attention should be paid primarily to the technology of electrolysis (using lithium carbonate) of the iron ore in order to minimize carbon dioxide emissions. This technology was developed as the result of scientific exchange between the universities of Europe, China and the United States. The second key trend is the reduction of energy consumption and the increase in the energy efficiency of the metallurgical production in the European Union through the introduction of the renewable energy technology (Wang et al., 2016; Li et al., 2016).

However, it should be understood that the production technology for the processing of the iron ore, involving the reduction of carbon dioxide emissions (on average by 20-25%), generally, causes no additional scientific and practical problems, and the return on investment in the modification of conventional technology of metallurgical production is <7 years. But, on the other hand, the introduction of renewable energy technology in the metallurgical industry may be accompanied by a number of restrictions.

One of the major restrictions is that it is very difficult from a practical point of view to perform the integration of the "green" technology of metallurgical production and the renewable energy technology. The second important restriction is the cost of production (generation) of the energy from the renewable sources. The problem is that the production (generation) of the energy from the renewable sources is characterized by volatility and stochasticity. In particular, when using wind turbines, the wind force and direction are required to be constant (the climate in Denmark is characterized by such parameters; therefore, the wind power engineering is foremost developed there, but mainly in the social and domestic sectors).

Similar problems are relevant also for the use of the solar (radiant) energy; as a rule, the most significant amount of power is generated out of the solar flux at noon, while the parameters of cloudiness are fundamentally important. But the use of energy derived from the solar flux is carried out in the social and domestic sectors in the evening, the use of radiant energy is complicated in the economic sector (particularly, in the metallurgical industry), because the high cost of production and relatively low power allow the use of the solar panels mainly within service and sales areas where the demand for the energy is low (e.g., in the field of tourism services, trade in non-food items, etc.).

Thus, the scientists, until recently, were required to find the practically applicable renewable energy technology that could be used in energy-intensive sectors of the economy (particularly in the iron and steel industry).

The content analysis, carried out as part of this article, allowed to determine that the appearance of the technology of the use of the solar thermal power to reduce the energy consumption of the process of metallurgical product production, based on the environmentally optimal technology (the electrolysis of the iron ore with the use of lithium carbonate) is a reasonable alternative to the traditional energetics.

3. RESULTS

In the past two decades, the Asian region has been leading in the metallurgical production, manufacturing about 70% of the world's steel and iron. No more than 10% of the global steel and iron market is produced by the European Union. However, only in the second half of the 20th century, the volume of rolled metal production increased 4.5 times, and in the period from 2000 to 2015 inclusive it increased additionally almost 2 times. In addition, the entire European Union produces about 160 million tons of rolled metal and 93-95 million tons of cast iron, of which at least 30-40% of products are intended for domestic consumption (Central Intelligence Agency, 2016; World Steel Association, 2016). When considering the metallurgical products, forming the global export market, it may be noted that the structure of the exports of the iron and steel metallurgy products has undergone significant changes only during the last 5 years (Table 1).

In 2010, more than 60% of world exports were covered by the products of advantageously low processing (including the ingots and semi-finished products, galvanized sheets, hot-and cold-rolled sheets, steel pipes), and in 2015, about 42% of world exports were covered by the share of products of advantageously high processing (hot-rolled bars, rolled steel, drawn wire, coated sheets, other bars and hot-rolled sheets) (Figure 1).

It should be noted that the production of the metallurgical products of low processing is characterized by significant environmental emissions, while the production of steel products of high processing is characterized by high energy intensity. On the one hand, in Europe (including the countries that form the economic core of the European Union) in the period from 1990 to 2015 inclusive, the volume of carbon dioxide emissions due to the use of traditional sources of energy decreased on average by 20% (from 4.4 million tons to 3.7 million tons), but at the same time, according to the data on carbon dioxide emissions in the metallurgical industry, the growth of the emissions can be noted primarily in the segment of low processing products (Figure 2).

