# Aspects of Modeling a Petrochemical and Petroleum Refinery Lifecycle

**Shamil Zufarovich Valiev, Olga Anatolevna Fedorova**

***Abstract***: ***The article considers the issues related to the method of modeling the lifecycle of petrochemical and oil refineries using a cognitive approach for making management decisions. The work gives the analysis of the current state of proven oil reserves in the Russian Federation and the Republic of Bashkortostan. It describes the assessment results of the technical and economic indicators of the PAO ANK Bashneft enterprises, made based on the schedule executed in the Sigma Plot program. For the purpose of sustainable future operation of petrochemical and oil refining enterprises in the Republic of Bashkortostan, several scenarios are proposed. The most optimal scenario is the production of an expanded range of commercial products based on biomass.***

***Index Terms: biomass, development scenario, lifecycle, petrochemical and oil refinery, management decision making, renewable energy sources.***

## I. INTRODUCTION

Efficient management decision made by public authorities is an important factor in the socio-economic development of the region, both in the long and medium term. Currently, the polarization of various sectors of the national economy on the territory of the Republic of Bashkortostan (RB) is taking the petrochemical and oil refining enterprises to a leading position. The proved reserves of oil in the global environment are decreasing, and the development of deposits goes to more and more distant areas from the previously established centers. Production of the traditional range of energy products in the future may face a shortage of raw materials – oil, and it might lead to adverse consequences for the region. To solve the above-mentioned problems, a method for modeling lifecycle scenarios has been proposed. The method makes it possible to analyze the basis of a graph performed in three-dimensional space using the Sigma Plot program; to assess the current technical and economic situation of the economic structure, based on a cognitive approach, consisting in evaluating the source of information objectivity, using the coefficient of knowledge indicators; to develop a bank of scenarios that will contribute to the development of a strategic plan for the development of a petrochemical and oil refining enterprise, allowing it to develop effectively in the future.

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## II. THEORY

The most common models of the economic structure lifecycle are the models of I. Adezis [1], L. Greiner [2], K. Pumpin and D. Prange [3], N. D. Kondratiev [4] and P. Draker [5]. Based on the analysis, it was found that the model by N.D. Kondratyev and P. Draker is the closest to the fact that the enterprises of the National Industrial and Scientific Committee on the territory of the RB need innovative changes to increase the lifecycle. G.V. Shirokova in her work [6]reflects the theory of stakeholders in terms of the lifecycle of the economic structure, which means that at all stages of the lifecycle there will be some interested parties more important than others, due to its ability to meet the basic needs of this structure, in turn, it should use different levers interaction with each interested party. Making management decisions using the methods of the cognitive approach is described in the works of the following authors: L.S. Vygotsky [6], O.A. Blinov [7], E.V. Petrunina [8]. The cognitive approach, based on cybernetics and human psychology is an information technology, specifically focused on the development of human intellectual abilities, it develops the imagination and associative thinking of a person. The coefficient of knowledge was considered by S.A. Kulagin in work [9], as an element of the state scientific and technical policy. His work proposed to codify the scientific and technical result. The result might be presented as products, works, services, scientific products, other intangible assets. Knowledge is characterized by three indicators: official statistical, regulatory and technical documentation, books, brochures, reviews, etc.; in-house documentation contained in reports, technology descriptions, in-house standards, etc.; the knowledge of specialists, including notes in a notebook or on a computer, etc. According to S.A. Kulagin, a specialist is different from a non-specialist, since in his/her head all information on a specific issue is ordered, processed, systematized, generalized and ranked. The study of innovation with the use of renewable energy sources (RES) are considered in the works of the following authors: R.G. Vasilov [10], G.B. Osadchy [11], Shibasaki-Kitakawa, N. [12], J. Baka, [13], M. Kodzima [14], O.Yu. Pogrebnyak [15].

## III. METHODS

Based on the existing methods of economic research, the study of scientific and statistical information, it is proposed to analyze the technical and economic indicators of economic structures, to construct a life cycle graph in three-dimensional space using the automated graphics software Sigma Plot.



