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TRANSFORMATION OF REFINERY LOADING AS A RESULT OF STRICTER ENVIRONMENTAL REGULATIONS AND DEVELOPMENT OF ALTERNATIVE FUELS

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ABSTRACT

The oil refining industry is currently challenged by the energy consumption transformation, which requires adaptation of the petroleum products output programs to the decreased demand for certain types of oil products and disbalancing of markets. The authors identify technological processes and world regions under the greatest risk of excess production capacity and analyze the efficiency of management decisions regarding the optimization of loading oil refining process units. The article presents recommendations for the long term optimization of existing capacities, which are based on the combined approach to the oil refining modeling in the context of the largest regions of oil products consumption. The article also shows that the main changes in the balance of supply and demand for petroleum products are local in nature, and the transformation of consumption will not lead to a decrease in oil refining, but also create incentives for additional investment in the industry.

Keywords: energy consumption transformation, energy transition, imbalances of oil products markets, configuration of model plants, optimization of capacity utilization, economic benefits.

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1. INTRODUCTION

The balance at the global oil market is achieved through meeting global demands by means of producing a wide range of oil products with the facilities of oil refineries. Oil refining is characterized by producing a number of oil products that have different properties and areas of application. Oil market has to be balanced to work effectively. The main regulation tool is to change capacities of oil refining units, their loading and mode of working. As a result, the prices that perform a signaling function and help prevent disbalancing of the system in the long term are formed in the oil products market.

Nowadays the demand for oil products is changing. In recent decades, there have been changes in the dependence of energy consumption on economic growth. As a result of energy efficiency growth, in the developed countries energy consumption does not increase together with the economic growth but in some cases it even decreases (Wang, R., Zhang, H., Shi, F., Zhang, Y., Zhang, L., 2018). In regards to oil products consumption, this trend is more pronounced because of the availability of alternative types of energy and inter-fuel competition. According to a number of studies by scientific and industry associations (ERIRAS, 2019, The Oxford Institute for Energy Studies, 2019), these changes are expected to accelerate in prospect. This tendency is a challenge for the sphere of oil refining. As it is mentioned above, in order to maintain the balance, the industry must make changes in the capacity, loading and operation of oil refining plants.

On the other hand, today the world witnesses events that reverse the competitiveness of alternative energy sources – further hydrocarbon fuel utilization is becoming more profitable because of the significant decline in oil prices related to the collapse of the OPEC+ agreement and possible global recession caused by the epidemiological situation. Nevertheless, the current situation is short-term and cannot have a significant impact on long-term development trends of the global energy. Therefore, this effect will not be considered in the further analysis.

The efficiency of oil production, just like production of other energy sources, determines the efficiency of the economy on the whole, as transportation and energy costs are parts of the prime cost of most goods and services. The operation of the industry, in which the minimum use of material, labour and financial resources is achieved, is possible only with a high degree of utilization of existing equipment and without excessive investments. Oil refining industry is characterized by high capital requirements of production and a long payback period. EIA estimates that the average amount of investment in oil refining necessary to increase the volume of oil refining by 5 million tons (it includes construction of primary processing facilities and secondary processes for processing naphtha fractions into components of motor gasoline) is \$720 mln paid off in 25 years with an internal rate of return of 12%. Thus, the efficient use of existing refining facilities can help avoid unjustified investments and multi-billion dollar financial losses.

Therefore, it is advisable to consider options for optimizing the use of existing facilities to meet the potential demand for oil products.

To achieve the stated objective, it is necessary to achieve the following goals:

- to study the global balance of the forecast demand and supply taking into account trans-regional oil products trade flows;

- to form the algorithm to optimize the loading of existing oil refineries;
- to use the suggested algorithm on the basis of the IEA 2018 forecast and to give recommendations for optimizing the loading of oil refineries.

There exists a great number of practical tasks of optimizing the loading of oil refining plants. The most widespread tasks are tactical and short-term. In modeling oil refineries as an object of management, the objective is to reduce operating expenses, improve the quality of fraction extraction; there are other objectives aiming at the use of available production reserves and optimal loading of production facilities. At the same time, an important characteristic of such models is that they are presented in great detail.

A set of detailed information and a regular factual comparison base open wide possibilities for applying various methods of mathematical modeling. The most popular method is the linear programming and its variations (multi-period and continuous production models, sequential linear programming, nonlinear optimization planning models). At the same time, the scientific community pays much attention to improving the convergence of such models and minimization of estimation error. This gives an opportunity to model each aspect of the plant operation in detail, including in-depth production and economic performances. Such models are used for corporate purposes (Honeywell, 2018) and for academic research (Ghaithan et al., 2017; Zhao et al., 2017). However, being very complex, narrow-oriented and dependent on a large number of variables, this approach is not suitable for long-term forecasting and achieving the stated objective.

