

GLOBAL OUTLOOK UNTIL 2040: POTENTIAL IMPACT OF SHALE OIL AND GAS TECHNOLOGICAL BREAKTHROUGH ON THE LIQUID FUEL AND GAS MARKETS

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Executive Summary

The world energy has undergone significant transformations. The global crisis has been followed by strong volatility in prices for hydrocarbons, there's been a noticeable slowdown in their demand and increased competition in the traditional energy markets, and, most importantly – the new technologies have been already started to redraw the fuels international trade. The main *aim* of the study is the evaluation of the actual trends in the global hydrocarbon markets, as well as their changes resulting from anticipated technological breakthroughs. In this regard, the following was worked out:

- 1) **The baseline scenario** of the development of the world fuel markets, made primarily on the basis of already developed energy technologies;
- 2) **Alternative** scenario depending on **the success** of required technological breakthroughs in the production of hydrocarbons.

For several important parameters the study gives new estimates, which are substantially different from the results obtained by a number of international organizations. The most important findings:

- The study of the dynamics of oil and gas prices in different scenarios **did not show fundamental reasons for alarmist forecasts predicting too high or extremely low prices within the period under review**. In all scenarios equilibrium¹ oil prices in 2040 will not come out of the range of 100 – 130 \$/bbl followed by a strong correlation of gas prices strongly differentiated by region (which does not exclude short-term large fluctuations in the prices influenced by political and speculative factors).
- Despite the integration of the oil and gas markets as the international trade in oil and liquefied natural gas (LNG) expands, **the trend towards the regionalization of prices**, followed by their noticeable difference, gains momentum.
- The most substantial increase in the absolute volumes of consumption and its share of the primary energy consumption will be provided by natural gas – **the next 30 years could be quite reasonably considered as “the era of gas”**.
- The results of the expected transformation of the world energy and, especially, hydrocarbon markets will not significantly change the fuel markets themselves, but **the positions of the leading market participants will be noticeably rebalanced**, while some of the global players will get additional influencing possibilities.

The baseline scenario for the development of fuel markets was prepared using world energy block incorporated in the SCANNER modelling and information complex [1], with substantially upgraded models of liquid fuels [2, 3] and gas [4] markets. Interfuel completion is described in 86 nodes of liquid fuel consumption (76 countries) and 192 nodes of gas consumption (147 countries). Production of conventional and unconventional hydrocarbon resources is modeled for 778 groups of oil fields and 504 groups of gas fields. The balance of production and consumption and the equilibrium fuel prices were calculated for all the regional fuel markets; the analysis of their sensitivity to the deviations in the most important resource and technological factors was made and the roles of the key market players were estimated.

For the *assessment of the potential technological breakthrough*, the models include the variants of changes in the volumes of production of unconventional oil and gas (with the estimates for the technical and economic characteristics required for the implementation of these new technologies).

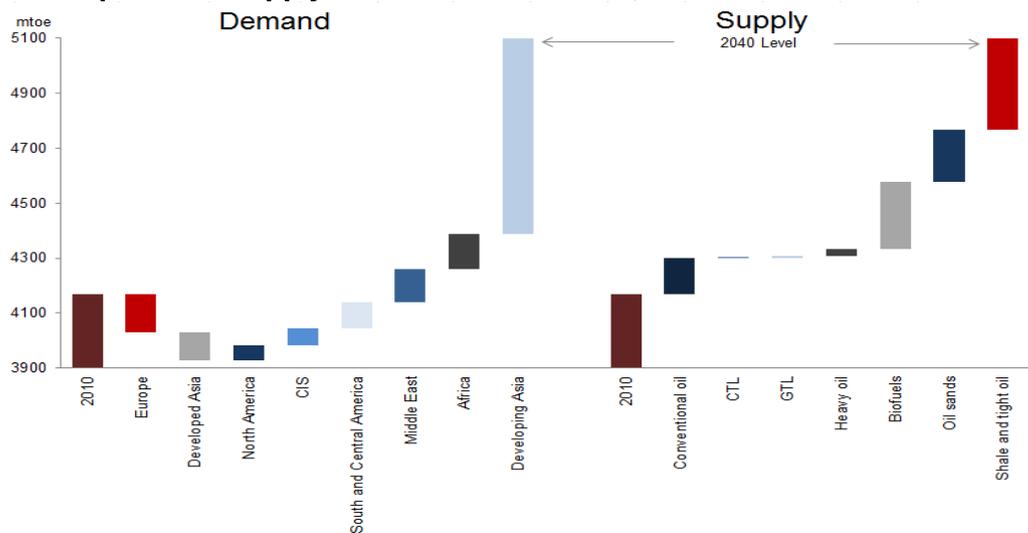
¹ equilibrium price of oil is a price at which the oil production in conventional and unconventional fields and the commercially viable options of oil substitution will satisfy the demand in the particular year of the forecast period (factually reflecting the supply and demand point of intersection).

1. Baseline Scenario – Liquid Fuel Market

Liquid Fuel Demand

Up to 2040, the global demand for liquid fuels will grow on average by 0.5% per year and reach 5.1 bln tons (26% increase) (Figure 1). The accelerated growth in their demand is expected in the developing countries. The OECD countries will demonstrate an opposite trend: the demand growth for liquid fuels will come to a halt in the US and Europe, while the OECD Asia (Japan, in particular) will be likely to significantly reduce their consumption. The main driver of liquid fuels demand for will be still the growing transportation sector. By 2040, the world, and, in particular the United States, the countries of the European Union and Japan, are expected to continue to reduce their specific fuel consumption in the transportation sector by 50% in the baseline scenario, as modern vehicles still have a significant potential for energy savings (up to 81% of tank-to-wheels efficiency potential) [5].

Figure 1 - Liquid Fuel Supply and Demand Balance, Baseline Scenario

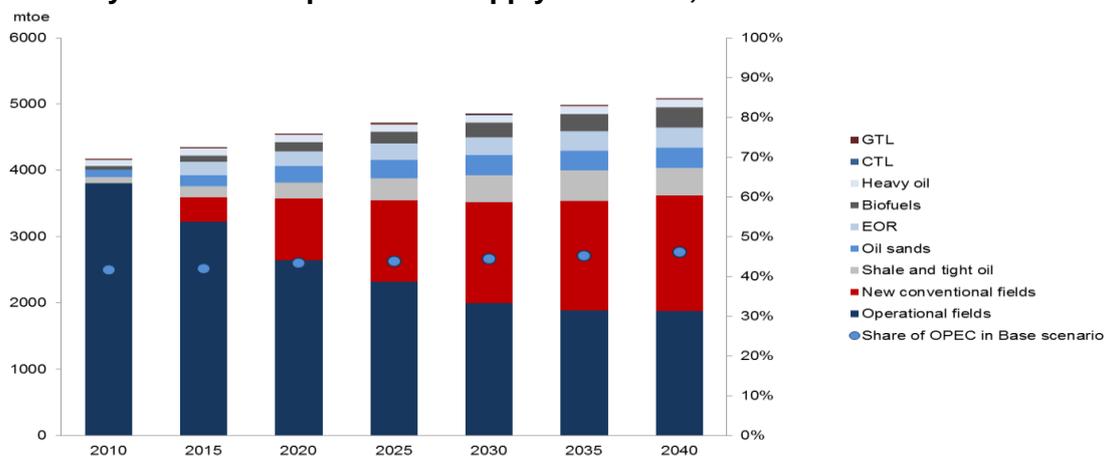


Source: ERI RAS

Liquid Fuels Supply

In the baseline scenario, the production of liquid fuels is assumed to reach 5.1 bln tons by 2040, while oil and gas condensate produced from traditional reserves will amount to 77%. A significant increase in the role of unconventional oil (shale oil, tar sands oil, etc.) will live up to the expectations [6] and reach 16.4% of the total production (837 mln tons by 2040). The remaining supply volumes in 2040 will be divided between biofuel (5.9%) and liquid fuels produced from natural gas and coal which will amount to just 23 mln tons (Figure 2).