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Making a strategic management decision requires for information. A clearly formulated problem reflects economic implications, such as financial indicators, as well as intangible ones. For example, in [16], multisectoral economic models were proposed that consider changes in profits, changes in the
value of fixed assets and inventories, the volume of output in physical units, and others. Cognitive technologies help to make a choice of both an indicator of the objectivity of information (as an information source about the problem), and the choice of specialists with professional competencies, which make it possible to accurately assess the current technical and economic situation, to develop scenarios for the economic structure lifecycle.

The variety of problems correspond to the variety of their solutions. The time for making a management decision is a period of time during which specialists [17] recognize the problem, evaluate and make a choice of the solution. This time is determined by the formula:

$$T=\left(t_1+t_2...t_{n-1}+t_n\right)+t_B, \qquad (1)$$

where T – is the actual decision time, the conventional unit of time;

$\left(t_1+t_2...t_{n-1}+t_n\right)$ – the sum of time to solve the problem of the n-scenario (option) and is determined for each scenario by the formulas (2), the conventional unit of time:

$$t_1=S_1\cdot V,\ t_2=S_2\cdot V,\ t_{n-1}=S_{n-1}\cdot V;\ t_n=S_n\cdot V, \qquad (2)$$

where $S_1...S_n$ – the set of integral indicators of the relative importance of *n*-scenarios (options), that is, the total set of performance indicators $\xi_i$ (determined according to the evaluation scale) with the dimension of the step directly proportional to their number;

$V$ – an indicator of awareness of the problem is determined by the formula (3), the conventional unit of information:

$$V=K_з\cdot I, \qquad (3)$$

where $K_з$ – the coefficient of knowledge indicators, characterizes the intellectual abilities of a person (leader, top manager and others) for each objective information in the form of a sum of dimensionless values equal to directly proportional to the number of abilities, according to the formula:

$$K_з=\sum_{i=1}^{m}\chi_i=\chi_1+\chi_2+...+\chi_{m-1}+\chi_m,\quad \chi_i=\frac{1}{m}, \qquad (4)$$

where $\chi_i$ – the weight of *i-th* human's abilities;

*m* –the total number of human's abilities;

*I* – the amount of incoming information with a certain indicator of objectivity, a conditional unit of information;

$t_B$ – time of the scenario selection is determined by the formula (5), the conventional unit of time:

$$t_B=S_B\cdot V',\ \max(V')=K_3\cdot I_n', \qquad (5)$$

where $S_B$ – the integral indicator of the relative importance of the scenario, determined based on the evaluation scale, the conventional monetary unit;

$V'$ – the maximum indicator of awareness of the optimal problem solution, the conventional unit of information;

$I_n'$ – the amount of incoming information (information) about the *n*-scenario of solving a problem with a certain sign of objectivity, a conventional unit of information.

The higher the knowledge indicator $0\le\max(K_3)\le1$, the higher the awareness of the existing problem, which is a prerequisite for reducing the time for decision making;

Efficiency evaluation of each scenario can be determined by the following features:

– ineffective (unprofitable) – high risks when making this decision $0\le S\le0{,}5$;

– effective (profitable), as a result of decision-making, the risks of effective actions are insignificant $0{,}5<S\le1$.

For example, according to [18], it is possible to suggest a combination of 5 indicators with a step of 0.2 and a positive answer gives an effective result. The evaluation scale is shown in Table 1.

**Table 1. Evaluation Scale**

| Result title | Indicator value |
|---|---|
| Yes | 0.2 |
| Possibly | 0.1 |
| No | 0 |

Awareness is equivalent to the concept of knowledge. Knowledge can be classified according to the indicators of objectivity of the information source and intellectual abilities of this source, given in Table 2.