There exists a conceptually different approach to oil refining modeling. It is used in large-scale analytical models like world energy model (IEA, 2016) and the national energy modeling system oil market model (EIA, 2012). In such models, the oil refining modeling unit is regarded as a means of meeting demand. At the same time, it does not allow to carry out the analysis of management decisions at the oil refinery level. To sum up, to achieve the stated objective we will use the combined approach that takes into account long-term planning capabilities of the latest model type and gives the opportunity to analyze the effectiveness of plant load changes at the supply and demand balance level.

2. Information Base and Methods

In order to achieve the objectives, the following methodology is proposed, consisting of three successive stages:

1. Based on the demand change forecast value for macro-regions, potential trade flows of petroleum products are calculated using a transport task that minimizes logistics costs;
2. On the basis of actual data, a technological model of the oil refining industry of each macro-region is formed to identify a number of technologically achievable variants of oil products output.
3. Based on the results of the first stage, the expected imbalances in the oil products markets in each macro-region are analyzed. For each case, an algorithm is consistently implemented to optimize the loading of existing refineries in order to reduce potential imbalances. The algorithm will be described below.

As an example, the IEA forecast for 2018 is used to demonstrate the application of the methodology, as the data of this organization are presented in a high level of detail and enjoy authority in the industry and scientific community. At the same time, data of this organization reflect energy consumption transformation trends that it will be agreed with the concepts described above.

The whole approach is based on voluminous indicators, with the target situation being the achievement of a balance of supply and demand in each region of the world under consideration. At some stages, current price parameters are used to rank the economic efficiency of processes or to determine the direction of export-import deliveries. The analysis was based on the following data (Table 1) obtained by the authors on the basis of the comparison of IEA data on world consumption of petroleum products in terms of regions and petroleum products.

The regional aspect is taken into account by using estimated regional prices of petroleum products in modeling interregional trade flows. Prices of oil products are determined by the following algorithm:

1. The European region is defined as the baseline region, and it is assigned a price equal to the average actual oil value for 2018 in North-Western Europe (NWE quotation);
2. Pricing in the region is defined on the basis of evidence on regional demand and supply;
3. If the region is a net exporter of oil, the price was determined by the following formula:

$$Pr = \max\{Pr_i - Fr_i\} \quad [1]$$

Pr – region price;
Pr_i – i-import region price;
Fr_i – freight rate on transportation to i-import region;

4. If the region is a net importer of oil, the price was determined by the following formula:

$$Pr = \min\{Pr_i + Fr_i\} \quad [2]$$

5. Flow modeling is carried out according to the principle of ranking deliveries according to the margin level for the exporter, i.e., according to the level of export price difference and domestic prices (the premise about the priority of the domestic market is applied). It can be shown that this approach is equivalent to minimizing logistical costs.

In order to identify many technologically achievable options for output of products, taking into account the previous detail, seven model plants of different configuration were built, each of which conditionally corresponds to the set of refining plants of each macro-region: North America, Central and South America, Europe, Former countries of the USSR, Africa, Middle East, South-East Asia.

Table 1. Forecast of world petroleum products consumption, 2017-2040, mln t

Region of Consumption	Liquefied Petroleum Gases			Gasoline			Naphthta			Jet Fuel			Diesel			Fuel Oil			Other Oil Products		
	2017	2040	Growth rate	2017	2040	Growth rate	2017	2040	Growth rate	2017	2040	Growth rate	2017	2040	Growth rate	2017	2040	Growth rate	2017	2040	Growth rate
North America	161,7	175,5	***9%***	547,2	463,2	***-15%***	16,8	20,8	***24%***	97,6	117,3	***20%***	253,4	237,5	***-6%***	34,5	23,7	***-31%***	119,3	91,9	***-23%***
C. and S. America	34,3	41,6	***21%***	101,8	96,3	***-5%***	9,2	12,8	***38%***	16,4	22	***34%***	109,6	114,8	***5%***	31	23,8	***-23%***	36,2	31,2	***-14%***
Europe	59	52,6	***-11%***	99	68,9	***-30%***	59,5	60,6	***2%***	74,5	73,6	***-1%***	339,5	261,5	***-23%***	50	28,3	***-43%***	67,5	42,7	***-37%***
Africa	19,5	35,4	***81%***	59,5	84,2	***42%***	1	2,1	***107%***	13,5	27,1	***101%***	83,5	130,9	***57%***	20	23	***15%***	12,5	16,1	***29%***
Middle East	82,5	153,8	***86%***	78,5	114,1	***45%***	5,5	11,7	***113%***	25,5	52,6	***106%***	94,5	152,1	***61%***	75	88,6	***18%***	55,5	73,4	***32%***
Eurasia	34	39,8	***17%***	56	51,1	***-9%***	31	41,4	***34%***	12,5	16,2	***30%***	60	60,6	***1%***	10,5	7,8	***-26%***	44,5	37	***-17%***
Southeast Asia	185,5	272,7	***47%***	335,5	384,6	***15%***	219,5	368,2	***68%***	129,5	210,7	***63%***	456,5	579,5	***27%***	133	123,9	***-7%***	192,5	200,8	***4%***
Total	576,5	771,5	***34%***	1277,5	1262,5	***-1%***	342,5	517,5	***51%***	369,5	519,5	***41%***	1397	1537	***10%***	354	319	***-10%***	528	493	***-7%***

Source: Authors' calculations based on International Energy Agency data.