Figure 2 - Dynamics of Liquid Fuels Supply Structure, Baseline Scenario



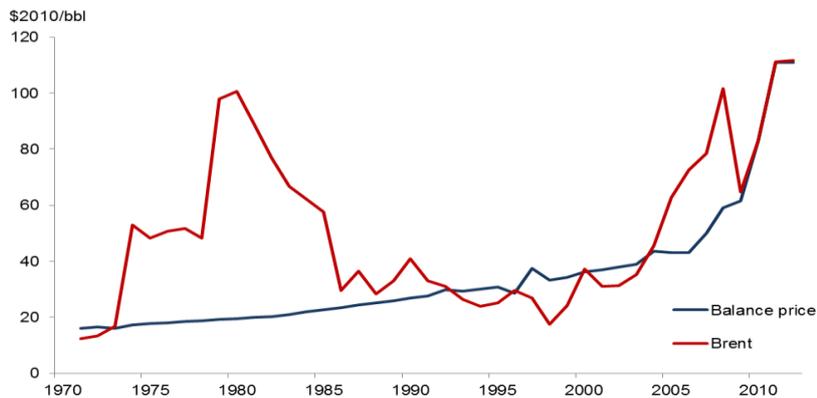
Source: ERI RAS

US tight oil development became already a game-changer: its potential has been evidently underestimated by the expert community. In 2012, the production of this oil, according to the US Department of Energy, was about 100 mln tons [7], and by 2030 the USA will come close to the Saudi Arabian volumes of oil production. Such a pace in the development of unconventional oil turns the yesterday's "shale" scenarios in the today's "baseline" ones. In our baseline scenario, the global oil production from the shale plays is estimated to reach 420 mln tons by the end of the forecast period and it will be mostly provided by the North American plays.

Oil Prices

Oil prices are formed by many countervailing factors, such as: the fundamental relationship between supply and demand, the positions of the oil market members and non-market factors mainly affecting the market in the short term. Since 1986, with the transition to pricing exercised in the highly liquid international oil exchanges, the oil prices came closer to the "ideal" equilibrium prices reflecting the balance of current supply and demand, despite the influence of speculative factors (Figure 3).

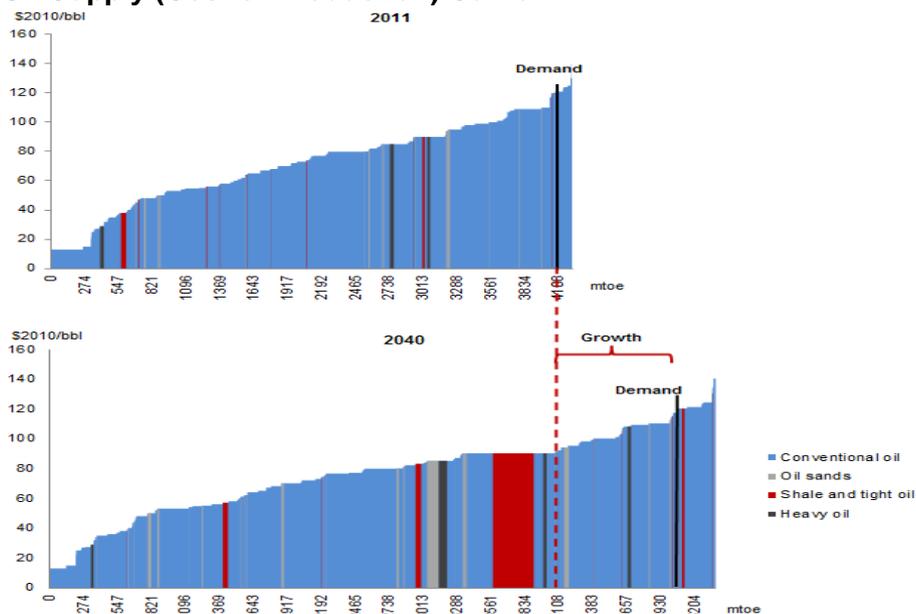
Figure 3 - Correlation of Equilibrium and Market Oil Prices



Source: ERI RAS

As shown in Figure 4, the baseline scenario assumes 1 bln ton increase in the oil supply by 2040, this will mainly occur due to unconventional supplies that would not lead to a significant increase in prices at the forecasted levels of demand.

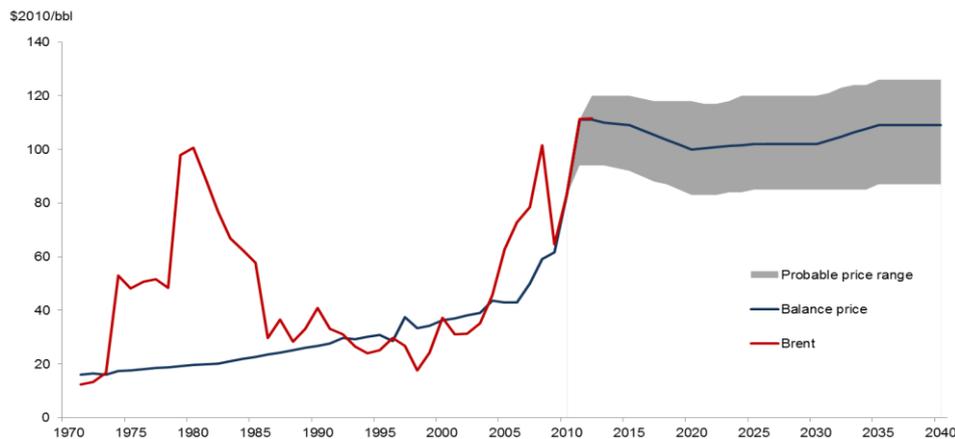
Figure 4 - Oil Supply (Cost of Production) Curve



Source: ERI RAS

Influenced by the growing production of shale oil in the US, there has been a new trend in the past three years - the regionalization of the world oil market. Under the influence of growing volumes of supply in the US, the trading floor prices in the North American market have started to fall, which, in fact, contradicts the dynamics of prices in the European market. The prices “segregate” on the two main global markers - WTI and Brent. In the forecast period, the change in the ratio of supply and demand in regional markets, as well as the redistribution of oil flows will create the preconditions for the formation of three oil markets: in the North America, with its main marker - WTI, in Europe, where the main marker will be Brent, and in Asia Pacific, where currently several oil markers compete [8]. In the baseline scenario, the equilibrium oil prices will remain within the price range corridor, defined as the possible deviation of the local oil markers of the European, North American and Asian markets from the estimated equilibrium prices (i.e. average global prices), giving account for the dynamics of prices of different markers in recent years (Figure 5).