**Table 2. The Coefficient of Knowledge Indicators**

| Objective information indicator | Intellectual abilities of a person | | | | | | | | | | Coefficients of knowledge indicators |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Clarity | Information accessibility | Position | Abstraction | Wisdom | Experience | Intuition | Imagination | Associative thinking | Logic | |
| 1 | + | - | - | - | - | - | - | - | - | - | 0.1 |
| 2 | + | + | - | - | - | - | - | - | - | - | 0.2 |
| 3 | + | + | + | - | - | - | - | - | - | - | 0.3 |
| 4 | + | + | + | + | - | - | - | - | - | - | 0.4 |
| 5 | + | + | + | + | + | - | - | - | - | - | 0.5 |
| 6 | + | + | + | + | + | + | - | - | - | - | 0.6 |
| 7 | + | + | + | + | + | + | + | - | - | - | 0.7 |
| 8 | + | + | + | + | + | + | + | + | - | - | 0.8 |
| 9 | + | + | + | + | + | + | + | + | + | - | 0.9 |
| 10 | + | + | + | + | + | + | + | + | + | + | 1.0 |

Thus, based on the coefficient of knowledge indicators, the leader of an economic unit is able to assess the objectivity of the information carrier, assess the specialists within their competencies, recognize the problem that is in line with the assessment of the current technical and economic condition of this structure, and select specialists to develop a strategic lifecycle development plan, contributing to effective future development.


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## IV. RESULTS

Consider the following sources of information:

1. According to [19], Russia as of 2017 is a leader in oil production (with condensate). 47% of the oil produced is exported. Proved, prospective reserves in the Russian Federation as of January 1, 2018, according to the order of the Ministry of Natural Resources and Environment of the Russian Federation dated November 1, 2013 # 477 "On approval of the classification of reserves and resources of oil and combustible gases", are of promising D0 – 12890.8 million tons (Mt), the forecast D1 + D2 44939.3 million tons. However, with oil production of 519, 3 Mt (an indicator of 2017) the perspective will be enough for 24 years. The main oil fields in the RB and adjacent territories are represented by the companies PAO ANK Bashneft, OOO Belkamneft in the Arlansky and Volga-Ural oil and gas basins. The reserves of these fields are estimated at 72.96 million tons, production in 2016 was 4.1 million tons. At this level of hydrocarbon production in the region, oil will be enough for 17.7 years;

2. In [20], oil reserves were calculated based on statistical data from British Petroleum and the OPEC Oil and Gas Bulletin, which corresponds to prospective oil reserves in the Russian Federation;

3. For 80 years, there has been intense oil production in the region. Based on the data of [21], Figure 1 shows a graph of the lifecycle of the oil, petrochemical, and petroleum refining industries of the RB and adjacent territories for the period from 1932 to 2017.

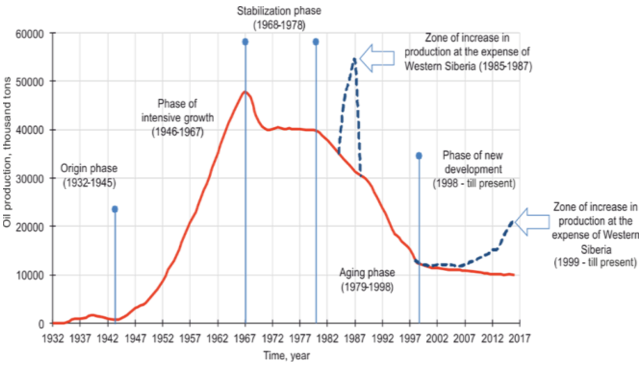


**Figure 1. The Lifecycle of The Oil, Oil Refining and Petrochemical Industries of The RB And Adjacent Territories for The Period From 1932 To 2017**

Figure 1 shows that oil production in the region is significantly reduced. As a comparison, a forecast of proved oil reserves in the region is presented in [22].

1. Based on the technical and economic indicators of the economic structure of PAO ANK Bashneft [23], the graph-mathematical model in three-dimensional space was built in the Sigma Plot program (Figure 2, 3). Since PAO ANK Bashneft owns three oil refineries and one petrochemical plant, the segment of petrochemical processing is one of the priority activities.