Table 2. Configuration of model plants, million ton per annum

Unit Capacity	Southeast Asia	North America	Europe	Middle East	Eurasia	C. and S. America	Africa
Atmospheric distillation	1747,0	1202,5	923,7	467,0	438,7	317,1	174,5
Vacuum distillation	610,0	587,2	411,2	146,0	175,3	140,4	32,7
Isomerization	20,5	35,2	31,2	10,7	11,6	3,3	1,9
Catalytic reforming	243,6	218,7	134,3	47,6	53,6	18,9	19,7
Hydrotreatment	547,2	305,0	345,2	104,6	98,8	62,6	24,5
Hydrocracking	273,7	133,2	156,6	58,4	31,3	20,1	5,5
Catalytic cracking	400,5	398,3	173,1	38,1	43,2	78,5	15,3
Delayed coking	192,2	172,6	31,3	12,1	16,2	31,1	4,5
Alkylation	15,4	59,6	13,2	3,3	2,9	5,4	1,2
Bitumen unit	43,7	64,1	36,2	14,0	14,1	10,5	4,3
Hydroconversion	109,4	19,2	7,0	12,4	-	-	0,8
Total	4203,2	3195,6	2263,0	914,3	885,8	688,0	285,0

Source: Authors' calculations based on Woodmac database.

Data about refineries and their capacity were collected to calibrate model plant material balances from the Woodmac database containing current data for 2014. The base was supplemented by the authors with a list of installations put into operation over the last five years. Data on new installations of Paradip and Mumbai plants in India, Star oil refinery in Turkey, modernized installations of Turkmenbashi plants, Chimkent and Atyrau refinery in Kazakhstan and Turkmenistan, and other installations were added to the database.

According to the collected refinery capacity database, the model plants have the configuration shown above (Table 2).

IEA information was used as a source of data on world demand for petroleum products. However, the organization does not provide open data on the production of petroleum products in the relevant nomenclature by region of the world. Therefore, the missing production data were filled with information from the UN databases.

Each of the model plants uses installations with universal material balances. In order to match the model result to the actual output of oil products, the material balance of each process is taken at the level corresponding to the generally accepted values, after which it is calibrated according to the production data of 2016, so that the sum of deviation of squares of oil products output is minimal (Table 3).

Many technologically achievable production options can be evaluated after refinery models that match the actual balance of demand and supply across regions of the world were build. In addition, with an understanding of material balances, it became possible to detail the supply side of petroleum products to the level of individual production processes.

In the third stage, the options for optimization of the load of existing oil refining plants are determined according to the following scheme:

- After taking into account the effects of international trade, the imbalances of a particular macro-region are analysed;
- On the basis of the model plant characterizing the oil refining industry of this region, details of products output to the level of individual technological processes are formed;

Table 3. Material balances of model plants technological installations

Unit	Feedstock	Product	Products Output, %
Atmospheric distillation	Crude oil	LPG	2.1%
		Naphtha	16.2%
		Jet fuel	8.1%
		Gas oil	26.9%
		Fuel oil	44.8%
		Losses	1.9%
Vacuum distillation	Fuel oil	Gas oil	3.8%
		Vacuum gas oil	47.2%
		Tar	47.1%
		Losses	1.9%
Isomerization	Naphtha	Gas	4.4%
	Naphtha of reforming		
	Naphtha of hydrotreating	Isomerizate	95.0%
	Naphtha of hydrocracking		
	Naphtha of delayed coking	Losses	0.6%
	Naphtha of hydroconversion		
Catalytic reforming	Naphtha	Gas	1.1%
		Naphtha	12.2%
		Aromatics	2.7%
		Reformat	83.4%
		Losses	0.6%
Hydrotreatment	Gas oil	Gas	1.3%
		Naphtha	1.1%
		Diesel	96.7%
		Losses	0.9%
Hydrocracking	Vacuum gas oil	Gas	2.8%
		Naphtha	21.8%
		Jet fuel	5.5%
	Vacuum gas oil of delayed coking	Diesel	45.8%
		Vacuum gas oil	22.1%
		Losses	2.0%
Catalytic cracking	Vacuum gas oil	Gas	3.1%
		Propane-propylene fraction	11.8%
	Vacuum gas oil of hydrocracking	Gasoline	53.1%
		Gas oil	18.6%
	Vacuum gas oil of hydroconversion	Vacuum gas oil	9.3%
		Losses	4.1%
Delayed coking	Tar	Gas	0.6%
		LPG	0.7%
		Naphtha	11.7%
		Gas oil	30.7%
		Vacuum gas oil	23.8%
		Petroleum coke	31.9%
		Losses	0.6%
Hydroconversion	Tar	Gas	5.8%
		Naphtha	12.2%
		Diesel	49.1%
		Vacuum gas oil	27.2%
		Losses	5.7%
Bitumen unit	Tar	Bitumen	99.1%
		Losses	0.9%

Source: Authors' calculations.

