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# Crude Oil Logistics, Production and Refining in Northern Europe

**Vladimir Pavlovich Klepikov[1]*, Vladimir Vladimirovich Klepikov[2]**

[1]National Research University Higher School of Economics, Russia, [2]PricewaterhouseCoopers, Russia. *Email: vklepikov@hse.ru

**ABSTRACT**

To develop the programs to supply crude oil to North European refineries, it is necessary to take into account refineries' location, oil refining capabilities and transportation infrastructure capacity. The paper envisages the geographic allocation of refineries and contains the evaluation of refineries' capacities. Sustainable operations of the refineries are determined by transportation system. The assessment of capacity of crude oil transportation to the refineries is conducted. Change in the refineries' capacities and the utilization of the refineries' in the Northern European region was studied. Research is performed for the period of 2005/2015. The study yielded the trend towards increase in crude oil output and refining in the region. If this trend persists, the cargo flow of imported crude oil and the utilization of logistics infrastructure may increase. According to the study, the existing transport and refining infrastructure in the region is able to handle the increasing imported crude oil flow.

**Keywords:** Oil Logistics, Oil Production, Oil Refining
**JEL Classifications:** F23, L71, L95, O52, R12

## 1. INTRODUCTION

Main goal of this research is to identify key trends and tendencies in oil production and refining in Northern Europe and asses the capabilities of oil logistics and refining infrastructure.

To achieve that goal it is necessary to make several steps such as:
1. Define countries which are the main contributors to the oil production and refining process in the region
2. Identify the global trend of oil production
3. Evaluate oil production and refinery concertation
4. Determine the breakdown of marine and pipeline transportation in oil deliveries and identify oil terminals capabilities
5. Asses the capabilities of oil transportation and refining infrastructures.

Thus, this paper analyses oil delivery schemes, trends in crude oil production and processing, crude oil transportation capabilities and the refineries' capacities, utilizing quantitative data analysis approach.

This approach can be used in development of the energy policy programs for other regions of the world. Its application will help detect the transportation infrastructure opportunities, the trends in fluctuations of crude oil output and refining in the region. The findings of such study would help forecast the development directions of the crude oil delivery and refining infrastructure, the volumes of oil supplies to the region's refineries.

As it will be shown later, the major part of the crude oil deliveries are made by marine transport through seaports. Moreover, all of these ports geographically located on seashore of the Northern European seas. This circumstance explains why Northern European region was selected for the further examination in this paper.

## 2. LITERATURE REVIEW

Crude oil has profound impact on transport development. Oil output, environment, crude oil consumption and prices, market risks, oil cargo delivery and other issues are widely covered in scientific literature. Farzanegan and Markwardt (2009) reviewed the relationship between oil price fluctuations and Iran's key macro-economic variables. Tang et al. (2010) studied the impact of crude oil price fluctuations on the economy of China. Marashdeh and Afandi (2017) analyzed the impact of oil price changes on stock market returns in three largest oil-producing countries in the world. (Rafiq et al., 2009) investigates into the influence of crude oil price on Thailand's economic parameters. Bayar and Kilic (2014) studied the effect of changes in oil prices on the industrial production growth in the Eurozone member countries. Alkhateeb et al. (2017) determined the correlation between oil revenue and employment level. Nadal et al. (2017) studied the impact of leaps in crude oil prices and the stock market yield. Ji and Fan (2015) consider fluctuations in prices for the basic oil grades on the global market. Gallo et al. (2010) study the correlation between oil prices, consumption and output for a number of countries. (Askari and Krichene, 2010) review the impact of key interest rates and USD exchange rate on oil markets. Morecroft et al. (1992) proposed the simulation model of the oil market behavior. Ibrayeva et al. (2018) analyzed the potential of the Caspian basin and its importance for Europe. Li et al. (2018) elaborated the models using the combination method for oil consumption forecasting. (Halkos and Tzeremes, 2011) investigate into economic efficiency and oil consumption in developed and developing countries. Ozturk et al. (2009) and Yaprakli and Kaplan (2015), analyzed Turkish primary energy needs. Global reduction in oil demand and consumption is reviewed in Goldemberg and Prado (2013). Lund (2017) considers Finland's decision to stop using coal and reduce oil consumption. Harvey (2017) reviews the efforts to eliminate global demand for oil by 2060.

Oliveira et al. (2016) analyzed the delivery system from a marine terminal to the refinery's oil pipeline and elaborated the optimization model with the view to uncertainty of oil supplies to the terminal. To minimize the refineries' overall costs, Guajardo et al. (2013) presents the model for comprehensive planning of production, transportation and sales of refined products. Al-Othman et al. (2008) is devoted to a stochastic model of the supply chain planning for oil companies. Authors show in this model that the economic uncertainty forces oil-producing countries to maintain the oil refining oil export balance. Aboudi et al. (1989) dwells on the key milestones of the oilfield development project and the transportation system design. The authors elaborated a mathematical model, determined the methods of addressing the same, and described their implementation methods. Kazemi and Szmerekovsky (2015) propose a linear programming model to determine the most appropriate supplies of oil to refineries. The model minimizes costs in the oil supply chain, in refineries and product distribution centers. Venus Lun et al. (2012) present the evolution of problems as may arise during oil marine transportation. Panagiotis and Georgia (2013) studied transportation of energy resources in the regions of Middle East and Central Asia. Klepikov (2017) reviews the multi-modal logistics of oil supplies to Southern Europe. Europe is one of the world's major crude oil refining regions. Guliyev et al. (2017) presented development issues oil refining industry in the countries of the Baltic Sea region. Oil delivery and refining evaluation is an important subject when elaborating and implementing the energy policy programs in that region. The transportation system's capabilities to deliver products, capacities of the refinery owners, and refineries' throughput are the key indicators of oil supply and refining processes. This problem has not been sufficiently addressed in literature, which makes it topical.

## 3. GEOGRAPHICAL SCOPE

European countries produce much oil and most of them have a network of refineries on their territory. However, in this research we include those having a marine boundary along the Northern Sea and the Baltic Sea (from Ireland in the west to Finland in the east) (Figure 1).