It is obvious that the specific contribution to the generation of carbon dioxide emissions in the European metallurgical production increased mainly due to the segment producing the products of low processing (the share growth of more than 1.3 times). At the same

Figure 1: The structure of the world exports of iron and steel products, in % of total volume (World Steel Association, 2016)

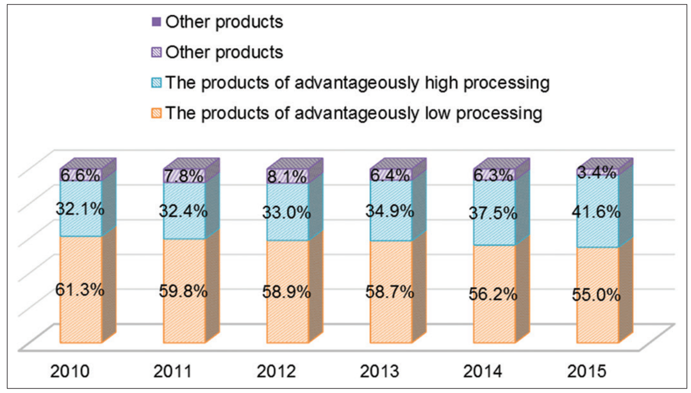
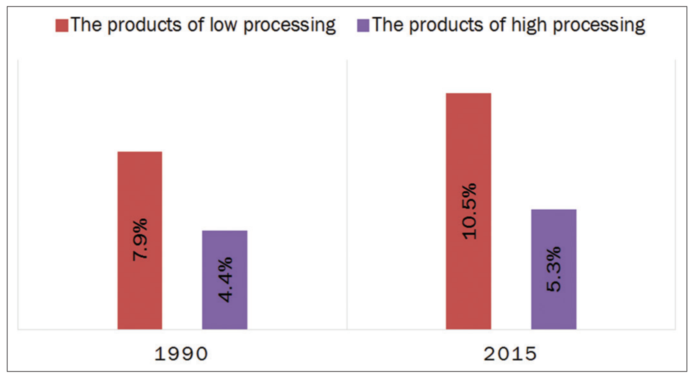


Figure 2: The specific contribution to the generation of carbon dioxide emissions by the metallurgical industry of Europe



Source: Central Intelligence Agency, 2016; Janovská, et al., 2012; The Centre for Energy Policy of the Institute of Europe, n.d.; United States Department of Energy, 2016; World Energy Council, 2016

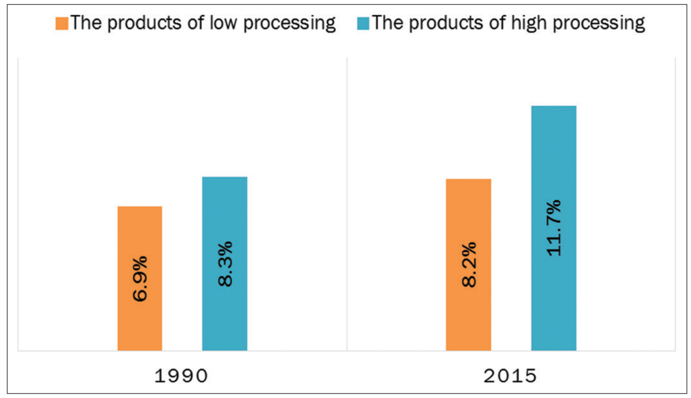
Table 1: Volumes and structure of the world exports of iron and steel industry products (World Steel Association, 2016)