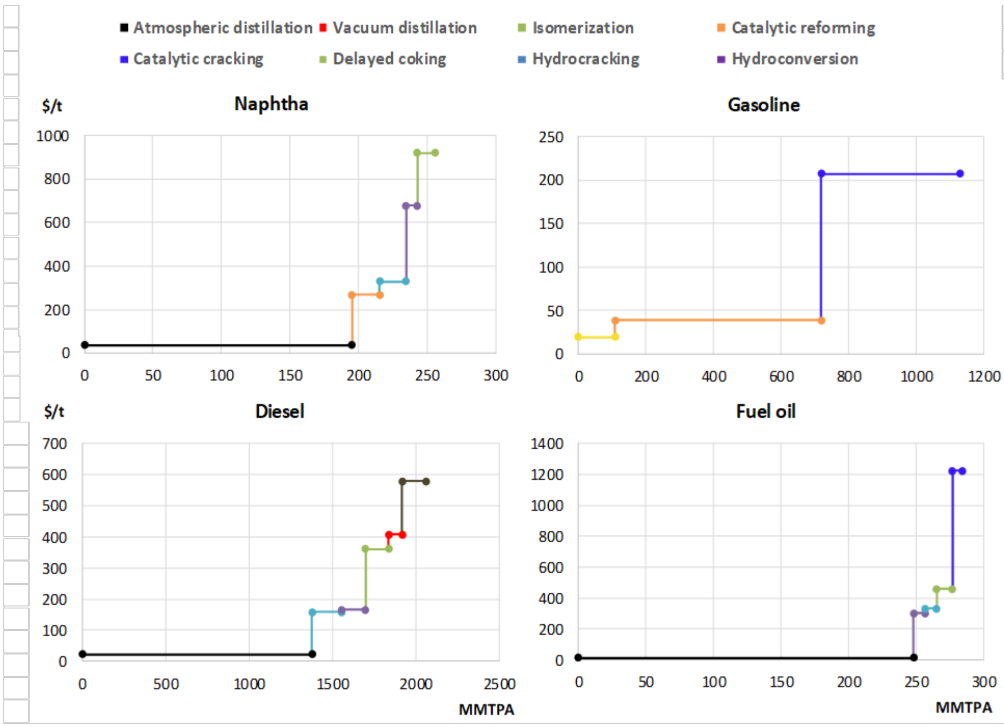
- In case of output surplus, the possibility of changing the operation of the processes is analyzed, replacing the output of surplus oil product with an alternative one, without reducing the load of processing plants;
- In case of impossibility of substitution or its insufficiency, for each of the key groups of oil products, supply curve is built based on economic benefit from production of additional ton of the target oil product (ΔEB_{top}).

The economic benefit from the production of an additional ton of target oil (ΔEB_{top}) is calculated as follows:

$$\Delta \text{EBtop} = \frac{\sum_n^i production\ of\ oil\ product_i * price\ of\ oil\ product_i - feedstock_i * price\ of\ feedstock_i}{output\ of\ target\ oil\ product, \%} \ [3].$$

Based on the price data of 2018, the supply curve of the main oil products is formed, showing the efficiency ratio of different processes in the production of the target oil product (Figure 1). Argus Media data is used as price parameters to construct indicative supply curves. Since the data set is not complete, the base was supplemented by estimates of oil products quotations, based on average annual spreads.

- Process load giving the least economic benefit is reduced;
- The effects of load reduction on the output of other petroleum products are analyzed.



Source: Authors' calculations

Figure 1. Supply curves of petroleum products by technological processes, US doll./t.

Optimization of the use of operating capacities to meet the prospective demand for petroleum products is achieved by carrying out the described sequence of actions.

The difference in the proposed approach to optimizing the loading of refining plants is as follows:

1. Long-term period (planning horizon more than 20 years) is considered;
2. Global scale - the global refining industry is modeled by macro-region rather than individual facilities;
3. Due to the long planning horizon, volume key figures are used in optimization (it is advisable to avoid price parameters due to their high volatility).

The most common application of optimization models in refining is optimization of individual refinery activities using techniques primarily based on variations in linear programming task. In this case, it is possible to take into account all the many nuances inherent in a particular refinery and to build a model that gives the result as close to reality as possible, but this approach has limitations that do not allow it to be applied to the task under study.

This approach in solving optimization problems has a fairly long history of application and has been detailed in the works of authors J. M. Pinto, M. Joly, L. F. L. Moro (Planning and scheduling models for refinery operations, 2000) and M. Göthe-Lundgren, J. Lundgren, J. Persson (An optimization model for refinery production scheduling, 2002). Subsequently, many authors continued to explore specific aspects of this approach, in particular Fragkogios, A., Saharidis, G. K. D. (Modeling and solution approaches for crude oil scheduling in a refinery, 2018) provide an overview of the approaches used in refining modelling, Silveira, E. A., Caldeira-Pires, A., Luz, S. M., Silveira, C. M. (Mass and energy allocation method analysis for an oil refinery characterization using multi-scale modeling, 2017) suggest a way to bridge the gap associated with the application of the life cycle method, and Oliveira, F., Nunes, P. M., Blajberg, R., Hamacher, S. (A framework for crude oil scheduling in an integrated terminal-refinery system under supply uncertainty, 2016) consider optimization features of integrated complex of refinery with an infrastructure in conditions of uncertainty.