These twelve countries are the main contributors to the oil production and refining process. In the year 2015, more than 90% of all European oil was produced by these countries and they refined more than 50% of all produced and imported oil as well. Therefore, further analysis in this paper will be focused on these particular countries: Germany, UK, Netherlands, Belgium, Belarus, Sweden, Poland, Norway, Finland, Lithuania, Denmark and Ireland.

**Figure 1:** Countries - main oil producers in the Northern Europe

## 4. GLOBAL TENDENCIES IN THE OIL PRODUCTION IN THE NORTHERN REGION

Long-term forecasts[1] predict annual reduction in oil consumption in Europe down to 2035. The global trend towards curtailing of crude oil consumption has already triggered the dramatic drop in refining capacities in a number of European countries and in turn slowed down the infrastructure development of the European oil transportation system. That is also true for the Northern region. Until the year 2013 there was steady decrease in oil production and refining.

However, since the year 2013 there is reverse in this downward dynamics. Therefore, the question – is the Logistics and Refining infrastructure of the Region is ready to deal with this increase, are there any reserves, and what should be adjusted, if any, in terms of oil supply.

As it shown on the Figure 2 - there are three leaders in terms of oil production in Northern Europe: Norway, UK and Denmark. It is possible to assume that oil production in the region is highly concentrated. To prove this it is necessary to run the concentration analysis - it is one of the component of quantitative evaluation approach.

## 5. TRENDS FOR CONCENTRATION OF CRUDE OIL PRODUCTION, THROUGHPUT, AND REFINERIES' CAPACITIES IN NORTHERN EUROPE

Let's carry out the quantitative assessment of concentration for produced and refined crude oil, for refineries' capacities in the countries of regions under review[2]. Several methods can be used to solve this problem. Jacobson et al. (2005) employed Gini index to determine the inequality in electricity consumption by households in some countries. To estimate the concentration in placement of European ports, Notteboom (1997) investigates into Gini and Herfindahl-Hirshmann indices. Yang and Dong (2016) used Gini and Herfindahl-Hirshmann indices to study the concentration of placement of oil companies' headquarters. When addressing this objective, we will determine trends for Gini and Herfindahl-Hirshmann for the studied indicators.

Gini index determines to what extent the studied parameter differs from the perfectly uniform distribution. The concentration is set in Lorenz graphic curve. Gini value is equal to the fraction where the numerator is determined by the area under Lorenz curve and the line of perfectly uniform distribution and the denominator is the area of the triangle formed by the line of perfectly uniform distribution and the horizontal axis (Figures 3-5). If all countries in the region under review produced the same oil volume, had the same refineries' capacity and throughput, Gini would be equal to 0, and Lorenz curve would coincide with the perfect distribution line. If all production, all capacities and crude oil refineries were located in one particular country, Gini would be equal to 1, and Lorenz curve would coincide with the horizontal axis (Figures 3-5) and the normal from the remotest point on the perfect distribution line from the coordinate root to the horizontal axis. In case of piece/linear approximation of Lorenz curve, which is used in this paper, the following formula (1) should be used for Gini ($G^M$) calculation in the regions under review:

$$G^M = 1 - \sum_{k=1}^{L} (x_k - x_{k-1}) * \left(y_k^M + y_{k-1}^M\right), k = 1 \div L, 0 < G^M < 1, \quad (1)$$

Where $x_k$ (is the cumulative percentage of number of countries) on the horizontal axis, $y_k^M$ (is the cumulative percentage of crude oil output, the refineries' capacities or crude throughput in the countries of the region) on the vertical axis of Lorenz curve and $L$ is the number of countries. As we mentioned earlier in this paper the Northern region comprises of 12 countries ($L=12$).