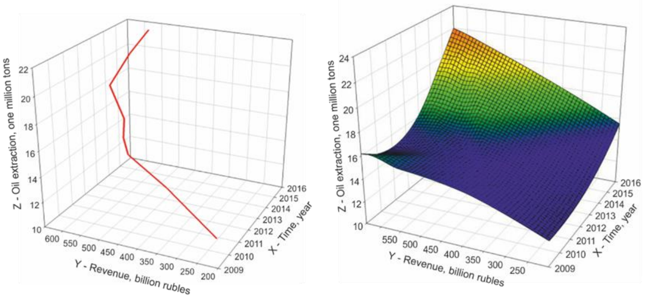


**Figure 2. Analysis of The Economic Indicators of PAO ANK Bashneft For the Period 2009-2016**

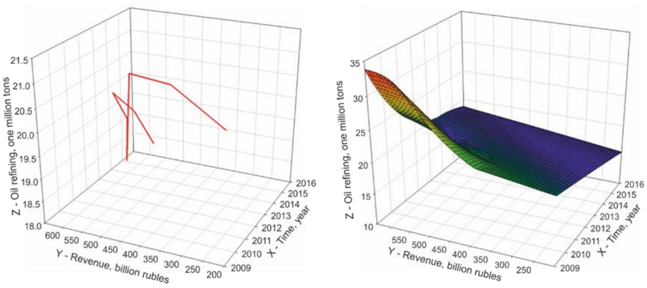


**Figure 3. Analysis of The Economic Indicators of PAO ANK Bashneft For the Period of 2009-2016**

The indicators presented in the figures, such as oil production, refining, revenue and time, allowed concluding that from 2009 to 2016 the volume of oil production increased, the volume of processed products decreased, the revenue fell.

Thus, we have assigned the coefficient of knowledge indicator for each objectivity attribute of the information source based on the intellectual abilities of these sources with a maximum rating, that is, an indicator of awareness of the problem V=1. Consider the options for problem-solving scenarios. According to the decree of the President of the Russian Federation of 07.05.2018 # 204 “On the national goals and strategic objectives of the development of the Russian Federation for the period up to 2024” one of the priorities is the development of RES. The development of renewable energy in the world is growing. The classification is represented by the following types of energy production in various sectors of the economy:

a) electric power industry: hydroelectric power; solar photovoltaic power; bioenergy power; geothermal power; wind power; a power of concentrated solar energy; a power of salt ponds;

b) heat supply: the power of solar water heaters;

c) transport: bioethanol production power; a power of biodiesel energy.

To make an effective management decision by the state authorities of the RB on the expansion of the share of the development of RES in the region, it is necessary to consider the information presented in Table 3.


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**Table 3. Development of Res in The Territory of the RB. Advantages and Disadvantages**

| Indicator name | Advantages | Disadvantages |
|---|---|---|
| ELECTRIC POWER INDUSTRY | | |
| Hydroelectric power | Environmental factor | There are no large flowing rivers, seas, oceans in the Republic |
| Solar photovoltaic power | Environmental factor | 7 months in the region have the average temperature below +8°C, lack of sunny days |
| Geothermal power | Environmental factor | Lack of geothermal sources |
| Wind power | Environmental factor | Forests impede wind flow |
| Power of concentrated solar energy | Environmental factor | 7 months in the region have the average temperature below +8°C, lack of sunny days |
| Bioenergy power | Development of rural agglomerations; development of new related innovative industries | Weather conditions |
| Power of salt ponds | Use in small localities; not affected by weather conditions | Environmental factor; water availability |
| HEAT SUPPLY | | |
| Power of solar water heaters | Environmental factor | 7 months in the region have the average temperature below +8°C, lack of sunny days |
| TRANSPORT | | |
| Power of biodiesel energy | Development of rural agglomerations; development of new related innovative industries, modernization of petrochemical and oil refining enterprises | Weather conditions |
| Bioethanol production power | Development of rural agglomerations; development of new related innovative industries, modernization of petrochemical and oil refining enterprises | Weather conditions |

Table 3 shows that, despite unstable weather conditions, the development of RES based on biomass is the most promising in the region. In the world, as of 2015, the share of energy production from biomass is increasing. There has been progress in the commercialization and development of biofuels of the new generation with an increase in power and production volumes by thermal and biological methods [24]. Based on statistical data [25], Figure 5 presents a graph of the distribution of energy production from biomass in some countries. The distribution of energy occurs between the industrial, transport, energy and other sectors.