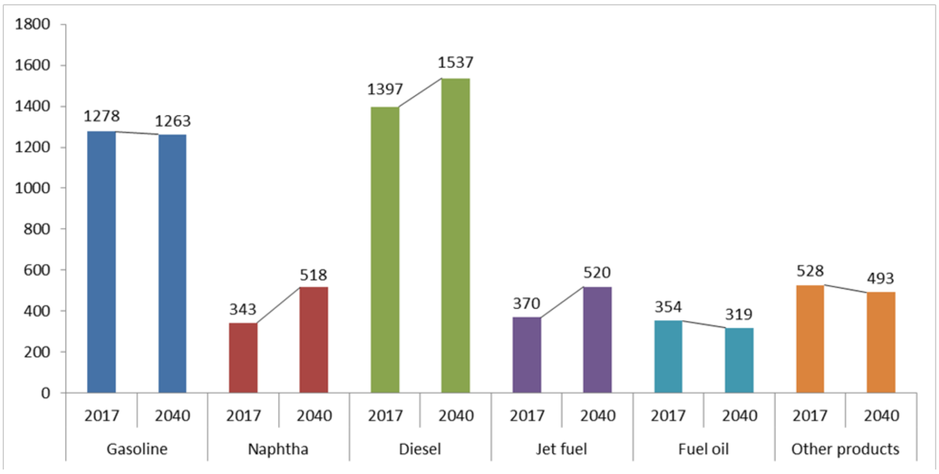
Far fewer works in which the task of optimizing refineries is applied to a set of plants at the national or regional level. An A. P. Caetani, L. Ferreira, D. Borenstein article (Development of an integrated decision-making method for an oil refinery designing in Brazil, 2015) examines the application of an optimization task to Brazil's refining industry. A combined approach to refining optimization is used in N. O. Kapustin, D. A. Grushevenko (Exploring the implementations of Russian Energy Strategy project for oil refining sector, 2018), an integral part of which is the modelling of refinery groups in bottom-up valuation.

Directly, the issue of the impact of energy transition on the economic efficiency of the oil industry was considered in the works of Goldthau, Westphal (Why the Global Energy Transition Does Not Mean the End of the Petrostate) and Bukar Zanna Waziri, Aminu Hassan, Reza Kouhy (The effect of transitioning to renewable energy consumption on the Nigerian oil and gas exports: An ARDL approach), however, the work focused in general on the oil industry as a combination of oil production, processing and distribution, and there was no separate detailed analysis of oil refining.

In contrast, the impact of energy transition or regulatory initiatives associated with it on individual refineries is considered in the articles Pagliaro, Meneguzzo (Oil refining in Sicily: A critical perspective looking to the future) and Haarstad, Rusten (The challenges of greening energy: policy/industry disillusioned). And while the examples and conclusions are very illustrative, this does not make it possible to draw conclusions on the global implications for the industry.

3. Calculations

According to IEA forecasts, total consumption of oil products will increase by 575 million toe by 2040 (by 380 million toe excluding liquefied petroleum gases - LPG, the vast majority of which are produced by gas processing plants), at the same time, demand growth is expected to be uneven both for consumption regions and for petroleum products (Figure 2).



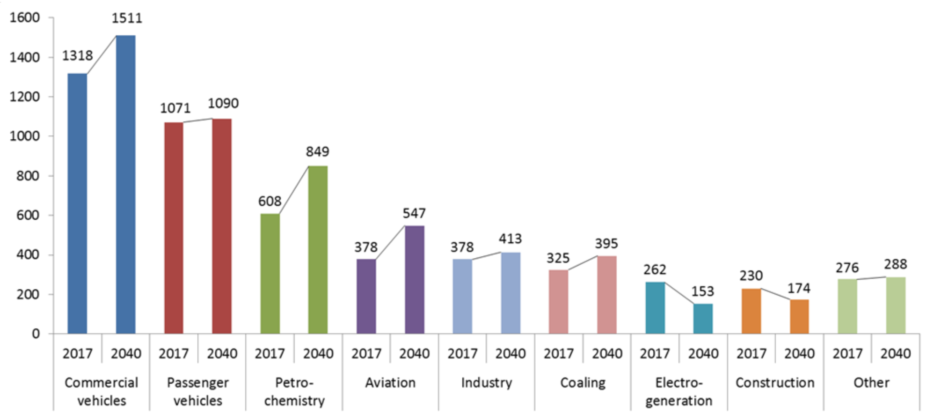
Source: Authors' calculations based on International Energy Agency data.