1 World Energy Outlook 2011. International Energy Agency. Paris. November 2011.

2 BP, IEA statistics.

**Figure 2:** Oil production trends in North European region

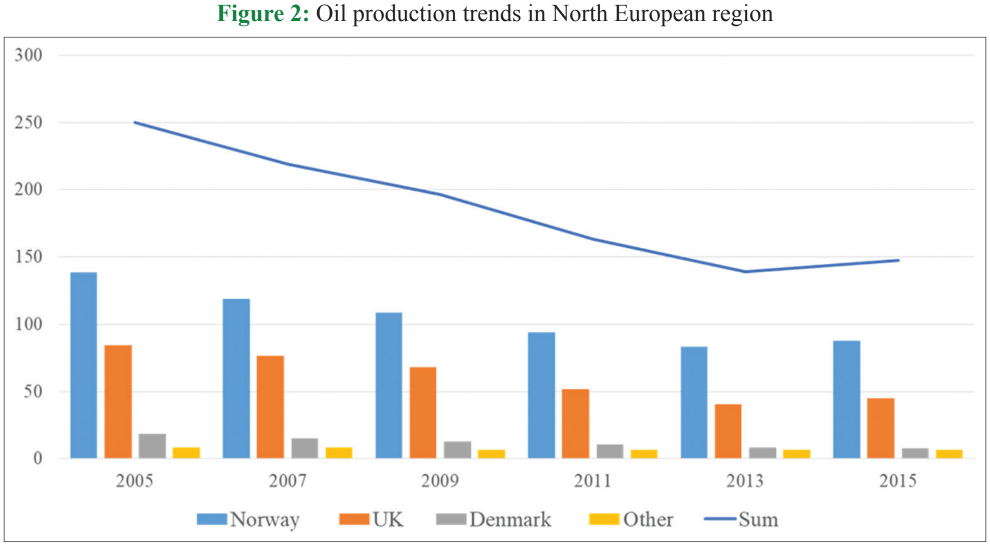


**Figure 3:** Lorenz curves for refineries' capacities across region in 2005/2015 (*L=12*)

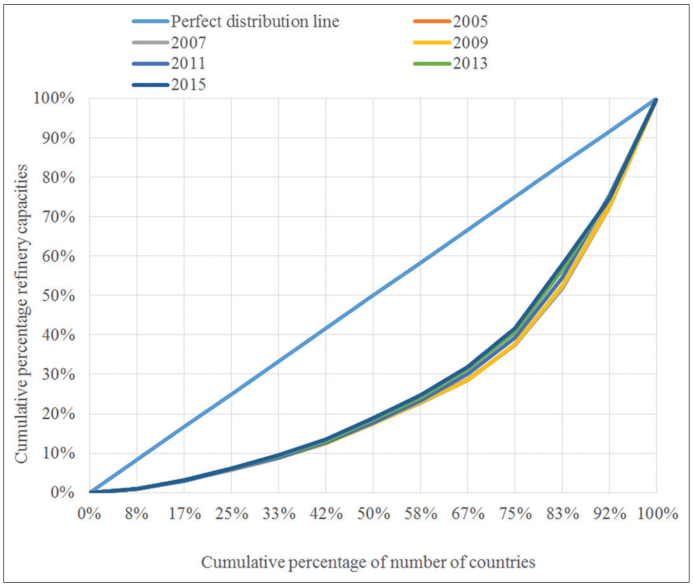
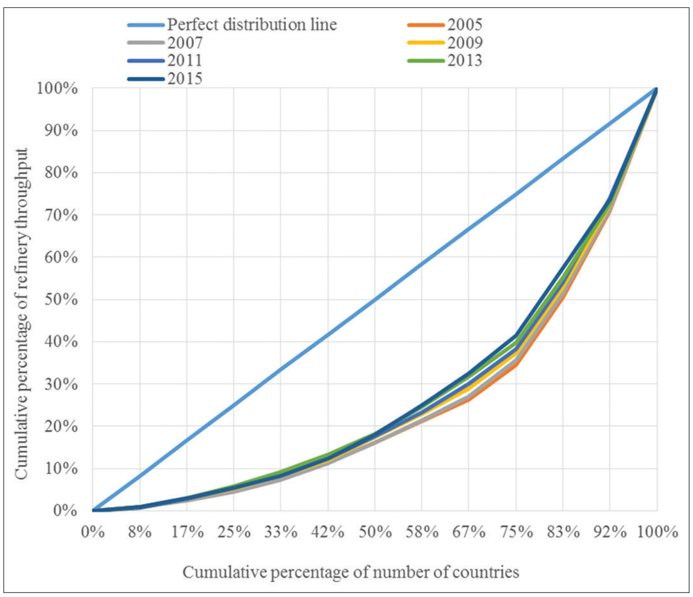



**Figure 4:** Lorenz curves for throughput volumes in refineries across region in 2005/2015 (*L=12*)




The following formula (2) was used to calculate *($HHI^M$)* (Herfindahl-Hirshmann index):

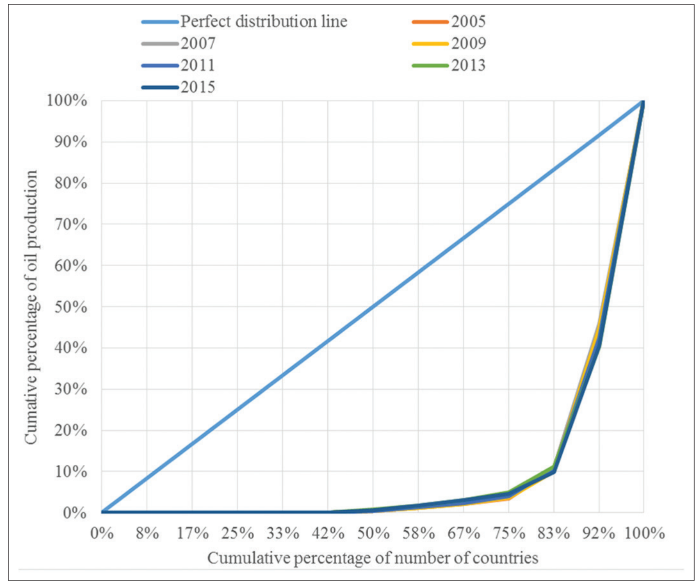
$$HHI^M = \sum_{l=1}^{L} (V_l^M)^2 / (\sum_{l=1}^{L} V_l^M)^2,$$

$$Where\ l = 1, \div L, \frac{1}{L} < HHI^M < 1. \tag{2}$$

Table 1 shows the calculation results for Gini and Herfindahl-Hirschman indices for the crude oil output, throughput and refineries' capacities in the countries of regions under the review in the study period.

The values in Table 1 suggest that slow decrease in Gini and Herfindahl-Hirschman indices in the study period is the general trend for refineries' capacities and throughput. That points out to the smaller concentration of refineries' capacities and throughput across the region. Oil production concentration in the Northern region is close to the monopolistic. Gini index values for the study period range from 0.8 to 0.81. Figures 3-5 shows Lorenz curves for the refineries' capacities, throughput and crude oil volumes production for Northern region in the study period.

**Figure 5:** Lorenz curves for oil production across region in 2005/2015 (*L=12*)




The nature of Lorenz curves (Figure 3) for refineries' capacities and throughput (Figure 4) across region suggests that concentration changed very slowly. Lorenz curves for 2005/2015 in the figures are rather close to each other, which testifies to the proximity of values of throughput and refineries' capacity concentration in the study period. Lorenz curves for oil output (Figure 5) illustrate the proximity of crude oil production in region to monopolistic concentration (max Gini = 1).

Gini and Herfindahl-Hirschman indices give the integral assessment of the unequal allocation of crude oil production and throughput volumes and refineries' capacities for region. Let's continue investigating into quantitative values of crude oil production and throughput volumes and review the allocation of crude oil production and processing volumes and refineries' capacities in the regions in the study period[3].

Now, when we have the idea about the situation with oil production in the region, let's analyze logistics components.

