

# Formation and development of petrochemical production in kazakhstan according to the cluster principle

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**Abstract.** The issues of the petrochemical industry development of the Republic of Kazakhstan by creating a petrochemical cluster in the western oil and gas region of the country are studied. The issues of creating a petrochemical cluster in Kazakhstan and creating an integrated petrochemical complex in the Atyrau region are considered. The essence of the cluster approach as the main factor in increasing the regional competitiveness of the Atyrau region is revealed, and the expediency and efficiency of creating a petrochemical cluster and an integrated petrochemical complex are substantiated. The stages of construction of an integrated petrochemical complex are described depending on the sources of supply of raw materials used. A schematic diagram of the formation of a petrochemical cluster in Kazakhstan is created. The main groups of factors substantiating the possibilities and economic expediency of creating a petrochemical cluster, which ensures the high profitability of this industry, are determined. It is shown that the innovative petrochemical cluster makes it possible to accelerate the diversification of the economy and the activation of non-primary, high-tech industries.

## 1 Introduction

Currently, in a market economy, the development of the world economy is characterized by globalization, and the increasing importance of knowledge and innovation, which leads to increased competition between producers of goods and enterprises providing services. Under these conditions, if the products or services of some companies in the local market become highly competitive, then the rest of the companies will have to increase their competitiveness or leave the market [1]. Thus, competition requires the geographical concentration of interconnected companies, such as the creation of clusters. Over time, an enterprise group with high competitiveness is created. Entering other regions, these enterprises force out local competitors from the market that are not able to compete with them and have not passed the selection. As a result, the industry market is dominated by a group of enterprises united in a cluster and concentrated in one territory. In a theoretical aspect, the concept of a cluster is

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based on the integration of individual subsystems of production into a single whole to perform a specific function and achieve a given goal. In the economy, clustering allows you to increase the competitiveness of the region, united in a cluster of enterprises and companies [2, 3].

The main characteristics of the industry cluster include:

- since the cluster is a system consisting of its elements - enterprises, it has the property of emergence. That is, the competitiveness of the cluster is greater than the total competitiveness of enterprises united in the cluster [4].

- the network structure of the cluster provides it with a comparative advantage. Because the network structure of the cluster consists of enterprises that are suppliers and consumers, both from the root and from associated enterprises with service, training, research, analytical, information and other functions.

- relations in the network structure of the cluster are characterized by competition, cooperation and interdependence.

Due to its enormous reserves of hydrocarbon raw materials, Kazakhstan is becoming one of the largest oil and gas exporters in the 21st century. In the Republic of Kazakhstan, programs are being implemented to accelerate the development of all sectors and sectors of the economy, where the diversification of manufacturing industries is central, including the creation and development of a petrochemical cluster, an integrated petrochemical complex in the Atyrau region [5-7].

Due to the expected development in the supposed regularity of the formation of the petrochemical cluster, the development of resource- and energy-saving technologies, the development of products with high added value; due to and concomitant production in the oil and gas phenomenon, a decrease in the energy intensity of domestic derivatives [8-10]. The implementation of these directions can save the country's economy from dependence on raw materials and give a strong multiplier effect within the country.

To effectively solve these significant tasks, it is necessary to conduct an interdisciplinary study (economics, technology, ecology, etc.) and make a scientifically based decision on the development of the petrochemical sector of the economy by creating a petrochemical cluster in the Atyrau region, which is the center of the oil region of Kazakhstan. In this regard, this work, devoted to the study of the state and determination of the prospects for the development of petrochemical production in Kazakhstan according to the cluster principle, is very relevant because of the geopolitical challenges for the country, which require diversification of the economy of the country's oil and gas sector

## **2 Materials and methods of research**

The materials of this study are the development processes of modern petrochemical complexes for cluster use and data on the application of processes - petrochemical enterprises, the implementation of the function of the petrochemical cluster as an integral system. To form a petrochemical cluster and create an integrated petrochemical complex in the Atyrau region, the cluster theory of economic development is used [11, 12], economic analysis methods [13-15], statistical analysis [16], system analysis methods [17, 18] and other scientific methods.