Figure 5 - Projected Price Range of Equilibrium Oil Prices

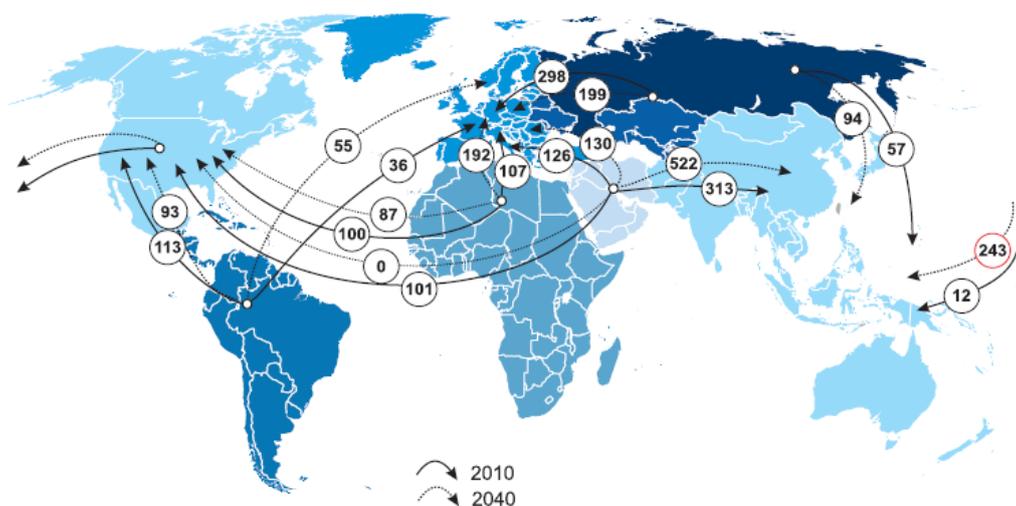


Source: ERI RAS

International Trade

The trade flows in the oil market in the baseline scenario will be essentially changed (Figure 6). By 2040, the export market niches will narrow for the key producers by 275 mln tons, compared to 2010.

Figure 6 - Main Directions of International Oil Flows, mln tons



Source: ERI RAS

First, the volumes of oil imports to Europe will reduce due to the decrease in the utilization level of European refineries and stagnant demand. Due to the growth in oil production from

the US shale formations and Canadian tar sands, the North America will become a net exporter after 2025 already. The most promising market for crude oil is the APR - the only region where imports increased compared to 2010.

Positions of the Key Market Players

Even today the change in the roles of the players in the global oil market is already becoming visible. During the forecast period, the decrease in the influence of international major companies is expected. In the regional markets of the developed countries, small independent companies with effective innovation components, which allow them to control costs throughout the whole supply chain and develop unconventional and scavenger oil fields, will gradually replace them. In the international markets, the majors will start to be replaced by growing national oil companies (NOCs), such as Saudi Aramco, Iranian NOC, Petrobras, and Rosneft. Moreover, national companies will not only take a large share in their own domestic markets, but also begin to compete for foreign markets. First, it is typical for Chinese CNPC and PetroChina, which assets already have a vast geography – ranging from the development projects in the Middle East to the participation in projects aimed at the development of Canadian oil sands.

It is also expected that the positions of major associations and largest countries playing in the oil market will be changed. Certainly, the major change in the balance of forces in the world oil market will be attributed to the global growth of the US influence. It is estimated that after 2030, owing to the development of oil shale, the USA will be able to cease the import of oil from all countries except Canada and the South America (from the fields in the portfolios of US companies). Moreover North America may become a net exporter of oil after 2030. Such an increase in the U.S. power on the world oil market, with the achievement of energy independence could lead to serious geopolitical shifts.

The leading position among oil exporters, in accordance with the baseline scenario, will retain the Middle East: the exports to Asia Pacific and Europe will grow. The rest of exporting regions will lose their positions by 2040, partly as a result of the compression of export markets due to the stagnation of demand (in Europe), in part because of North America coming to the markets as an exporter. High costs of oil production are the main problem for the exporting non-Middle East regions, which for the CIS is exacerbated by high tax burden. China, like the North-East Asia at large, will not be able to meet its own demand for oil on its own and will have to increase imports, primarily from the Middle East. In the forecast period, it is expected that oil imports from the most politically stable regions (the North America, the CIS) to China will increase and the North and Central Africa, as the most unstable suppliers from North and Central Africa will be gradually replaced. Securing of oil imports will be also achieved by the expansion of the Chinese NOCs in oil development and processing projects in the Middle East, the USA, Canada and the South America.

The positions of the OPEC oil cartel will undergo unorthodox changes. On the one hand, given the relatively low oil prices, some of the OPEC members will be likely to insist on reducing the production quotas so that to induce the shortage of supply, which would lift the level of the world oil prices that are relatively low for them (Ecuador, Venezuela, Algeria, Libya, Iran). On the other hand, the leading producers of the cartel (Saudi Arabia, Kuwait and Iraq) will continue to work in a price range suitable for them, while they would see the production growth and the build-up of their share in the export markets as appropriate steps to be undertaken. A significant difference in the prices, which are suitable for the members of OPEC might signal on the potential instability and incoordination of the activities of the organization members. Generally, over the forecast period, the potential impact of the OPEC on the average annual oil price is estimated at 2-9 \$2010/bbl with the provision for significant changes in volumes of spare capacities. In fact, such a small sensitivity of the forecast equilibrium prices to the OPEC potential activities objectively characterizes that the oil cartel will have little impact on the world prices.

Summing up, it can be stated that there will be a redistribution of the influence between the groups of countries and international organizations.