## 6. PARTICULAR FEATURES OF CRUDE OIL DELIVERY INFRASTRUCTURE

### 6.1. Main Variants of oil Delivery to the Northern Region

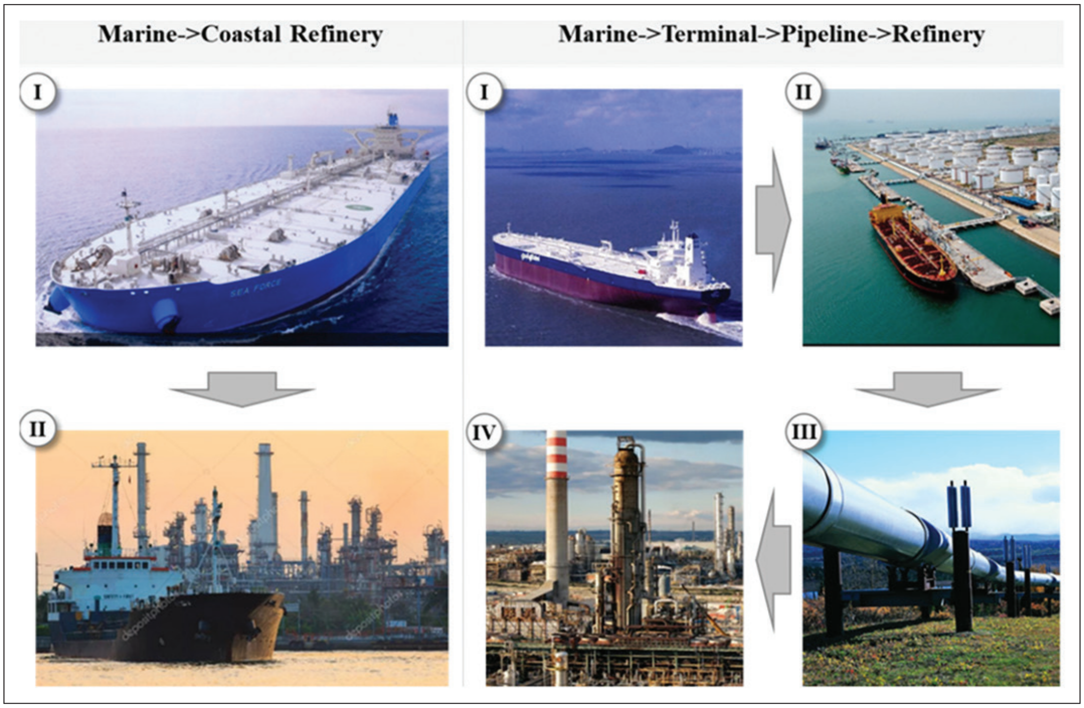
A ramified system for crude oil delivery to European refineries for processing operates and comprises crude carriers, oil terminals, pipelines and other transportation methods.

3 BP, IEA Statistics.

**Table 1: Gini and Herfindahl-Hirschman indices for refineries' capacities, refineries' throughput and crude oil production in the region, 2005-2015**

| Category | Min indices values | 2005 | 2007 | 2009 | 2011 | 2013 | 2015 | Max indices values |
|---|---|---|---|---|---|---|---|---|
| **Gini indices** | | | | | | | | |
| Capacities | 0 | 0.4784 | 0.4815 | 0.4787 | 0.4637 | 0.4526 | 0.4454 | 1 |
| Throughput | 0 | 0.5045 | 0.5013 | 0.4818 | 0.4713 | 0.4596 | 0.4530 | 1 |
| Oil production | 0 | 0.8124 | 0.8089 | 0.8128 | 0.8143 | 0.8133 | 0.8158 | 1 |
| **Herfindahl-Hirschman indices** | | | | | | | | |
| Capacities | 0.083 (3) | 0.1578 | 0.1596 | 0.1580 | 0.1497 | 0.1460 | 0.1441 | 1 |
| Throughput | 0.083 (3) | 0.1691 | 0.1656 | 0.1584 | 0.1531 | 0.1511 | 0.1466 | 1 |
| Oil production | 0.083 (3) | 0.4267 | 0.4210 | 0.4299 | 0.4368 | 0.4459 | 0.4514 | 1 |

**Figure 6:** Major oil delivery schemes in the Northern Region (Variant I and II)




However, mainly two principal delivery schemes are used (Figure 6):

- Variant I - Crude oil delivery by marine crude carriers via port terminals located in close proximity from the coast refineries.
- Variant II - Crude oil delivery via trunk pipelines from the specialized oil terminal in ports.

It is worth mentioning that about 20% of oil is delivered to refineries directly from its production sites via pipelines.

Crude oil delivery by railways and motor transport is also possible, but the volumes of such transportation are negligible as compared with aqueous and pipeline transportation reviewed in the paper.

In the majority of these cases, European refineries are the final destinations of crude oil supplies.

To find out the role the pipeline and water crude oil transportation has to play, it is necessary to calculate the aggregate capacity of the refineries receiving oil via marine and pipeline transport in each of European countries. Then we will determine what shares the capacities of the refineries receiving oil by sea and those receiving oil by pipeline transport in each country bear in the total capacity of the entire region's refineries in 2015.

## 6.2. Breakdown of Marine and Pipeline Transportation in Oil Deliveries

The share of the total capacity of 52 refineries in the Northern Region[4] of Europe, which receive crude oil by sea, via coastal terminals[5] and

4 European Refineries (2017).

5 Refineries and Terminal reports and websites: Slagen refinery(2017), Fawley Southampton refinery (2017), Humber refinery (2017), Lindsey oil refinery (2017), Milford Haven (Pembroke) (2017), Stanlow refinery (2017), Kalundborg (2017), Brunsbuettel (Erdoelwerk Holstein Heide) (2017), Oiltanking Deutschland GmbH (Elbe Mineraloelwerke Hamburg Harburg) (2017), Vopak Terminal Hamburg GmbH (НПЗ Elbe Mineraloelwerke Hamburg Harburg) (2017), Wilhelmshaven (NWO) (2017), (The Netherlands) Shell Pernis, BP, Botlek, Koch HC Partnership, Gunvor Petroleum Rotterdam (Port Rotterdam(2017)), Vlissingen Refinery (2017), BRC Antwerp (2017), Preemraff Lysekil (2017), Preemraff Goeteborg, Goteborg, Nynäs (2017), Nynäs (2017), Porvoo (2017), Naantali (2017), Mazeikiu Nafta (2017).