Product type	2010		2011		2012		2013		2014		2015	
	Million tons	in %	Million tons	in %	Million tons	in %	Million tons	in %	Million tons	in %	Million tons	in %
Ingots and semi-finished material	58.7	15.7	57.7	14.8	58.5	14.8	54.1	13.7	54.3	12.1	51.5	12.1
Railway track material	3.1	0.8	2.9	0.7	2.6	0.7	3	0.8	2.2	0.5	2.1	0.5
Angles, shapes and sections	18.8	5.0	21	5.4	21.8	5.5	22.1	5.6	24.6	5.5	21.7	5.1
Concrete reinforcing bars	18.1	4.8	17.5	4.5	21.9	5.5	18.9	4.8	22.2	5.0	18.9	4.4
Bars and rods, hot-rolled	11.6	3.1	13.6	3.5	15.4	3.9	18.1	4.6	29.7	6.6	40.7	9.5
Wire rod	20	5.3	21.8	5.6	23.2	5.9	24.2	6.1	29.4	6.6	29	6.8
Drawn wire	6.9	1.8	7.5	1.9	7.6	1.9	7.7	2.0	8.9	2.0	8.4	2.0
Other bars and rods	4.4	1.2	5.4	1.4	4.9	1.2	4.9	1.2	6	1.3	5.3	1.2
Hot-rolled strip	4.3	1.1	3.2	0.8	3.1	0.8	3	0.8	3.3	0.7	2.9	0.7
Cold-rolled strip	3.7	1.0	3.7	0.9	3.6	0.9	3.5	0.9	4.1	0.9	3.8	0.9
Hot-rolled sheets and coils	65.3	17.5	63.4	16.3	64.4	16.2	67.3	17.1	75.8	16.9	77.8	18.2
Plates	29.1	7.8	32.9	8.4	31	7.8	29	7.4	34.5	7.7	30.1	7.1
Cold-rolled sheets and coils	33.9	9.1	34.4	8.8	32.7	8.2	33	8.4	37.2	8.3	32.8	7.7
Electrical sheet and strip	4.3	1.1	4.6	1.2	4.3	1.1	4	1.0	4.2	0.9	4.1	1.0
Tinmill products	6.6	1.8	6.4	1.6	6.2	1.6	6.4	1.6	6.7	1.5	6.3	1.5
Galvanised sheet	35.1	9.4	36.1	9.3	36.1	9.1	37.1	9.4	40.7	9.1	37.6	8.8
Other coated sheet	11.9	3.2	14.5	3.7	15.2	3.8	15.4	3.9	17.9	4.0	16.3	3.8
Steel tubes and fittings	36.1	9.7	41.4	10.6	41.6	10.5	39.7	10.1	43.6	9.7	35.3	8.3
Wheels (forged and rolled) and axles	0.8	0.2	0.7	0.2	0.8	0.2	0.9	0.2	0.8	0.2	0.8	0.2
Castings	0.5	0.1	0.7	0.2	0.7	0.2	0.7	0.2	0.9	0.2	0.8	0.2
Forgings	0.7	0.2	0.7	0.2	0.7	0.2	0.7	0.2	0.8	0.2	0.7	0.2
Total	374	100	389.9	100	396.4	100	393.8	100	447.7	100	426.9	100

time the degree of influence on the environment of the segment producing the products of high processing is substantially less (the share growth of no more than 1.1 times). But in the course of estimation of the power consumption of the European steel production it is worth noting that in the segment of low processing the consumption of the energy resources does not show such a significant rate of growth as compared to the high processing segment (Figure 3).

It is obvious that the current situation in the European metallurgical industry requires the integrated solutions aimed at both minimization of carbon dioxide emissions and the substitution of traditional energy sources with the renewable energy.

Figure 3: The specific contribution of the European metallurgical industry in the consumption of energy resources



Source: Central Intelligence Agency, 2016; Janovská, et al., 2012; The Centre for Energy Policy of the Institute of Europe, n.d.; United States Department of Energy, 2016; World Energy Council, 2016

4. DISCUSSION

The European countries, including the ones forming currently the economic core of the European Union, actively introduce the renewable energy technology (Protopopov and Feyler, 2015; Popescu and Mursa, 2016; Deutsche Energie-Agentur GmbH, 2015; Scarlat et al., 2015; Gross et al., 2005; Mysachenko, 2008; Reshetov, 2015):

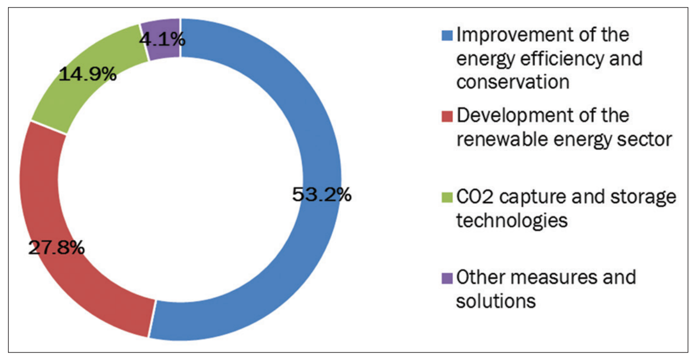
- The United Kingdom ranked third in the world in terms of the total volume of investments in the development of renewable energy and the production of biofuels;
- Germany is the fourth largest in the world in terms of total installed capacity in the wind power segment and the fifth in the geothermal power industry segment;
- France is in the top 10 countries for the production of biofuels.