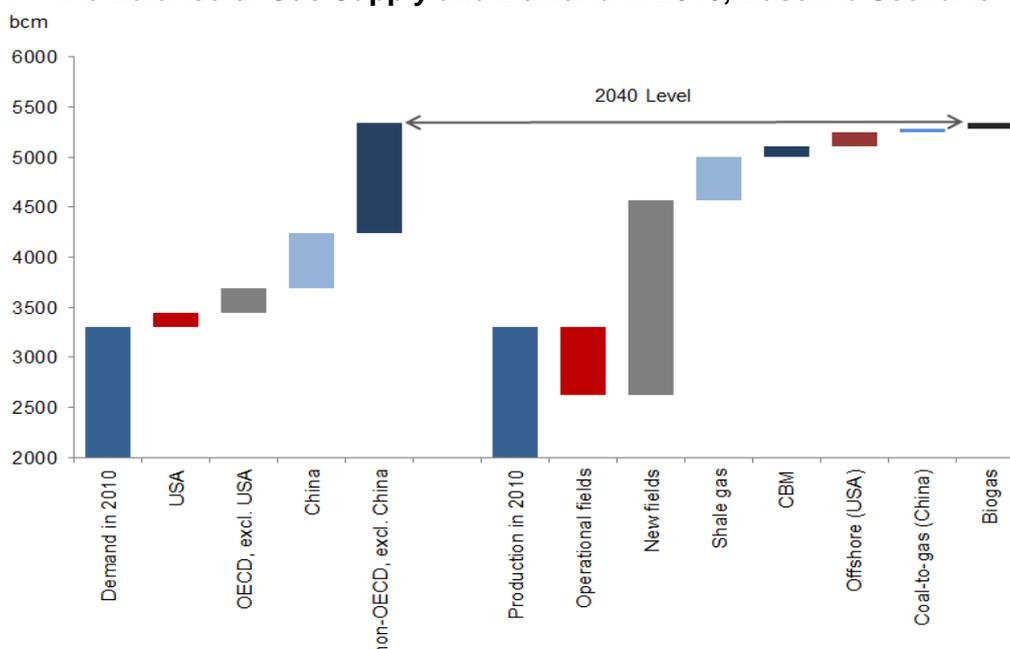
3. Baseline Scenario – Gas Market

Gas Demand

In the baseline scenario, by 2040, the forecasted growth in global gas consumption will reach up to 5.3 tcm - this is by 60% higher than the volumes consumed in 2010. The main increase in demand (81%) will be attributed to the developing countries. The main driver will be primarily the development of gas power generation. Among other OECD countries, only the North America will show relatively high growth rates - an average of 0.8% per year, due to oversupply and low gas prices. The gas demand in the region will grow in all the sectors – together with the electric power (with the displacement of coal), use of gas for industrial purposes will actively develop, including its use for gas chemistry and transportation.

The expected decline in the economic growth in the Eurozone and the ambiguity of the European energy policy aimed primarily at the decarbonization of the economy accompanied by reducing the role of fossil fuels, lead to cautious assessment of the prospects of gas consumption in the region, according to our estimates, the average annual growth in the European demand for gas will not exceed 0.5% (the total growth will be only 15% from 2010 to 2040). Gas consumption will more intensively increase in the developing world: in Asian countries, it will more than triple, it will double in the South and Central America, and will rise by 75-78% in the Middle East and Africa (Figure 7).

Figure 7 - The Balance of Gas Supply and Demand in 2040, Baseline Scenario



Source: ERI RAS

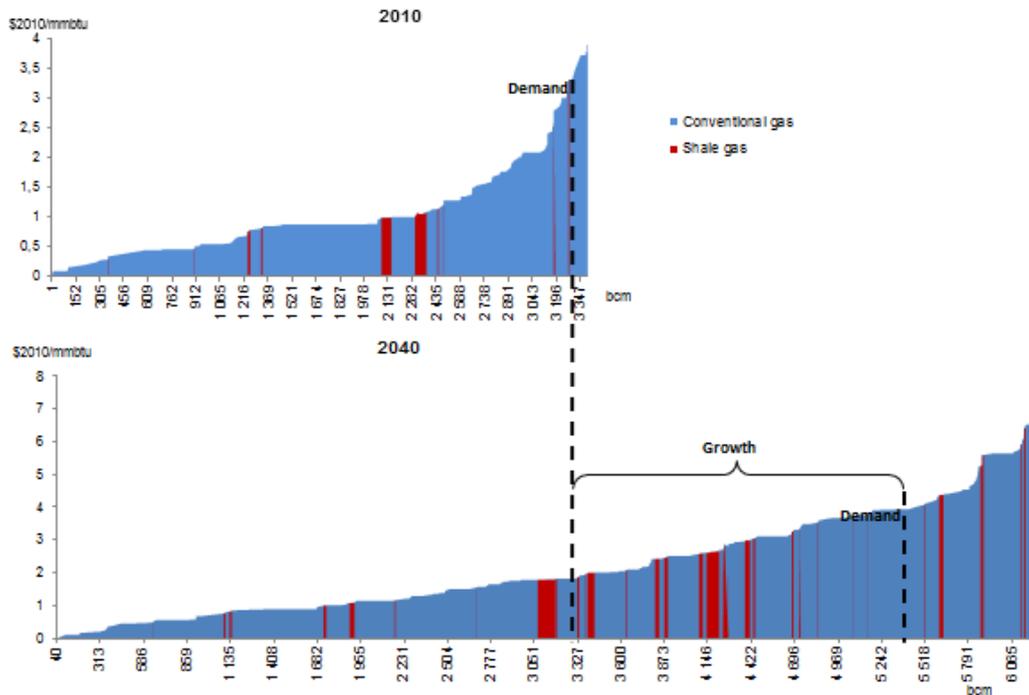
Gas Supply

The analysis of the areas of gas production show that there is sufficient potential of its available resources in the world, which can be produced by 2040 at less than 4 \$/Mbtu (Figure 8). In the baseline scenario, all world regions (excluding Europe) will significantly increase gas production. The leaders of its growth, in addition to the traditional suppliers (the CIS and the Middle East - 59% and 95%, respectively, by 2040), will also become the developing countries of Asia (+202%). The North America will follow them, its production will increase by 39%.

Major production gains will be provided by new reserves of conventional gas and further expansion of unconventional gas, which, by the end of the forecast period, will make 15% of the world gas production (11% - shale gas, 3% - coal-bed methane and 1% - biogas) (Figure 9). North America will show the largest increase of unconventional production. It is assumed in the baseline scenario, that aside from the North America, shale gas production will be

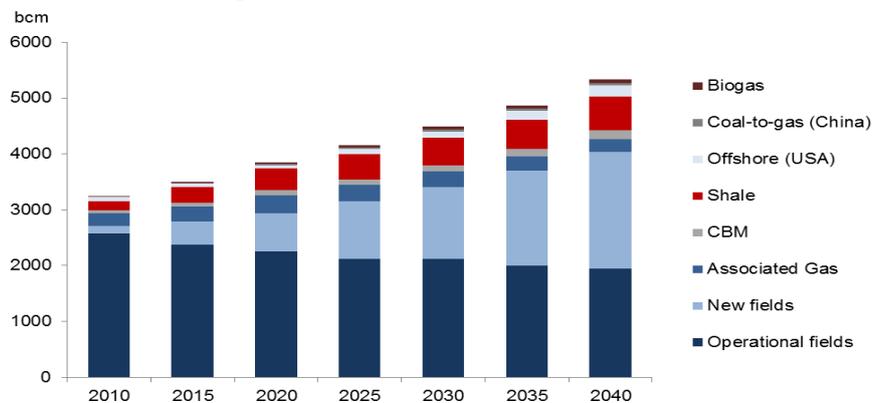
carried out only in Argentina, China, India, the South Africa, Australia and Europe, and will not exceed 70 bcm in total by 2040.