Due to the oil and gas reserves concentrated on its territory, the Atyrau region is one of the attractive and promising regions of the Republic of Kazakhstan for a petrochemical cluster formation. The Atyrau region is characterized by the following major indicators of resources and expected results, which substantiate the feasibility of creating a petrochemical cluster in the Atyrau region of the Republic of Kazakhstan:

- sufficient opportunities and resources necessary for the creation of a petrochemical cluster and for its development;

- the possibility of developing the labor potential and labor resources of enterprises that are part of the petrochemical cluster;
- the presence in the region of a large volume of oil and gas reserves;
- the proximity of suppliers of hydrocarbon raw materials and other material resources;
- availability of opportunities in the region for the intensive formation and further development of the petrochemical cluster;

In the Atyrau region, it is possible to form a petrochemical cluster based on new petrochemical facilities of two enterprises for the production of plastics, 50% of the shares of which were bought by JSC "Exploration - Production "KazMunayGas," based on which a single petrochemical complex will be created. Processing enterprises can be introduced into the petrochemical cluster: JSC "Polypropylene," Aktau Plastics Plant, JSC "Atyrau Oil Refinery", LLP "Tengiz Gas Processing Plant" and a new oil and gas processing plant under construction in the Karabatan district of Atyrau region, etc. [5, 19]

The proposed version of the petrochemical cluster, provided with Kazakh raw materials, has not only the domestic market but also foreign markets (Iran, China, Russia). Therefore, this option of creating a petrochemical cluster in the Atyrau region has every reason to become a subject of the cluster development of the petrochemical complex of Kazakhstan in the future.

The petrochemical cluster creation in the Atyrau region of the Republic of Kazakhstan will increase the depth and pace of oil refining with the deepening of production. That, in turn, leads to an increase in the production of petrochemical and chemical products.

Over the past few years, petrochemical enterprises located in the cities of Atyrau Aktau in Western Kazakhstan have been completely dependent on raw materials suppliers. At the Aktau plastics plant, which belongs to a high-tech enterprise, due to disruptions in the supply of ethane products and benzene from Russia and Ukraine, the enterprise is currently almost not working. At present, the production of styrene and polystyrene stopped in this petrochemical enterprise. If we consider that these products on the world market are 700-710 US dollars per 1 ton, the capacity of the Aktau plastics plant is about 240 thousand tons of finished products, then it turns out that Kazakhstan is losing profit in the amount of 1 billion US dollars due to the lack of supply of this plant the necessary raw materials. Moreover, it should be noted that in Kazakhstan, there is a possibility and conditions for the supply of raw materials to this plant and other petrochemical enterprises. Atyrau chemical plant got into the same situation (JSC "Polypropylene"). Since the Atyrau oil refinery did not operate at full capacity, the specified chemical plant received an insufficient number of raw materials, namely propane-propylene and ethane-ethylene fractions. This eventually led to the shutdown of JSC "Polypropylene", respectively, to annual losses of several million dollars.

Atyrau region is one of the primary exporters of hydrocarbons to world markets. These product types are the major commodities with which Kazakhstan can compete in the world market. Income from the export of products, primarily hydrocarbons, is the main factor in the development of other sectors of the economy and the integration of the region with the world economic system. If the price of oil drops to a level at which its production becomes not inefficient or even unprofitable, then the export of hydrocarbons to world markets also becomes inefficient. Therefore, it is necessary to switch to the integrated use of hydrocarbon raw materials, deepen the depth of oil and gas processing, expand the range of hydrocarbon processing products, and develop oil refining and petrochemical production, which will allow achieving higher processing stages in the production of added value.

The development of the oil and gas industry should go through the totality of its constituent links, especially since it already included enterprises of the processing complex. Based on this, a real increase in the economic efficiency of oil and gas production is achievable only under the condition of deep processing of raw materials with the release of marketable products that have high competitiveness in the foreign market and a significant

need for domestic petrochemical enterprises. In this regard, the prospects of the Atyrau region of the Republic of Kazakhstan should be linked, first, with the development of deep processing of oil and gas, for which it is already necessary today to build a petrochemical complex, create a petrochemical cluster near hydrocarbon production sites. This is a priority and promising direction for the development of the industry, the region and the country as a whole.

The creation of clusters activates innovations and accelerates the development process of the industry and the region, increasing the competitiveness of products in the world market [18]. Merging into a cluster based on vertical integration will form not a spontaneous concentration of various technological inventions but innovations, a certain system for the dissemination of new knowledge and technologies. At the same time, the most substantial condition for the effective transformation of inventions into innovations, and innovations into competitive advantages, is the formation of a network of stable links between all cluster members.