**Table 2: Allocation of refineries' capacities in the Northern Region, depending on the crude oil delivery method**

| Country  | Variant I  | Variant II  |
|---|---|---|
| UK | 14,7% | 2,5% |
| The Netherlands | 14,3% | 1,7% |
| Germany | 5,6% | 23,4% |
| Sweden | 5,1% | - |
| Finland | 3,2% | - |
| Lithuania | 2,1% | - |
| Norway | 1,4% | 2,4% |
| Belgium | 1,3% | 9,5% |
| Denmark | 1,3% | 0,8% |
| Ireland | 0,8% | - |
| Poland | - | 6,1% |
| Belarus | - | 3,7% |
| **Total** | **49,9%** | **50,1%** |

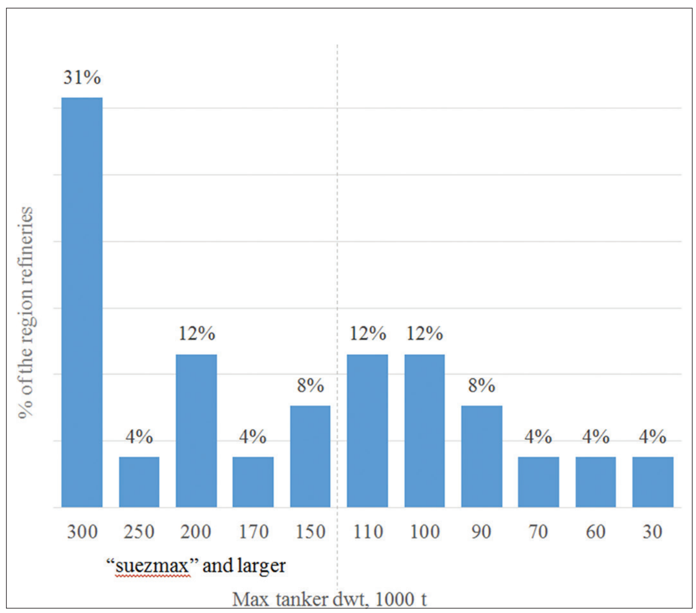
via trunk pipelines[6], in the total capacity of the region's refineries is shown in the (Table 2).

As the values (Table 2) suggest, there is a parity of the marine and pipeline oil transportation to refineries in this region. German and Belgian refineries receiving crude oil by pipelines account for a great share in the region's aggregate capacity. UK and Netherlands refineries are leaders in marine transport supplies.

- Vlissingen plant located in Zeeland, the Netherlands, partially supplied with crude oil from Total's 7 mta pipeline from the port of Rotterdam, accounts for 1.7% of Dutch plants' contribution to the pipeline share of supplies.
- Most of crude oil is supplied to Polish and Belarusian plants via the Druzhba pipeline that delivers oil from Russian fields.

Region's biggest refinery capacities receiving crude oil via pipelines are located in Germany, Belgium, Poland. Most of region's refinery capacities receiving crude oil via marine crude carriers are situated in UK, Netherlands. A part of oil supplies from fields to refineries is carried out via the Druzhba pipeline (Pototskaya et al., 2016) bypassing transshipment in ports. The throughput of its central portion is 80 mta, that of its Northern and Southern branch is 52 mta and 17.5 mta, respectively (Vatansever, 2017). FTS 28.75 mta pipeline system sends a portion of the transported oil directly from fields to Grangemouth 10.5 mta refinery located in East Coast of Scotland. The rest of oil from the FTS system is transported to the port for subsequent shipment to marine crude carriers.

**Figure 7:** Shares of refineries' ports by accepted crude carriers' dwt in Northern Region




## 6.3. Northern Region Oil Terminals Capabilities

The marine delivery of crude oil to refineries occurs via oil terminals servicing them. Port oil terminals' capacity servicing the refineries is estimated by the size of crude carrier they can accept. For this purpose, let's break down all oil terminals servicing refineries of the regions by the maximum size of crude carriers they accept. Figure 7 shows the allocation of the share of ports with a certain maximum dwt of accepted crude carriers in Northern Region total refinery terminals.

6 Pipelines reports and websites Troll Oil Pipeline (2017), Mongstad refinery (2017), Grangemouth refinery (2017), Hamburg Holburn (NDO) (2017), Fredericia (2017), Emsland Lingen, Gelsenkirchen, Wesseling (NWO), Wesseling, Cologne Godorf (RRP), Schwedt, Mitteldeutschland Spergau (Druzhba (2017), Miro Karlsruhe (SPSE, TAL), Neustadt, Vohburg, Burghausen, Petroplus Ingolstadt (TAL), Vlissingen Refinery (Total), Total Antwerp, Exxon Mobil Antwerp, Antwerp N V (RAPL), Plock, Gdansk (Druzhba), Novopolotsk, Mozyr (Druzhba).

The result shown in (Figure 7) suggests that:

- 31% oil terminals of the refineries are able to accept crude carriers with 300,000 t dwt,
- 27% terminals can accept vessels of 150,000 t<dwt<300,000 t,
- 35% ports can accept crude carriers with 70,000 t<dwt<150,000 t.

Most of European pipelines run from specialized marine oil terminals (pipeline ports) on European coast. Table 3 shows these pipelines' ports capacities to receive crude carrier with the respective dwt.

The data shown in Table 3 suggest that region have three pipeline ports capable to accept crude carriers with up to 300,000 t dwt on their territories. All of region pipeline ports are able to discharge vessels with up to 150,000 t dwt.

## 7. CAPABILITIES OF NORTHERN EUROPE OIL PRODUCTION AND REFINING

**Table 3: Capacity to accept crude carriers by pipeline ports in the region**

| Ports terminals capabilities (Variant II) | |
|---|---|
| **Port (pipeline)** | **Max tanker dwt (1000 t)** |
| Rotterdam (RRP) | 300 |
| Rotterdam (RAPL) | 300 |
| Rotterdam | 300 |
| Wilhelmshaven (NDO) | 150 |
| Wilhelmshaven (NWO) | 150 |

## INFRASTRUCTURES

### 7.1. Capacities of Northern Region Refineries' Owners

Refinery owners play an important part in crude oil supplies to Northern region. Let's review the distribution of refinery owners' capacities[7] in 2015. Twenty-seven companies with different refining capacities operated on the Northern Region's refining market.