Figure 8 - The Natural Gas Supply Curve (Cost of Production) in the World, Baseline Scenario



Source: ERI RAS

Figure 9 - Gas Production by Source, Baseline Scenario



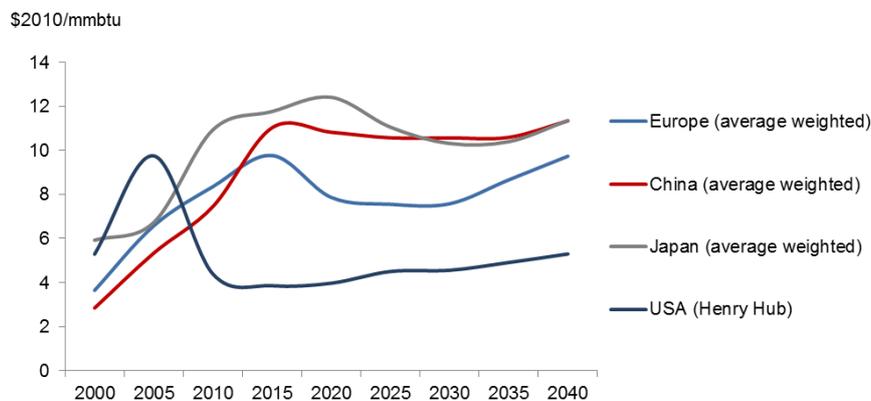
Source: ERI RAS

Gas Prices

Currently, the world witnesses the transformation of the various regional gas pricing systems - primarily due to the gradual expansion of trade based on the "gas to gas" competition. Further changes in regional pricing mechanisms will be driven, apparently, in the direction of increasing the proportion of spot-indexed supplies in all the markets. The rapid development of the LNG market and its globalization will reinforce this process, not only in Europe but also in Asia Pacific, where consumers, against the background of high prices, look for any opportunity to reduce their bills. Most of the developing countries will obviously retain significant volumes of gas traded in domestic markets with pricing based on government regulation, the competition in the closed domestic market or link the gas prices to the international market prices with a reduction factor.

The model calculations have confirmed that in the baseline scenario the significant difference of regional gas prices, which took place in 2006-2012, will remain. The main reason for this is the high price of gas transportation, which for intercontinental shipments, adds up more than 4 \$/Mbtu to the price of gas. Accordingly, the high cost of transportation promotes the regionalization of the gas markets and does not give a chance to create a single liquid market. Within 2015-2030, Europe will have a decline in prices due to sluggish demand and oversupply of gas, while there will be a rapid growth in demand in the Asia-Pacific region, which would stimulate the development of a large number of new quite expensive gas supply projects, and, by contrast, an additional price premium will remain here until 2020-2025. By the end of the forecast period, Europe and in the Asia-Pacific region will experience a noticeable price increase (Figure 10), due to the need to develop new and more expensive fields to meet the demand. The North American market will practically find itself in the price range determined by its own production; the US will retain the lowest prices, which, however, will be also increased by the end of the period.

Figure 10 - Forecast Average Weighted Price* of Gas by Regional Market, Baseline Scenario



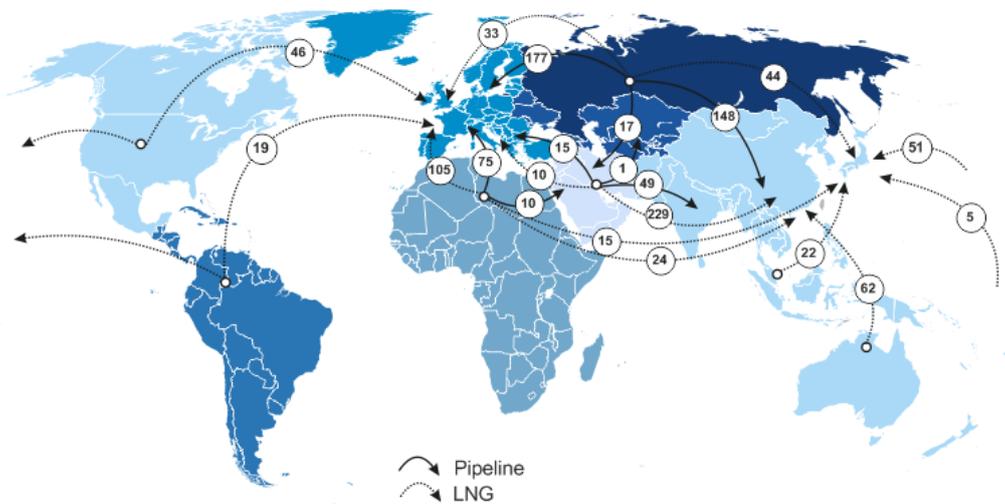
* Weighted average price between the prices of the long-term contracts linked to alternative fuels, and spot prices.

Source: ERI RAS

International Trade

For the next three decades, the focus of international gas trade will be mainly Asia, which will increase net imports by nearly 500 bcm by 2040, which implies, in its turn, the need for a new huge infrastructure and supply routes (Figure 11).

Figure 11 – Inter-regional Gas Trade in 2040, Baseline Scenario, bcm



Source: ERI RAS

The development of shale gas production in the US, even while remaining a regional phenomenon, has already had a significant indirect impact on the world market, especially in terms of redistribution of LNG flows. This influence would only increase with the possible launch of LNG exports from the US and Canada, which, starting from 2016-2018, will likely be delivered to premium markets of the Pacific, Latin America and Europe. In the perspective, the emergence of new major players in the LNG market (in addition to the US and Canada, it will be Australia, which by 2018 will leave behind Qatar in terms of liquefaction facilities, and the East Africa) will significantly redirect the routes of traditional producers that will increasingly focus its exports on Asia.

Positions of the Major Market Participants

In the forecast period of the baseline scenario, the US and China will become the most influential members of the gas market, in addition to Russia. The US, being behind Russia in terms of gas production and export volumes by 2040, will, however, significantly increase its influence by entering the LNG market. The North America will become completely self-sufficient, reduce dependence on any external suppliers, and will be able to add about 100 bcm of gas to the global markets. As a result, it is likely that the US spot prices (plus the cost of gas liquefaction and transportation) will form a kind of "ceiling" prices in the markets of the Pacific and Atlantic basins: when the prices would rise above this level, the US LNG plants would send significant amounts of gas to the market, forcing down the prices to the desired level. Therefore, the US will be able to influence the price situation in the major regions, and the US spot index might become a price reference for the other markets.

The European market will show low rates of growth, but against the background of weak domestic production, its needs for gas imports will inevitably grow. Some of them will be covered by pipeline gas, but the growing share in the gas demand (31% of European consumption by 2040) will be covered by LNG supply. The gas market of the North-East Asia will be the fastest growing - it will hold the second place in the world by volume, partially due to the rapid growth of demand in China.