Figure 2. Forecast of world petroleum products consumption, 2017-2040, mln t.

The largest increase in consumption of oil products is expected in South-East Asia - 401.2 million tons, in the Middle East - 158.1 million tons and in Africa - 93.3 million tons. In the CIS and Central and South America, according to forecasts, stagnation of consumption of oil products is expected at the level of close values of 2017 - a decrease of 0.4 and 3.3 million tons, respectively. In North America and Europe, on the contrary, demand for petroleum products is expected to decline significantly - by 114.5 million tons and 154.5 million tons.

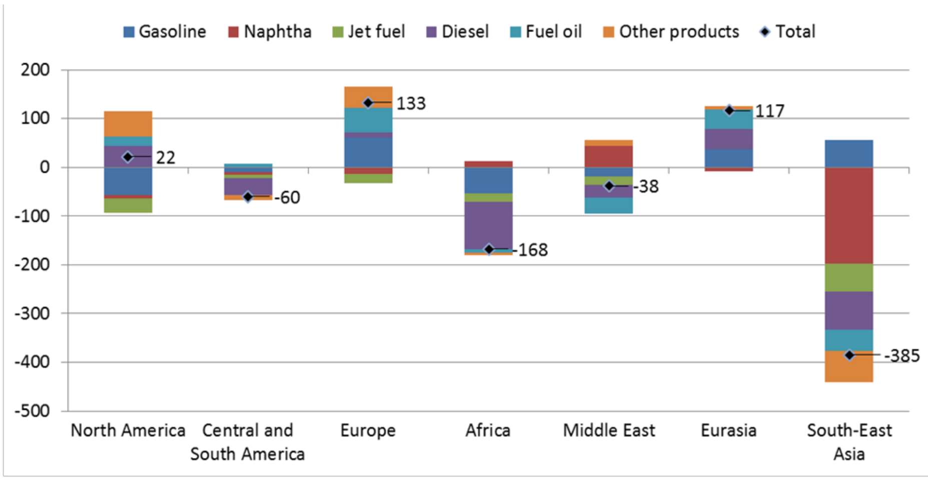
Naphtha has the greatest prospects, the growth of which, depending on the region, will be from 2 to 113% during the analyzed period. Of the petroleum products used as fuel, kerosene will maintain a steady demand for aviation transport, in the absence of an affordable alternative. The expected change in kerosene consumption would be between -1% and 106%. Other petroleum products used as fuel - gasoline, diesel and fuel oil will have different dynamics depending on the region of consumption (Table 1).

Significant growth is expected in other segments of petroleum products consumption by vehicles especially in the absence of an economically affordable alternative - by 193 million tons by trucks and by 170 million tons in aviation. The largest increase in consumption will be in the petrochemical sector - more than 240 million tons. The spread of the synthetic and composite materials usage, substitution of natural materials in various spheres of human life creates a significant non-fuel niche for petroleum products. Increasing the use of petroleum products as raw materials for processing is consistent with the global goal of reducing carbon emissions.



Source: Authors' calculations based on International Energy Agency data.

Figure 3. Structure of world petroleum products consumption, 2017-2040, mln t.



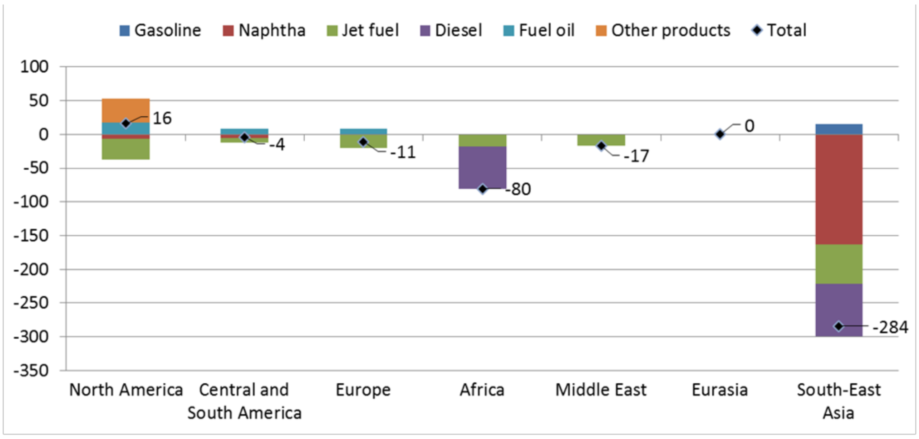
Source: Authors' calculations based on International Energy Agency data.

Figure 4. Projected imbalances of petroleum products markets by regions of the world, 2040, mln t.

The values of potential imbalances in the oil products markets were obtained without taking into account the factor of international trade, comparing the forecast changes in demand with the current demand to supply ratio (Figure 4). The modelling of export-import flows is carried out in accordance with the methodology described above. Product markets and sales volumes are determined by comparing sales prices with transportation costs and then ranking them in descending order, which ensures the highest level of revenue from the sale of a certain oil product. The calculations are also made taking into account the premise of equidistance of production of a ton of oil product as a result of a similar process in different regions of the world (in fact, there are differences in operating costs of similar processes in different regions of the world, primarily due to different costs of labor and energy, but the impact of this factor is not significant and it is not the subject of research).