- Three major companies accounted for over 35% capacities of the region's refineries:
  - Shell (13.1%),
  - ExxonMobil (11.8%),
  - Total (10.8%).
- The three following companies accounted for over 20% capacity together:
  - BP (8.1%),
  - ConocoPhillips (7.6%),
  - PKNOrlen (5.6%).

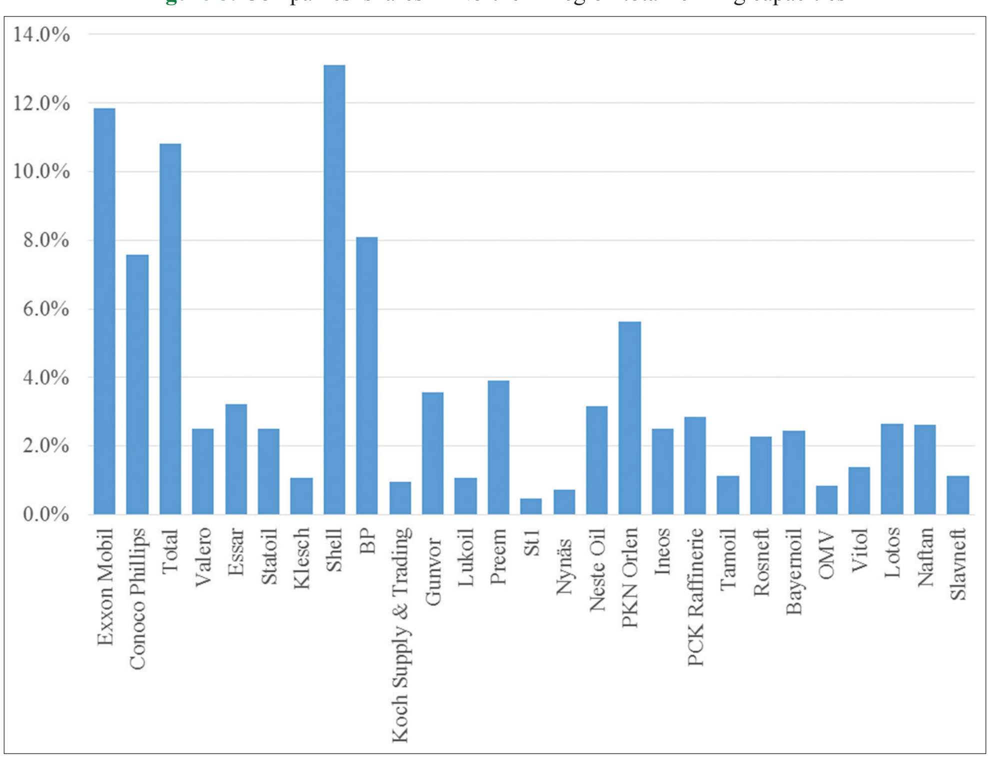
The rest of owners had 43% of capacities Figure 8 shows the shares of the leading companies' capacities in region's total refining capacities.

### 7.2. Trends for Crude Oil Production, Throughput and Refineries' Capacities in Northern Region

For this part of the analysis we introduce the integral indicator, $V_l^M$ , which means, depending on the values of variables *M* and *l*: Crude output (*M=1*), refineries' capacity (*M=2*), refineries' throughput (*M=3*) for the respective country (*l*) in the region. Crude oil output and throughput volumes, refineries' capacity and

7 European Refineries (2017)

**Figure 8:** Companies' shares in Northern Region total refining capacities



pipelines' throughput is measured in million tons a year (mta). The time period under review is from 2005 to 2015.

Crude oil disparity is a difference between the volumes of the crude oil throughput at refineries and those produced in the region.

As we identified earlier (Figure 2) there are three leaders in terms of oil output in Northern Europe - Norway, UK and Denmark. Oil is produced offshore the Northern Sea in these countries. Via pipelines and sea transport, the bulk of crude oil is delivered from offshore fields to coastal terminals and then, using crude carrier, forwarded to refineries' terminals and port terminals where trunk pipelines start. The key producers take an active part in global cooperation of oil supplies. For instance, in 2015, Norway imported 70% of the crude oil it needs for own refineries, despite sufficient volume of own produced raw material. UK, one of the biggest crude oil producers, imported 105% of crude oil of the volume refined on its territory. Crude oil import to Denmark came to 49% of the volume the local refineries need.

The total oil output in the Northern $(\sum_{l=1}^{L} V_l^M, L = 12, M = 1)$ Region dropped from by 44% from 250.3 mta in 2005 to 139.3 mta in 2013 (Figure 2). However, crude oil production recovered by 6%, to 147.9 mta, in 2015 in the region (Figure 2). In the study period, the Northern Region accounted from 87% to 91 % of total crude oil production in Europe.

Oil refining countries can be conventionally divided into three groups, by the aggregate oil throughput in their refineries in 2015. The first (I) group comprises the countries with the aggregate throughput volume of over 50 mta. The second (II) group throughput from 10 mta to 50 mta, and the third (III) one, <10 mta.

In the Northern Region, the first group includes Germany, UK and the Netherlands; Belgium, Poland, Belarus, Sweden and Norway belong to the second group and Finland, Lithuania, Denmark and Ireland, to the third one.

The share of total capacity of refineries in Group I of countries in total capacity of all refineries of the Northern Region declined from 62.6% in 2005 to 58.4% in 2015 gradually. The share of Group II countries rose from 28.6% in 2005 to 32.2% in 2015, and that of Group III, from 8.8% in 2005 to 9.5% in 2015.

The aggregate capacity of the region's refineries $(\sum_{l=1}^{L} V_l^M, L = 12, M = 2)$ dropped gradually, from 432.8 mta in 2005 to 399.4 mta in 2015, with the crude oil transportation capacity in the region remaining unchanged in the region on 2005.

The trends for the share of refineries' capacity of the countries in the total capacity of existing refineries in Europe is shown in Figure 9 for the study period.

The data (Figure 9) suggests that the share of refineries' capacity in the total refineries' capacity across region:

- Remained at 26% in Germany,
- Reduced from 21% to 17% in UK,
- Increased from 15% to 16% in the Netherlands.