### 3 Results

Based on the studies and analyses carried out, the stages of the implementation of the integrated petrochemical complex in the Karabatan region, the cities of Atyrau and Kulsary, depending on the sources of distribution of natural resources, have been systematized and made available:

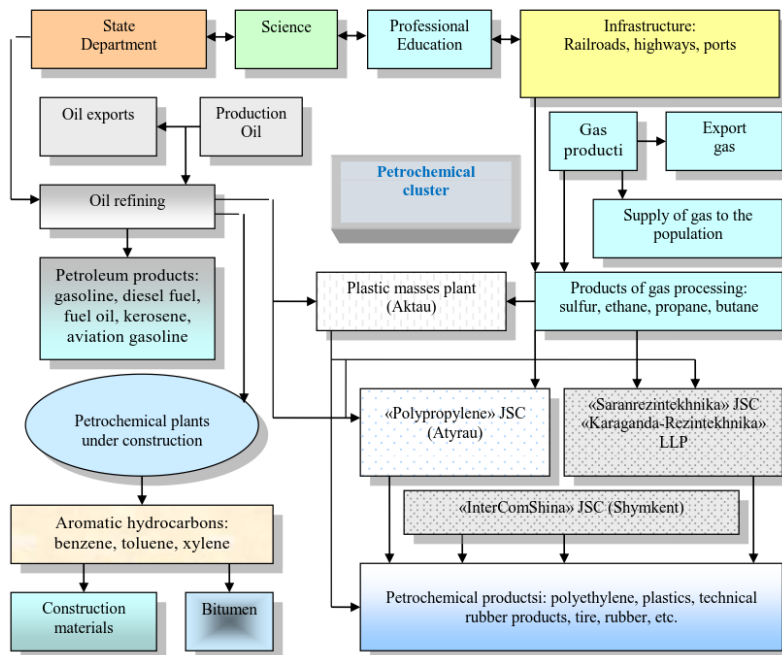
Stage 1: 2008–2015. The construction of a plant for ethane production from purified gas from the Tengiz field near Kulsary city has been completed. The capacity of this plant, thousand tons/year: for the production of ethylene - 800; for the production of high-density polyethylene - 380, low-density polyethylene - 380; for the production of styrene -120; propylene production - 380, and polypropylene - 400. In the city of Atyrau, an ethane steam cracker was built to produce ethylene, and plant construction for chemicals production for the oil industry is nearing completion.

Stage 2: 2015–2018. Construction of two plants for ethane production from purified gas from the Kashagan field near the Karabatan station. The design capacity of this plant is in thousand tons/year: ethylene - 650; low-pressure polyethylene - 350; methyl ethylene glycol - 400.

Stage 3: 2020–2025 Construction of the 3rd plant for ethane production from gas from the Karachaganak field. The ethylene production capacity of this plant will be 700,000 tons/year.

The development strategy of the national economy of the Republic of Kazakhstan is based on the creation of large petrochemical industries and a petrochemical cluster, using oil and gas from exploited and promising fields as raw materials. This paper proposes a schematic diagram of the formation of a petrochemical cluster in Kazakhstan (Figure 1).

The created special economic zone (SEZ) "National industrial petrochemical technopark" creates conditions for the formation and construction of an integrated petrochemical complex in the industrial zones of Karabatan, Kulsary and in the Tengiz region, which are the optimal points according to the umbrella principle for fractionation and deep processing of raw materials [22, 23]. Thus, the main goal of the FEZ is to create petrochemical production facilities in Kazakhstan for the deep processing of domestic hydrocarbon raw materials and the production of basic, high-value-added petrochemical products. Within the framework of the SEZ, a project was implemented to build and launch a technological complex to produce benzene at the Atyrau Oil Refinery, and other investment projects for the construction of petrochemical plants with high added value are being implemented.



**Fig. 1.** Schematic diagram of the formation of a petrochemical cluster in Kazakhstan

Source: built by the authors

It is necessary to ensure a low cost of production due to the complex processing of petroleum feedstock to be competitive in the oil products market. The Petrochemical enterprises of Kazakhstan currently cannot be competitive enough. That requires reforming the petrochemical industry of Kazakhstan based on the scientific concept of reforming and applying advanced technologies and modern management systems. [19, 20].

During the implementation of the stages of construction of an integrated petrochemical complex in the Atyrau region, the following were determined:

- the number and list of cost-effective petrochemical complexes that need to be built;
- specific indicators on the parameters of petrochemical complexes, sources, and volumes of hydrocarbon raw materials necessary to ensure their uninterrupted processing.

Natural and associated gases are recommended as raw materials, in which the ethane fraction is from 13 to 16% or more of the total gas volume. This gas composition provides economic and technological advantages in the basic petrochemical product production-ethylene. Further, a wide range of petrochemical products can be obtained from ethylene. For Kazakhstan, the most economically advantageous is the production of polyethylene, polypropylene of various grades, styrene and polystyrene, ethylene glycol and benzene, and methanol from ethylene.

## 4 Discussion

Kazakhstan has sufficient scientific potential in chemistry, which can find a systematic solution to any problem. To improve the development of petrochemical production, it is necessary to consider that:

- it is impossible to focus production on the production of a single product;
- petrochemistry and oil refining are non-waste productions because the waste of one

product is a raw material for another production;

- Orientation of oil refineries to produce only fuel to the fact that flare-forming reforming gases containing up to 30% of gaseous feedstock and 10% of C2-C4 light olefins are necessary for other processes of hydrocarbon feedstock processing.