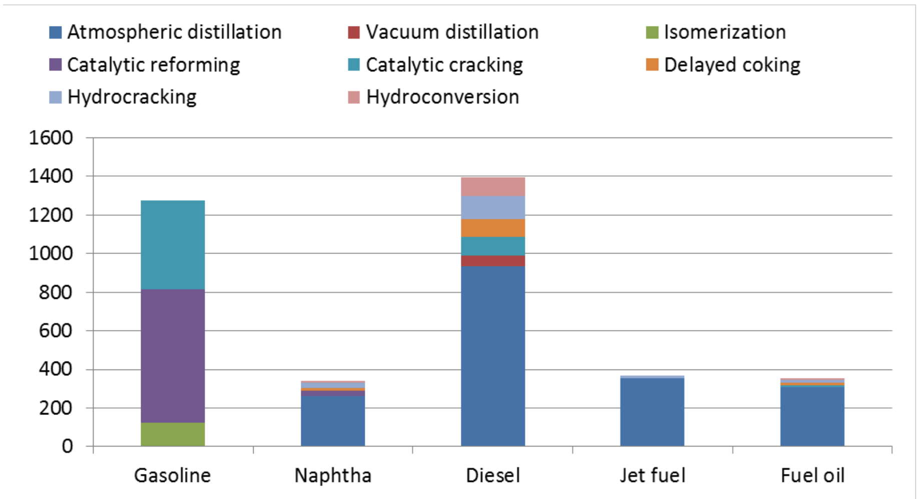
With the elimination of the international trade factor, the imbalances in the oil products markets have significantly decreased and their structure has changed considerably (Figure 5). It is important to note:

- At the global level, the market is not expected to overburden by motor fuels;
- Local surpluses related to demand reduction in the production region are absorbed by developing regions as a result of international trade;
- The main surplus oil products in the future will remain fuel oil and other heavy residues;
- South-East Asia and Africa are the most promising regions for refining because of their proximity to growing markets;
- Potentially at the lowest cost, the transformation of oil products markets will be carried over by the oil refining industry of CIS countries, the largest in terms of capacity of which are Russia, Belarus and Kazakhstan - with oil resources, substantial production capacity and a successful geographical location (proximity to Africa and South-East Asia), countries will only need to develop appropriate infrastructure and reorient export flows of petroleum products;;
- The most problematic is likely to be the surplus of heavy products, such as petroleum coke and the residue of catalytic cracking in North America, primarily the United States. Most of them are exported to developing countries in South-East Asia now, such as India, where they are used as fuels for industry and for electricity generation. But as environmental regulation is tightened and other cleaner energy sources become more accessible, the need for them will decrease significantly.



Source: Authors' calculations based on International Energy Agency data.

Figure 5. Projected imbalances of petroleum products markets by regions of the world after accounting for international trade, 2040, mln t.



Source: Authors' calculations.

Figure 6. Structure of world oil products supply by technological processes, 2017, mln t.

It is possible to evaluate the effectiveness of options to optimize the loading of processing plants in the context of future demand, using model plants corresponding to the actual supply by regions of the world. For this purpose, oil products are considered, global or regional demand for which may decrease in the future. After that, a set of management solutions is determined, the implementation of which reduces the production of a potentially redundant product in the market, and the optimal one in terms of achieving a balance of demand and supply is chosen.

Once the supply side has been detailed to the level of individual petroleum products, the region of production and the production process (Figure 6), the next step is to project a forecast change in demand for the current supply in order to identify imbalances, that potential management decisions will be aimed at preventing in the future.

4. Analysis Results

Global demand for petroleum products will not decrease in the future, but its structure will change significantly both in terms of petroleum products and in terms of consumption regions. South-East Asia, the Middle East and Africa, as a result of higher economic development, will be key drivers of increased consumption of petroleum products. However, in North America and Europe, demand for petroleum products is expected to decline significantly.

The role of traditional drivers of oil products consumption growth will change significantly - economic growth and growth of motorization will be compensated by influence of technological and environmental factors. Population consumption is no longer a source of growth, but industry and commercial transport will account for the bulk of the increase. Among petroleum products, naphtha has the greatest prospects, the growth of demand for which is due to the increase in consumption of petroleum products by the petrochemical sector. Gasoline is the only light oil product used as fuel, the demand for which will decrease in the future.

At the global level, the market is not expected to become overfilled by motor fuels, as local demand-side surpluses in the production region are absorbed by developing regions as a result of international trade. The main surplus products in the future will remain fuel oil and other heavy residues of oil refining. South-East Asia and Africa are the most promising regions for refining because of their proximity to growing markets.