The share of refineries' capacity in the rest of countries shown in (Figure 9) and the aggregate share of other countries did not change significantly, or increased slightly.

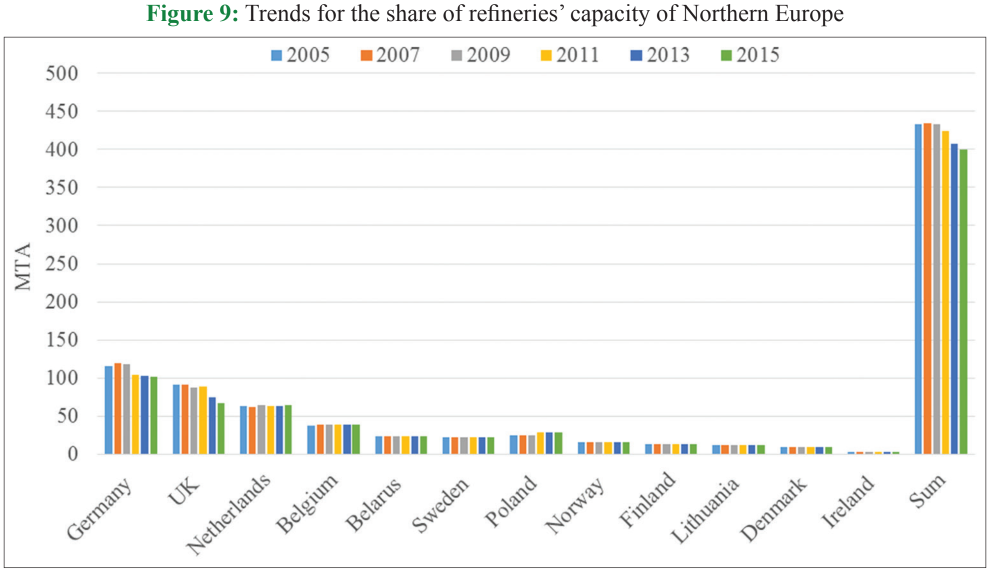
Share of throughput in Northern Region refineries:

- In Group I, reduced from 65.5% in 2005 to 58.5% in 2015
- In Group II, increased from 27% in 2005 to 33% in 2015,
- In Group III, remained unchanged at approx. 8%.

Throughput in German and Dutch refineries in 2005 came to 115 mta and 62.9 mta, respectively, and then reduced to 92.8 mta (−20%) and 52.2 mta (−16%) in 2013, and rose to 93.8 mta (+1%) and 56.9 mta (+8%) in 2015, respectively. UK throughput dropped from 81 mta in 2005-56.8 mta in 2015 (−30%).

In the same period, throughput remained almost unchanged and came to 32 mta, 20 mta, and 14 mta in Belgium, Sweden and

**Figure 9:** Trends for the share of refineries' capacity of Northern Europe



Norway, respectively. Throughput volumes increased in Belarus: From 19.9 mta in 2005 to 24.6 mta in 2015, and in Poland: From 18.8 mta in 2005 to 26.6 mta in 2015.

In Group III, throughput volumes remained almost unchanged in 2005 and 2015. Just 37% reduction was observed in Lithuania in 2007. In 2005, Lithuania refined 9.6 mta, and in 2007, 5.9 mta. However, the throughput recovered to 8.7 mta in 2009 and 2015.

Aggregate throughput in the Northern $(\sum_{l=1}^{L} V_l^M, L = 12, M = 2)$ Region refineries dropped from 395.3 mta in 2005 to 340.5 mta (−14%) in 2013. But the growth resumed in 2013/2015, to 354.9 mta (+4.2%). The aggregate crude output $(\sum_{l=1}^{L} V_l^M, L = 12, M = 1)$ in the Northern Region amounted to 147.9 mta in 2015.

Crude oil disparity $(\sum_{l=1}^{12} V_l^3 - \sum_{l=1}^{12} V_l^1)$ in the Northern Region deteriorated in the study period: From 145 mta in 2005 to 207 mta in 2015. The gap between the aggregate capacity of the region's refineries in 2015 (399.4 mta) and the throughput volumes at refineries (354.9 mta) reached 44.5 mta.

Trends for the oil throughput by refineries of North European countries in the study period is shown in Figure 10.

The chart of crude production, throughput volumes and the total capacity of refineries in the temporary range under review is shown in (Figure 11).

The data (Figure 11) suggests that in 2005/2013, the crude oil throughput volumes in North European refineries dropped from 395 mta to 340 mta (−14%), and in 2013/2015 increased to 355 mta (+4.2%).

Difference between the aggregate refineries' capacity and the throughput of the refineries $(\sum_{l=1}^{12} V_l^2 \cdot - \sum_{l=1}^{12} V_l^3)$ became 44.5 mta in 2015. Oil disparity across Northern Europe $(\sum_{l=1}^{12} V_l^3 - \cdot \sum_{l=1}^{12} V_l^1)$ increased from 145 mta in 2005 to 207 mta (43%) in 2015.

The ratio of the oil throughput to the refineries' capacity

**Figure 10:** Trends of the throughput of North European countries

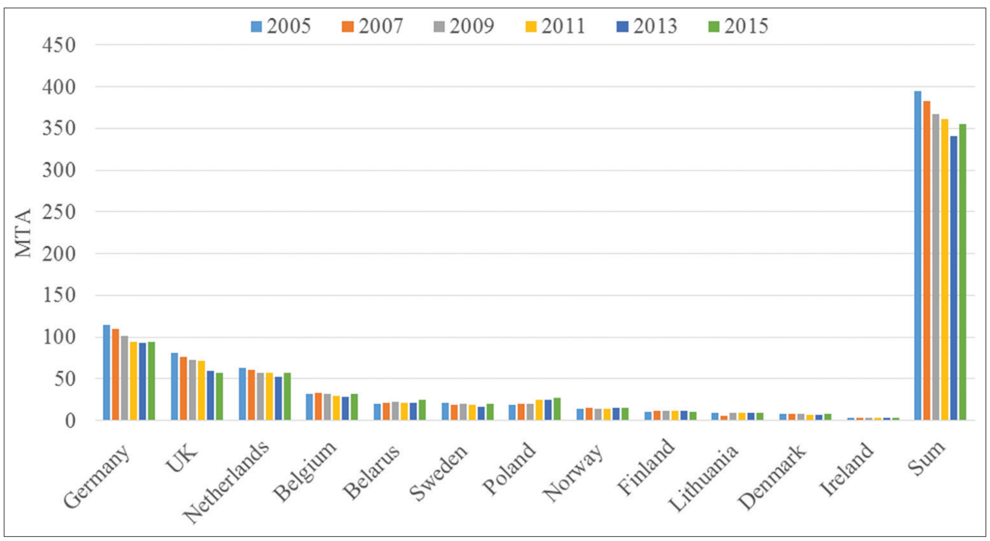



**Figure 11:** Crude oil production and throughput, with the aggregate capacity of North European refineries in 2005/2015