The OPEC members will clearly lose their positions in the gas market due to the emergence of new potent players (the US, Australia), and because of the explosive growth in domestic demand for gas and the need to satisfy it to avoid social problems, even at the expense of the gas export.

Russia in this scenario, will remain an important player on the gas markets, while maintaining leadership in production and export. However, Russia's bargaining position will weaken, as its investment in the expensive projects marginal in all export markets will make the country susceptible to even not so very large fluctuations in market conditions.

4. The Impact of "Shale Breakthrough" on the Energy Markets

Even today, one can say that the "shale breakthrough" is a fait accompli: oil production from shale formations² increased from 8 mln tons in 2007 to 100 mln tons produced in 2012, shale gas production - from about 40 to 250 bcm for the same period. A detailed analysis of this phenomenon, the state and prospects for the development of technologies aimed at the shale oil and gas production are presented in the ERI RAS studies [9, 10]. They show that there are a number of factors limiting the further rapid expansion of oil and gas production from shale plays:

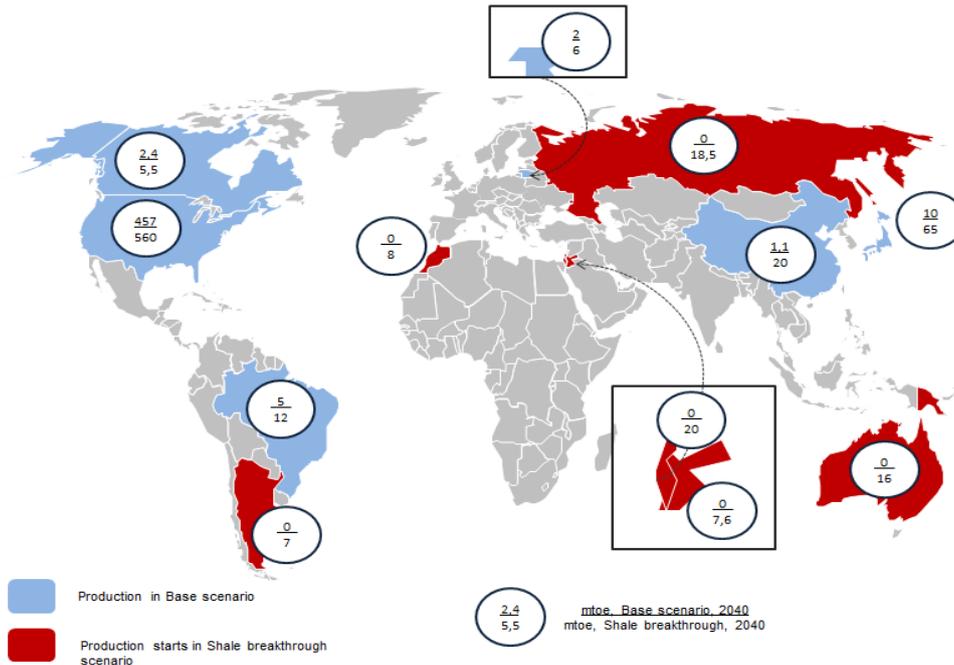
- Relatively high costs for the production from shale plays located outside the North America - 80-140 \$/bbl for oil and 3,5–11,5 \$/Mbtu for gas production;
- High rate of water consumption (it takes about 7 bbl of water to produce 1 bbl of oil from low-permeability formations);

² Oil found in shale plays includes all types of oil extracted from oil shale deposits, which mainly consist of fine-grained sedimentary rock rich in kerogen (clay, marl or carbonates); in particular there could be found tight oil (oil produced from low-permeability plays or other deposits by drilling horizontal wells followed by multistage hydrofracturing) and shale oil (thermally produced oil from shale rich in kerogen).

- Environmental risks related to the contamination of ground water, soil and air;
- Untested technologies for in situ oil shale retorting.

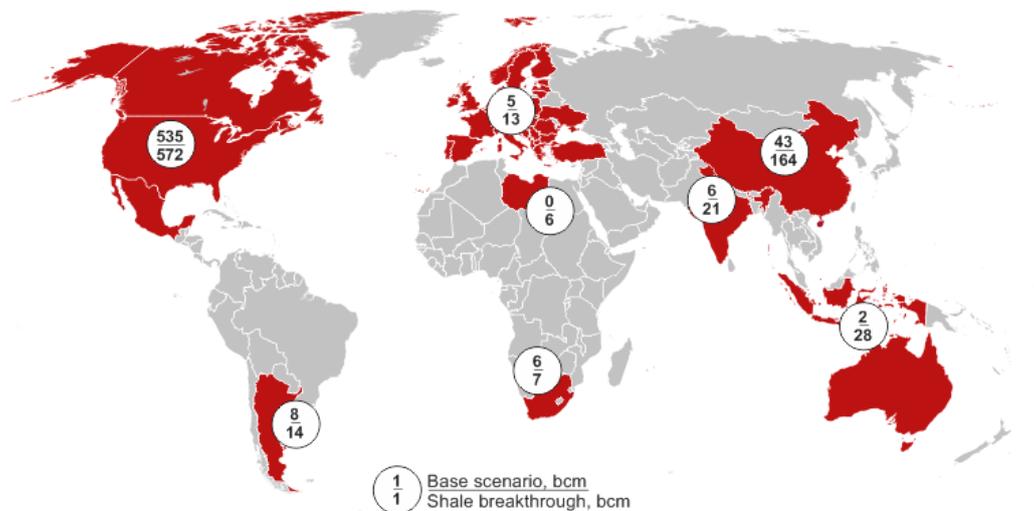
It is most likely, that the technologies able to remove these limitations, will be based on a low cost waterless fracking method and modern techniques of in situ retorting. If they could be employed on an industrial scale, the resource base of the world oil and gas industry will significantly expand, the production of shale oil will be become possible in the countries where oil has not ever been produced, and the shale plays located in the areas with limited amounts of fresh water will be “unlocked”, which will provide a significant increase in production (Figures 12 and 13).