Hydrogen, rarely produced in Kazakhstan, is required in large quantities for hydrotreatment processes that exist in refineries. Hydrogen is also needed for hydrocracking and alkylation processes, which are planned. Olefins can be used as monomer feedstock for petrochemicals. If any of the processes discussed above are missing, then high costs will be required to meet environmental requirements. And this, in turn, will lead to an increase in the production cost. In Kazakhstan, oil is processed according to the atmospheric distillation scheme, which means that from each ton of oil, products worth about \$ 880 are obtained. The implementation of all refining processes and existing petrochemical syntheses makes it possible to obtain products worth \$ 2,200 from one ton of oil, i.e., the amount received from the products is increased by 2.5 times.

From fuel oil, which is used mainly as fuel in thermal power plants, it is possible to extract such expensive oil products as lubricating oils, which are not produced in Kazakhstan. It is also possible to obtain tar from it, which is a raw material for petroleum coke and bitumen production. Coke is used in metallurgy, space technology and the electronics industry, and bitumen is especially necessary for road construction, which is one of the priorities for Kazakhstan.

In addition, when using fuel oil as a quality, expensive metals such as vanadium, nickel and cobalt, which are contained in heavy fractions of Kazakhstani oil, are lost. If we also consider sulphur, the content of which in fuel oil reaches up to 2% and which, when burned, is released into the atmosphere in the form of sulphur dioxide, turning into acid rain, it is clear that burning fuel oil is an inefficient way to use it. Associated, petroleum gases are not deeply processed in Kazakhstan. The gas part of oil and gas raw materials can be used as fuel but is mainly flared. At the same time, the combustion of associated gases without preliminary purification is unacceptable since they contain hydrogen sulphide in addition to hydrocarbons, which is especially harmful to the natural environment.

Thus, based on the above information, oil refining, according to a truncated scheme, without achieving the complex use of raw materials, leads not only to the loss of large cash receipts but also leads to insoluble environmental consequences. Therefore, it is necessary to deeply and comprehensively process hydrocarbon raw materials to obtain all the necessary products of oil refining and petrochemistry.

## 5 Conclusion

Based on the analysis of the prerequisites results, opportunities and conditions for the development of the economy of the western region of Kazakhstan, it can be concluded that the petrochemical industry of the republic is promising and competitive. Consequently, it is necessary to direct domestic and foreign scientific potential to the creation of a petrochemical cluster in the Atyrau region and its development. That will raise the petrochemical industry and innovation to a new qualitative level.

As a result of the analysis of the state of petrochemical production in Kazakhstan, for its development, it was proposed to create a petrochemical cluster in Kazakhstan. The main prerequisites for the accelerated creation and development of the petrochemical cluster in Kazakhstan are given. To justify the feasibility and effectiveness of creating a petrochemical cluster based on the Atyrau region, the following groups of factors have been identified:

1st group of factors - the presence of a relationship between potential resource and technological prerequisites: Kazakh heavy paraffinic and sour oil is the best feedstock for petrochemistry; technological interconnectedness of the petrochemical cluster; the possibility



of creating new industries, considering the existing infrastructure for the extraction and processing of hydrocarbon raw materials. These prerequisites make it possible to create conditions for the development of the petrochemical industry along the chain of subsequent complications of production to increase the added value of the final product.

2nd group of factors - due to the large global demand for petrochemical products, as well as the need to ensure an equivalent exchange in the international division of labor. The demand for petrochemical products on the international market shows that the most economically beneficial for Kazakhstan will be the creation of basic petrochemical plants to produce polyethylene, polypropylene, styrene and polystyrene, ethylene glycol and benzene.

3rd group of factors - the possibility of revitalizing the activities of existing petrochemical enterprises in Kazakhstan and new petrochemical enterprises creation.

4th group of factors - the presence of its own base of hydrocarbon raw materials, more suitable for deep processing of raw materials into final high-tech and science-intensive types of petrochemical products. That makes it possible to fully provide the domestic market with petrochemical products and expand the export potential of the final product.

5th group of factors - predetermined by the strategic platform for diversifying the country's economy in connection with entering the category of highly competitive countries. That dictates the expediency of forming a cycle to produce final products, which is the basis for creating a petrochemical cluster in the Republic of Kazakhstan.

To conclude, the development of the petrochemical industry in Kazakhstan, according to the scheme of industry, the cluster should be the highest priority, the most crucial and strategic direction of the republic's economy.

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