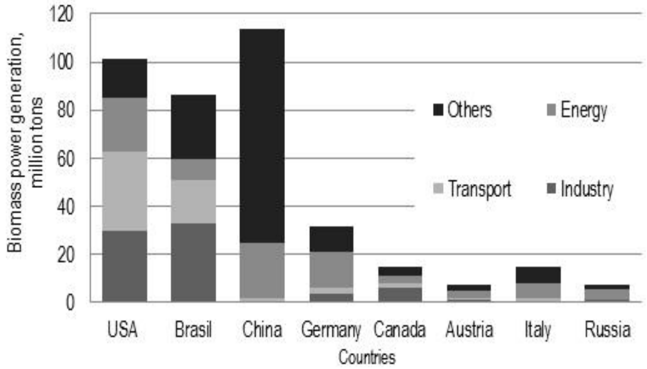


**Figure 4. Energy Production from Biomass for Some Countries In 2015**

Figure 4 shows that the Russian Federation is at a low level in the development of this area. As a comparison, consider the experience of countries in which the energy system is based on or is being introduced on biomass. For example, the energy system of Ethiopia [26] (the total area of the country is 1104.3 thousand km2, the population is over 90 million people [27]) is characterized by the predominance of traditional use of biomass fuels, which is 89% of the total energy consumption in the country. Traditional fuels, such as oil and electricity – 11%. The non-biomass-related contribution of the non-biomass sector of Ethiopia is less than 15%. A significant part of the energy consumption of oil is due to the increase in transport industrial and commercial services. Since 2008, a five per cent blending of ethanol produced from sugar cane in gasoline has been introduced. There is a plan to increase the percentage of ethanol in gasoline as the production capacity of sugar-containing plants increases. It should be noted that investors for the production of biodiesel in the country allocated about 300 thousand hectares of land. Brazil is another example of renewable energy. The total area of the country is 8515.7 thousand km2, the population is 206081.4 thousand people. A special place in the economic development of the country is taken by the period that began in 1964 – an economic miracle in which more than 560 state-owned companies operated, 50 of them provided 42.5% of all sales, then about 500 private – 28.9%. This period of a miracle ended in 1973 when energy prices rose drastically, inflation began to rise, and the state finances deteriorated. In 1975, the implementation of the program "Pro Alcohol" began, which set itself the task of reducing the consumption of gasoline as automobile fuel, replacing it with ethyl alcohol, developed based on sugar cane. Alcohol mixed with gasoline in the ratio of 24:76 as the best. Since the late 1970s, the production of vehicles adapted to the use of fuels with higher alcohol content began. Their release by 1986 amounted to over ¾ of the total automobile production in the country. However, a sharp drop in world oil prices in the second half of the 1980s led to the suspension of this program. The rise in the world oil prices has returned the country to the use of unconventional energy sources, such as bioethanol, based on sugar cane and biodiesel, by processing soybean oil, followed by cotton oils and animal fats as sources of raw materials.


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The experience of Brazil shows that the increased interest of some countries, such as the USA, China, Germany, Japan, and India to biofuels is determined by several factors [12-14]: the desire to diversify energy sources and reduce the impact of price fluctuations in the international oil market; rural development; reduction of environmental pollution by exhaust gases; net reduction in greenhouse gas emissions during the full operational cycle.

Another example of territory development and the creation of a support system for RES is Germany. The area of oilseed crops (including rapeseed) in the territory is about 9% of all arable land (approximately 1-1.5 million hectares.) For rapeseed oil, biofuel production is an important sales market, which contributes to an increase in profitability in the country for many years. Biodiesel, which is produced based on sustainable certified rapeseed oil, makes an important contribution to reducing greenhouse gases. It is available throughout the country and is indispensable in the medium and long-term. If we compare the power of biofuels with the power of wind turbines, then the biofuel produced in Germany today provides as much energy as 10,700 wind turbines, which corresponds to 38% of all installed systems. If this share of biofuels were completely replaced by an electric car, 38% of German wind energy would have to be spent on transportation [28].