Figure 12 - Shale Oil Production in 2040, Baseline and "Shale Breakthrough" Scenarios



Source: ERI RAS

Figure 13 - Shale Gas Production in 2040, Baseline and "Shale Breakthrough" Scenarios



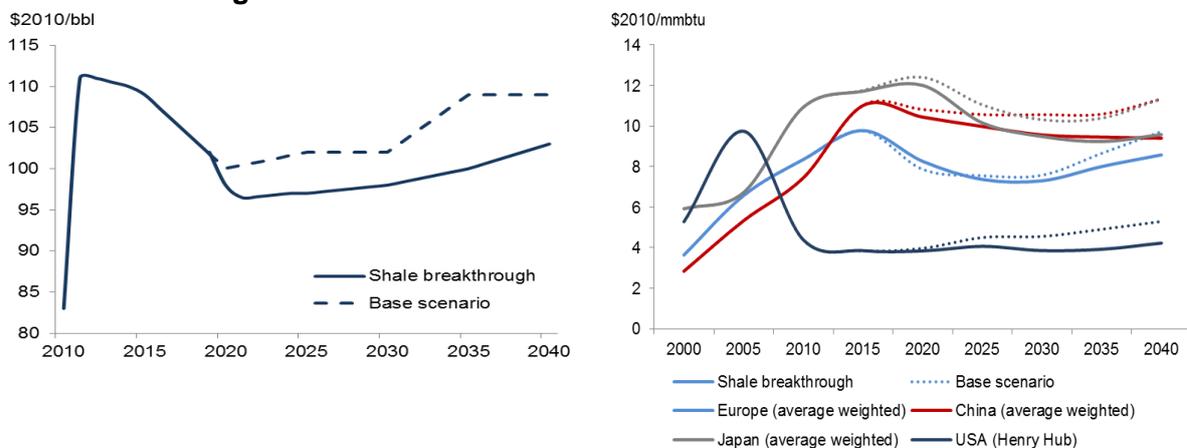
Source: ERI RAS

Thus, the "shale breakthrough" scenario is based on the following assumptions:

- By 2020, the new waterless technology for the production of oil and gas found in low permeability formations would be fully developed. As the result, oil and gas fields located in China, Jordan, Israel, Mongolia and other countries will enter into operation;
- Environmental restrictions on oil and gas production from shale plays would be lifted;
- Global shale oil production costs would equal the levels of the costs of the US production in (less than 80 \$/bbl of oil and 4 \$/Mbtu for gas);
- Active development of not only low-permeability oil reservoirs, but also of oil shale plays (kerogen) would start

In accordance with the "shale breakthrough" scenario, the production of unconventional oil in the world by 2040 will increase by 117 mln tons, gas - by 222 bcm compared to the baseline scenario and could shift oil and gas prices down (Figures 14), after 2020, however, on the contrary to a widely discussed estimates, our calculations show that in the "shale breakthrough" scenario there is no significant drop in the price of oil and gas as compared to the baseline scenario (mean reduction is about \$5/bbl for oil and 1,5 \$/Mbtu for gas).

Figure 14 - Equilibrium Oil Prices and Gas Prices by Region in the Baseline and in the "Shale Breakthrough" Scenarios



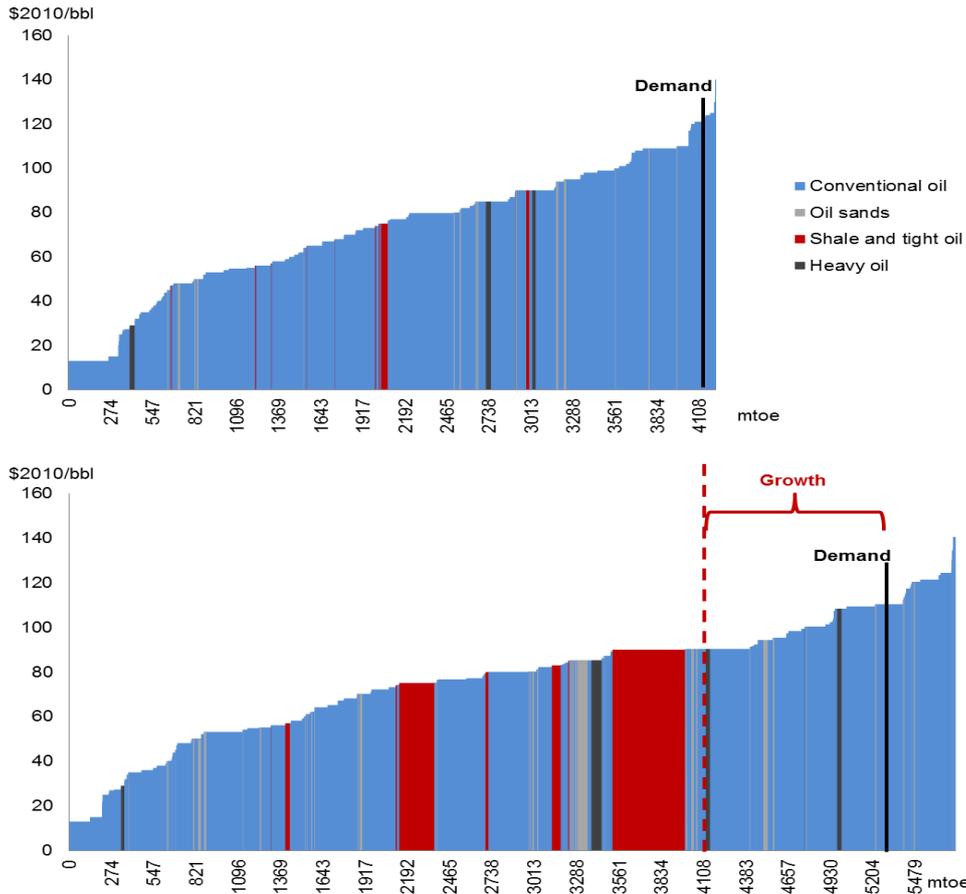
Source: ERI RAS

Such a price response is explained by the fact that quite significant volumes of oil and gas production from shale plays have been already included in the baseline scenario, and without them, the prices of these energy resources would be much higher. The bottom line is that if during the realization of the "shale breakthrough" scenario, the oil and gas supply curves are considerably expanded and get more flat, which means an increase in the supply of oil and gas in the mid-price range (additional longer "steps" appear in the central part of the curve), thus making impossible a sharp decline in the equilibrium prices (Figures 15, 16). However, the absence of a sharp fall in prices does not mean that this scenario is "safe" for the producers. The analysis shows that, while the oil and gas markets are well balanced, the balance of power of the leading participants in these markets significantly changes in this scenario. Some global players will have additional opportunities for influence, while for others, it implies a loss of positions. Generally, in terms of positions of the main players in the oil and gas markets, the scenario actually results in the increased trends defined in the baseline scenario.

The beneficiaries of this scenario:

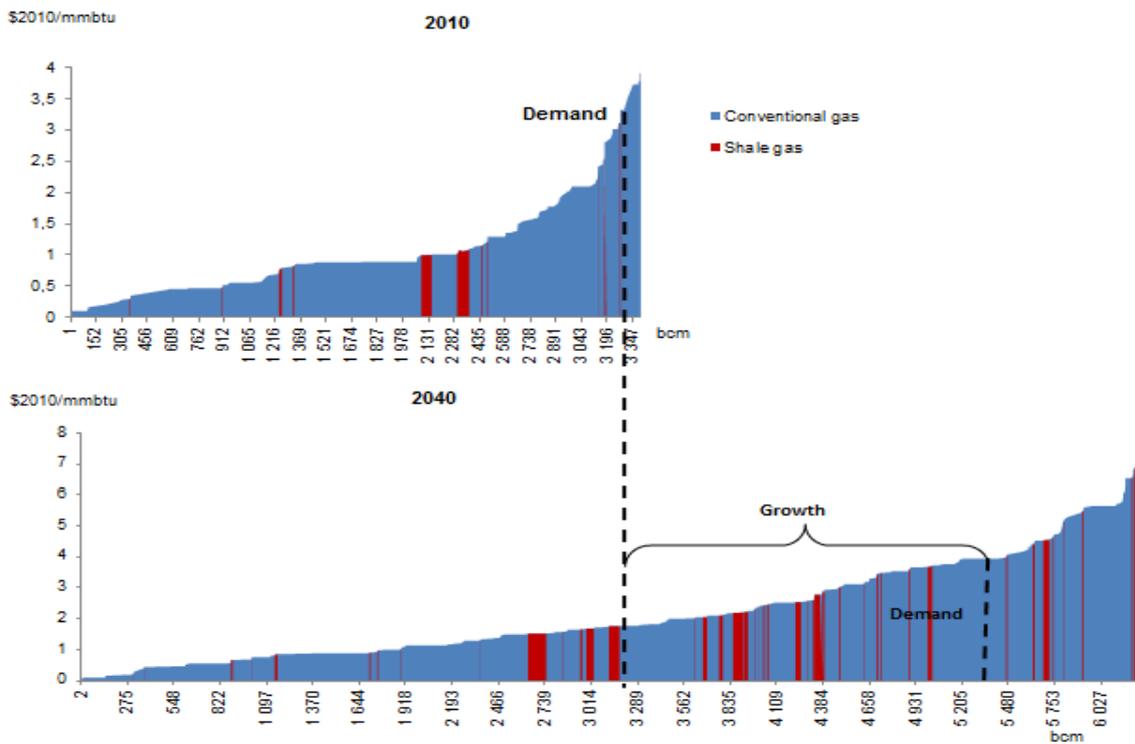
- The United States - due to the domestic production of oil (70 mln tons more than in the baseline scenario) and gas (a little less than defined in the baseline scenario, due to the decrease of export, as the volume of the global gas trade will decline in general, mostly due to the increase in the domestic production in China) will become the largest producer of hydrocarbons in the world. This fact, given the overall geopolitical significance of the US, will actually turn them into the most influential player in the global hydrocarbon market;
- China - by reducing the volume of imports relative to the baseline scenario, which will occur due to the development of its own shale deposits after 2020.

Figure 15 - Oil Supply Curve (Production Costs), the "Shale Breakthrough" Scenario



Source: ERI RAS

Figure 16 - Gas Supply Curve (Production Costs), the "Shale Breakthrough" Scenario

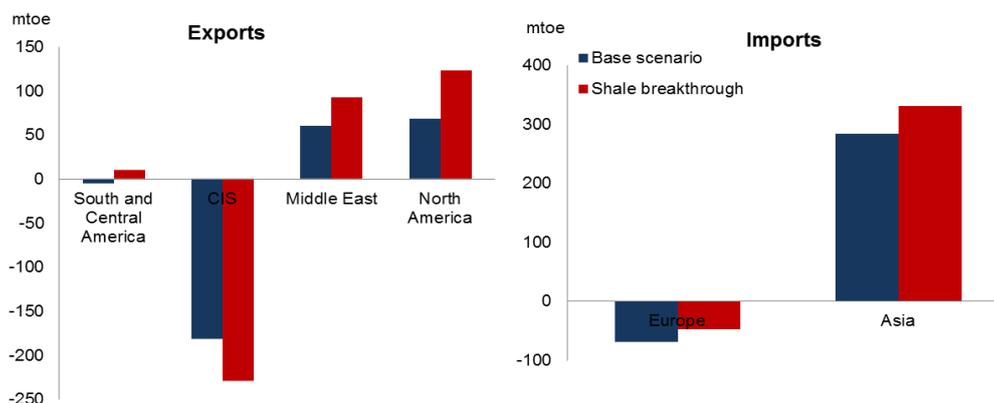


Source: ERI RAS

Loosing parties of this scenario:

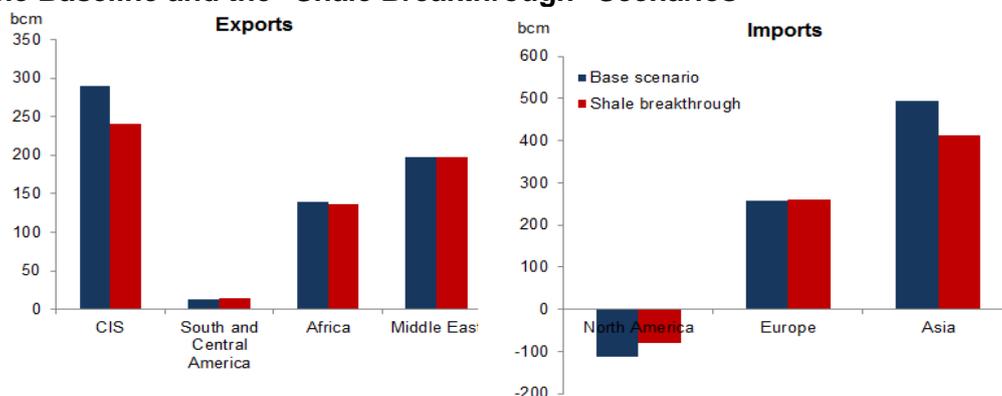
- The European countries - at lower levels of oil prices (compared to the baseline scenario) even greater volumes of European oil will be displaced from the market prices, the North Sea shelf projects will not be put into operation, the attractiveness of renewable energy will be reduced in relation to hydrocarbon fuels, energy dependence on suppliers will grow;
- The OPEC countries will face the decline in production and the reduction of their market share will be almost inevitable in 2025-35. The "Shale breakthrough," will apparently force the cartel to tighten control over production costs, reduce the tax burden on the industry (which may destabilize the economic and political situation in some countries), and create a shortage of supply by introducing quotas. However, even in the "extreme" scenario, it is unlikely to expect the coherence in the actions of the OPEC members because of the difference in oil price levels, which these countries need, and a potential destabilization of a number of "oil-dependent" economies. This means that the "shale breakthrough" is likely to weaken further the organization. By the end of the forecast period, the OPEC market niche will stabilize somewhat, but if the "shale breakthrough" scenario is realized, it would practically deprive the cartel of possibility to influence the world price of oil in the middle of the forecast period;
- The CIS countries and Russia would be forced to cut a great deal of its oil exports in this scenario. Russia's production would reduce by 50 mln tons by 2020 as compared to the baseline scenario, and Russia's exports would decline by the same amount due to the narrowed niche in the Asian market (Figure 17). Russian gas exports in this scenario would be lower by 70 bcm as compared to the baseline scenario (Figure 18). The obtained results show that during the forecast period the CIS would be the most sensitive to this scenario.

Figure 17 – Changes of the Oil Net Export and Import Volumes in 2040 Relative to 2010, the Baseline and the "Shale Breakthrough" Scenarios



Source: ERI RAS

Figure 18 - Changes of the Gas Net Export and Import Volumes in 2040 Relative to 2010, the Baseline and the "Shale Breakthrough" Scenarios



Source: ERI RAS

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