But at the same time in some areas and economic sectors the level of the use of traditional energy sources (hydrocarbons) increases, and the environmental hazards caused by such activities grow steadily. As shown above, this problem is typical for the European metallurgical production and it is quite natural:

- First, the renewable energy cannot provide all the energy needs of the economic and socio-domestic sectors (Dudin et al., 2015; Dudin et al., 2017);
- Secondly, the reduction of energy consumption of the society in this period economically forms the reserves for its increase in future periods, as the energy reserve is being created for the expansion of business and public activity of the actors (Jacobson 2009);
- Thirdly, the generation and exploitation of renewable energy sources are not accompanied by the release of carbon dioxide, but at the same time the utilization of the equipment and renewable energy systems may potentiate the emission of greenhouse gases, as well as cause other environmental damage (International Electrotechnical Commission, 2015).

At the same time, it should not be forgotten that the decline in carbon dioxide emissions projected by 2050 (at least 45% compared to current levels in 2015 and 2016) is planned to be provided primarily due to both energy conservation and efficiency measures (Figure 4).

Figure 4: Contribution of the main measures and solutions to a reduction of carbon dioxide emissions



Source: The Centre for Energy Policy of the Institute of Europe, n.d; World Energy Council, 2016

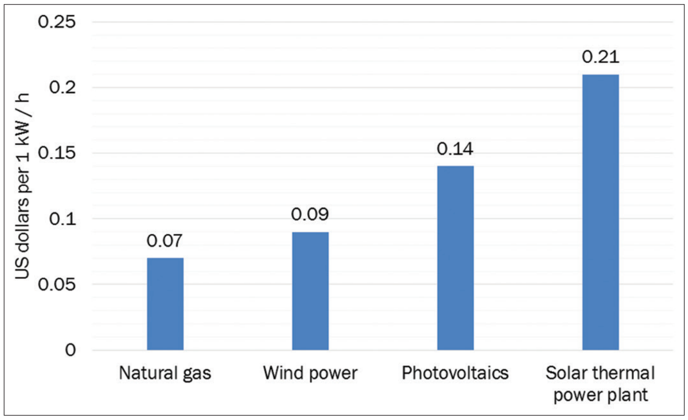
The renewable energy is a solution of the second choice, and the third is the technology of capture and (underground or underwater) storage of carbon dioxide. Thus, the ecological trend should be considered at the same time as the limiting condition for the development of the renewable energy sector. It follows here from that the equipment, tools and parts manufactured for the renewable energy sector should be characterized by a capacity for long-term operation in any geo-climatic conditions, or the recycling technology should be used in production of the equipment and components for the renewable energy sector.

The second major restriction is the cost of production (generation) of energy from renewable sources. According to the reports, the scientific and technical solutions proposed by the Chinese producers, allow to reduce 3-4 times the cost of solar panels and wind turbines (Wang et al., 2016; Li et al., 2016; World Energy Council, 2013).

But at the same time it should be noted that the average cost of generation of the electrical energy (per 1 kWh) combined with the use of the radiant energy converting technology (photovoltaic and solar thermal power plants) is higher as compared to other sources of energy (e.g., as compared with obtaining of the electric power based on conversion of natural gas or wind power) (Figure 5).

The reduction of the production cost of the solar power generation using the photovoltaic cells was achieved not through

Figure 5: The average cost of generation of one kilowatt/hour of electric power using the renewable and conventional



Source: United States Department of Energy, 2016; Schwass, 2011; World Energy Council, 2016