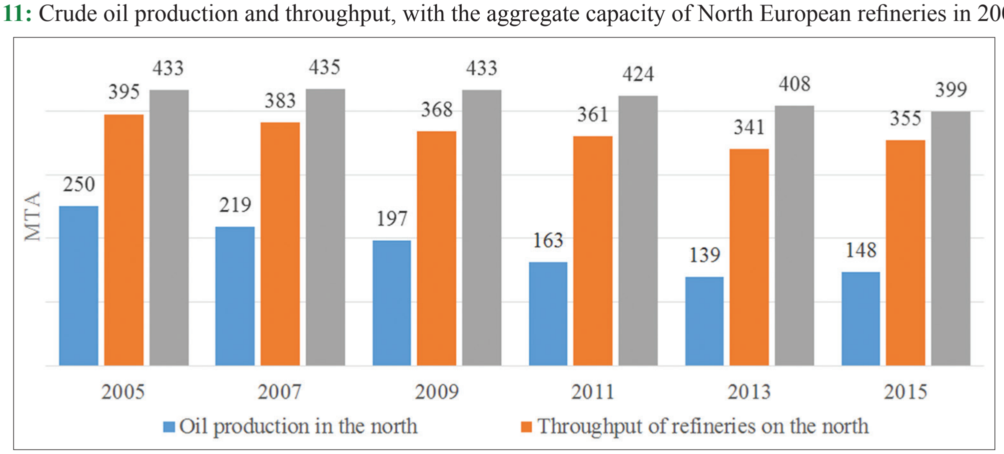
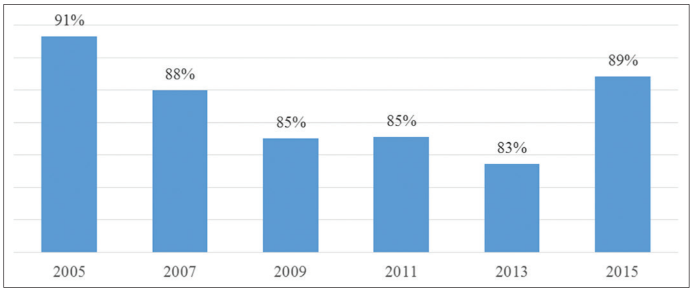


**Figure 12:** Utilization of refineries in region in 2005/2015




suggests the enterprise's utilization rate. Figure 12 shows the utilization rate of the refineries in the Northern of Europe in the study period.

The utilization values (Figure 12) of the refineries were derived as the ratio of the aggregate quantity of crude oil throughput in the refineries of region to the aggregate active capacities of the refineries in the region in this period $(\sum_{l=1}^{12} V_l^3) \cdot / \cdot (\sum_{l=1}^{12} V_l^2)$ . The average utilization rate of North European refineries dropped from 91% in 2005 to 83% in 2013 and then recovered by 6% (to 89%) in 2015.

In this research, we deal with aggregate numbers of oil production, logistics and throughput. Actually, each oil refinery is set up to deal with certain oil types. However, the idea of this research was to demonstrate the general approach, which than can be used in each particular case in more details.

## 8. CONCLUSION

The majority of Northern Europe port terminals is suitable to accept "suezmax" size crude oil carriers. Port terminals and pipelines are intended to refine at least the same volumes as their output in 2005. There is a parity of the marine and pipeline oil transportation to refineries in this region. A significant share of consumers, to whom oil is delivered by pipelines, is located in Germany, Belgium, Poland. A great share of the refineries receiving oil by sea transport are situated in UK, the Netherlands. Six out of 27 companies in North European refining market (Shell, ExxonMobil, Total, BP, Conoco Phillips, PKN Orlen) held more than 57% refining capacities of region, in the aggregate. Such capacity distribution cannot be regarded as monopolistic. The study of trends for oil capacity and throughput concentration in North Europe, using Gini and Herfindahl-Hirshmann indices, suggested that the crude oil capacities and throughput tends to level off in North European refineries. Indices for oil production in region demonstrate the close to monopolistic concentration, which corresponds to the concentration of the core oil production in Norway, UK and Denmark. Even though 12 countries have the refining capacities, their greatest concentration is seen in Group I in 2015, namely, in Germany (26%), in UK (17%), the Netherlands (16%) of the total capacity of North European countries. In 2005/2013, oil production was on the decline across Northern Europe. However, a 6% oil output growth was observed in 2013/2015. Gap between produced and refined oil also increased by 43% from 145 MTA in 2005 to 207 MTA in 2015, means that region became even more depended on the import oil deliveries. In 2013/2015, oil throughput by North European refineries increased (+4.2%), and the growth in local oil production (+6%) was demonstrated. Such trend may entail the increase in oil supplies. Throughput of the increased oil flows would result in greater utilization of refineries and in additional utilization of marine oil terminals of pipelines. Such trend is unlikely to cause any major difficulties in oil supplies because Northern European refineries had 44.5mta (11%) refineries capacity reserve in 2015.

Even if the outlined growth rates for own crude oil production and the growing disparity of imported crude oil remain, the North European transport infrastructure had a guaranteed capacity reserve of 78 mta in 2015. Accordingly, the available capacities of the transport and production infrastructure would allow for the increase of crude oil supplies to Northern Europe at the same rate, without extra investments, in the next few years.

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