According to the author of the work [15], biofuels have a number of advantages compared to traditional oil: the fuel is environmentally friendly, the exhaust gas toxicity decreases to 60-50%, and ethanol itself is decomposed into carbon dioxide and water that is not harmful to the health of human and animal world; fuel is biodegradable and does not pollute the soil, as well as water bodies; this type of fuel is a renewable resource; bio-ethanol production is waste-free, after-process related products are used for animal feed; vegetable fuels can replace environmentally harmful gasoline additives, while adding one part of ethanol saves three parts of oil.

Based on the estimated scale given in Table 1, we give an estimate for potential variants of scenarios for the development of the life cycle of petrochemical and oil refining enterprises presented in Table 4.

**Table 4. Analysis of The Effectiveness of Scenarios for The Continuation of The Lifecycle of Petrochemical and Oil Refineries in the RB**

| Scenario | Key efficiency indicators $\xi$ | | | | | An integral indicator of relative importance *S* |
|---|---|---|---|---|---|---|
| | Natural and climatic conditions | Development of innovative product mix nomenclature | Technological support | Resources (labor, financial, technical, etc.) | Regional development of territories and agglomerations | |
| Hydroelectric power | 0 | 0 | 0 | 0.1 | 0.1 | 0.2 |
| Solar photovoltaic power | 0 | 0 | 0 | 0.2 | 0.1 | 0.3 |
| Bioenergy power | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.7 |
| Geothermal power | 0 | 0 | 0 | 0.2 | 0 | 0.2 |
| Wind power | 0.1 | 0 | 0 | 0.2 | 0.1 | 0.4 |
| Concentrated solar power | 0 | 0 | 0 | 0.2 | 0.1 | 0.3 |
| Salt pond power | 0.2 | 0 | 0 | 0.2 | 0 | 0.4 |
| Power of solar water heaters | 0 | 0 | 0 | 0.2 | 0 | 0.2 |
| Power diesel power | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.9 |
| Bioethanol energy power | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.9 |

Table 4 shows that the integral indicator of relative importance for each scenario of the development of the life cycle of petrochemical and oil refining enterprises in the RB is different. However, the best option is the generation of electricity from biomass S=0.7, production of biodiesel S=0.9 and bioethanol S=0.9.

## V. DISCUSSION

Based on the analysis of the described graphics in Figures 2 and 3, we concluded that in PAO ANK Bashneft, in the segment of oil refining, inefficient management takes place, namely, revenue falls, refining volumes fall, and the volumes of oil produced are increasing.

For many years in a row, the enhanced spatial polarization of the territories of the RB, including various sectors of the national economy, has put petrochemical and oil refining enterprises in a dominant position in the gross regional product, which in turn affects the region's socio-economic, technological and scientific well-being. Based on this fact the reserves of D1 (prospective) and D2 (projected) are estimated.



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Hence, there is a risk to a decrease in the raw material base – oil, which is a prerequisite for the unsustainable development of petrochemical and oil refining enterprises, as well as support and service organizations, which in turn will lead to a decrease in the gross regional product and affect the socio-economic potential of the region and adjacent territories. And this is a serious argument for the future economic and energy security of the region, which in turn proves awareness of the problem.

The development of RES from biomass based on the experience of several countries and the integral indicator of relative importance for the territory of the RB is the best scenario for the future lifecycle of petrochemical and oil refining enterprises. However, it should be noted that oil-producing enterprises, as an interested party, will adhere to a different scenario, therefore, when making this management decision, their interest must be considered.

## VI. CONCLUSIONS

The methods of modeling the lifecycle of petrochemical and oil refining enterprises, proposed by us, allowed analyzing the technical and economic condition of these enterprises, assessing according to each indicator of the objectivity of the information source, understanding the problem and choosing the best scenario, based on the integral indicator of relative importance, allowing effective development of these enterprises in the future.

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