Considering the arguments described above and the "supply curves" formed earlier, it is noted that at the global level there is a tendency to increase the demand for jet fuel. The current oil refining volume meets increasing needs by increasing the extraction of the kerosene fraction in atmospheric distillation and separating a kerosene fraction in vacuum gas oil hydrocracking units. At the same time, an excess of fuel oil supply is formed in almost all regions (except South-East Asia). According to the obtained "supply curves," the most painless method is to reduce processing, but in this case, it will be impossible to meet the demand for other petroleum products, especially diesel and naphtha. Thus, the investment attractiveness of capital investments in the construction of deep oil refining processes aimed at increasing the production of diesel fuel is confirmed.

Investments in vacuum gas oil hydrocracking and tar hydroconversion are most appropriate. Delayed coking is less suitable despite lower capital costs relative to hydroconversion (based on current project estimates, the capital cost of the tar hydroconversion construction is almost 2 times the cost of a delayed coking unit construction of similar capacity - 325 and \$633 million for 1 million tons per year, respectively), since processing produces a large number of other products (coke), global demand for which will decline. In the case of investments in a delayed coking unit, it is advisable to reduce the risks of product sales by integrating with electric generation, which involves additional costs for the conversion of power plant equipment to coke consumption as fuel and the installation of carbon air filters.

The decline in demand for gasoline creates a risk of excess capacity for the production of gasoline components. However, demand for naphtha is growing every region, at a faster pace. Thus, the total demand for the gasoline fraction is increasing, but its consumption pattern is changing significantly. According to the corresponding "supply curve" from the point of view of economic efficiency, it is optimal to reduce the load of isomerization units. However, reducing the isomerization and catalytic reforming load will not solve the problem. The most rational approach is to convert part of the catalytic reformers to the production of aromatic hydrocarbons and to change the operating conditions of the catalytic cracking plants in order to maximize the production of the propane-propylene and butane-butylene fractions. In this case, the utilization of the active capacities is optimized, and part of the demand for naphtha in petrochemicals is replaced by another feedstock used in the polymerization. The main petrochemical process is the polymerization, whereby long carbon chains are formed from monomers (chemical elements consisting of one molecule). The main products of this process are basic polymers - primarily polyethylene and polypropylene, the further processing of which allows to produce most of commercially used plastics. The pyrolysis feedstock is typically petroleum products such as liquefied petroleum gases and naphtha. Ethane is also used in the dehydration process. An alternative may be to use propane-propylene, butane-butylene fractions and aromatic hydrocarbons immediately in the polymerization process (skipping the pyrolysis process).

When considering oil refining problems at the regional level, according to the authors, the most relevant solutions are proposed for Europe, North America and South-East Asia. For the countries of CIS and the Middle East, a more important task will be to take advantage of its geographical location and resource potential to integrate into the new emerging configuration of international trade of petroleum products. For example, the main export market of Russian petroleum products is North-Western Europe and the main product stream is served by Baltic Sea ports. According to the analysis, it is advisable to develop infrastructure to reorient flows towards the Black Sea and the Pacific coast to meet the increasing demand of African and South-East Asian countries. For Africa, South and Central America, there are currently no preconditions for the formation of excess refining capacity.

The development of this study and the expansion of its results is promising. The logical continuation will be to consider not only volume indicators, but also price parameters, which, although derived from the ratio of volume indicators, are important for the economic assessment of the activities of refineries and the efficiency of investment projects.

On the basis of regression analysis, it is planned to identify the relationship between cross spreads (the difference in the cost of petroleum products and the raw materials from which they were produced), the capacity of various refining processes and the volume of demand for petroleum products, which were replaced by alternative fuels as a result of environmental and technological factors.

Based on the obtained results, it will be possible to switch from analysis of forecast volume indicators changes to economic analysis of oil products output efficiency by various technological processes and their investment attractiveness in the forecast period.

CONCLUSION

The research showed that “energy transition” is changing the structure of demand, but global demand for oil products will continue to grow. The main changes in the balance of demand and supply for oil products in the future will be local. The transformation of consumption will not reduce the volume of oil refining, it will create incentives for additional investments in the industry. Expected changes in demand can bring opportunities for oil refining development, increasing processing depth, expansion into foreign markets or integration with related business areas such as petrochemistry and electric power industry.

The combined approach to oil refining modeling and the proposed algorithm justified the management measures that could optimize the loading of oil refineries. The proposed method allowed to offset restrictions related to inability to review management decisions at the oil refinery plant level, which is specific to macro-level modeling, and to using a large number of variables that are not available in long-term forecasting used to optimize the load at the certain factory level. This approach can be used in the development of oil refinery development strategies.

In the long term, optimization of the loading of oil refining plants will be achieved by changing the level of fraction extraction and altering the operation mode of the refineries. Reduction of the primary crude load is not expected due to the increased demand for straight-run fractions such as kerosene and naphtha. In order to solve the problem of excess fuel oil, deepening processes will be loaded at the maximum level and in the future, it will be necessary to build additional deep oil refining processes. Conversion of a part of catalytic reformers and catalytic crackers to release of products used as a raw material for petrochemistry optimizes facility loading and will replace part of the prospective demand for naphtha used in the polymerization.

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