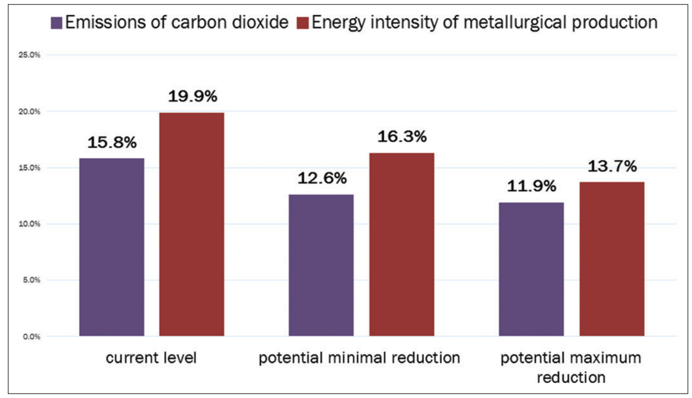
the improvement of the efficiency level (the efficiency of the photoelectric converters is about 16-25%, for comparison, in solar collectors of various modifications the efficiency may range from 10% to 75%), but due to the direct one-step transfer of the solar energy into the electrical energy, which reduces the loss and ensures the efficiency of the conversion (Branker et al., 2011).

In the course of aggregation of the trend of greening of the metallurgical production and the trend of replacement of traditional sources of renewable energy power, the proposal on the introduction of the iron ore electrolysis using lithium carbonate melt at a temperature of 800°C was formed, and it was also proposed to use solar energy to reduce the energy consumption (the STEP technology - solar thermal electrochemical photo) (Wang et al., 2016; Li et al., 2016).

The idea is that the electrolysis of iron ore using lithium carbonate eliminates the generation of carbon dioxide (the iron ore under electric current decomposes into basic components - iron and oxygen, which are collected on two respective electrodes) while the use of solar thermal energy in the process minimizes the energy costs and allows to reduce the consumption of traditional energy sources (hydrocarbons). In other words, the STEP technology uses the solar thermal energy to melt lithium carbonate and the light energy to perform the electrolysis.

In terms of the above-described idea, the preliminary calculations were carried on by a number of researchers, which showed that the electrolysis of iron ore using lithium carbonate melt can reduce carbon dioxide emissions by 20% (minimum) to 25% (maximum) in the metallurgical industry, and can reduce the energy intensity (in the context of traditional energy) by an average of 18% (minimum) to 31% (maximum). The data on potential reduction of carbon dioxide emissions in the European iron and steel production and the reduction of energy intensity of the production are shown in Figure 6.

Figure 6: The expected effects of the introduction of new technologies in the European metallurgical production



Source: Calculated on the basis of the sources (Wang et al., 2016; Li et al., 2016; World Energy Council, 2016)

5. CONCLUSIONS

The metallurgical segment in the industry in Europe is one of the leading segments creating high added value. In the future, the metallurgical industry products characterized by high restrictions will be in demand in the domestic and foreign markets. But to achieve the goal of the development of steel metallurgy it is required to improve the production technology, to modernize the production capacity and to optimize the logistics processes (supply, sales, internal distribution). It should be understood that the improvement of technology and production and the environmental components should imply the complementary solutions.

While solving the issues of improvement of production and processing efficiency and production and ecological optimization, the following should be kept in mind. The market of ferrous metallurgy will certainly grow in the medium term, in this aspect the expert and analytical opinions are not in contradiction. In particular, in the medium term the increase in consumption of the steel metallurgy products is expected in the construction, energy, mechanical engineering sectors.

On the other hand, in the long run, many enterprises of metallurgical industry, the functioning of which is characterized by high environmental risks, will be competing not only among themselves but also with the enterprises of the industries producing the substitute products (e.g. the metal-plastic products of industrial and household purpose) and causing less environmental damage. Of course, the metal-plastic products are unable to replace completely the steel products, for example, in the construction industry. But at the same time, even now the trend of increasing in the demand for metal-plastic products is apparent in the infrastructure of the municipal and social-domestic sector. In the medium term, the production and technological renovation as well as the environmental optimization of the European iron and steel industry will form the necessary reserves and strategic potential for the diversification of the activities of the metallurgical enterprises in the long term, taking into account the changes in the specifics of the demand for the metallurgical and similar products.

The general aspects of production and technological improvement as well as the greening of the European metallurgical production were studied in this article. The authors plan to reveal the problems of assessment of the risks related to the replacement of the traditional energy sources with the renewable energy sources, as well as the methods of analysis of the effectiveness of the transition to new production technologies in the metallurgical industry.

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