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The impact of global refinery upgrade programs on the fuel oil throughput in Port of Rotterdam

by

Jaap Raymans

Abstract

With roughly 50 Mt, fuel oil is the most important oil product flowing through the Port of Rotterdam (PoR). So far fuel oil throughput seems to increase yearly, with Russia as the most important origin for the imports. But for some years now PoR is anticipating the commencement of Russian refinery upgrades. Once completed these upgrades are expected to seriously impact the amount of Russian fuel oil exports and therefore the fuel oil throughput in PoR.

This research aims at estimating the potential impact of the Russian refinery upgrades on the fuel oil throughput in PoR. This is done through qualitative research. In addition the author constructed a quantitative model in order to forecast the global developments in oil product supply and demand for 8 different regions, up to 2025. This second step allowed for a broader identification of threats and opportunities to the oil product throughput in PoR and potential alternatives to the expected decline in fuel oil throughput.

Results from the qualitative research indicate a drop of more than 50% in Russian fuel oil exports by 2020, compared to the 57 Mt in 2012. And due to the distribution of Russian exports between the Baltic Sea ports and Black Sea ports the supply of Russian fuel oil to PoR could drop even more drastically. Simultaneously the vastly increasing demand for medium distillates in Europe, combined with growing surpluses on medium distillates in regions as the ME, FSU and North America create new opportunities for PoR. This research concludes with a short management advice to PoR on how to anticipate to these developments.

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List of Abbreviations

CAGR	Compound annual growth rate
DWT	
IEA	International Energy Agency
IFO	Intermediate Fuel Oil
Kt	Kilo tonnes
IMO	International Maritime Organization
Mb/d	Million barrels per day
ME	Middle East
MGO	Marine Gas Oil
Mt	Million tonnes
MTOMR	IEA Medium Term Oil Market Report
OPEC	Organization of the Petroleum Exporting Countries
STS	Ship-to-ship
WOO	OPEC World Oil Outlook

1. Introduction

Liquid bulk accounted for 45% of the total cargo throughput in Port of Rotterdam (PoR) over 2014 (Castelein 2014). And with an annual throughput of 48 million tons, fuel oil is the most important oil product within the 202.5 million tons of liquid bulk that went through the port in 2014. 60% of the incoming fuel oil originates from Russia and for the outgoing cargo 60% is destined for Singapore (Backers 2013). The Russia-Rotterdam-Singapore route is clearly the most important route for fuel oil going through Rotterdam. An important underlying reason for this route is the beneficial price difference for bunker fuels in Rotterdam compared to Singapore (Smit & Faber 2011). And the shallow ports of Russia only allow smaller vessels to call their requiring a transhipment port on the route between Russia and Singapore.

The fuel oil cargo flow for the Port of Rotterdam is under serious threat due to multiple developments. The general threat to this cargo flow is that, with the exception of the maritime bunkers, the global demand for fuel oil is on a steady decline for over 30 years now. Adding to that, IMO, the International Maritime Organization, mandates that the sulphur level for marine bunkers is limited to 0.5% by 2020. This puts further pressure on the demand for fuel oil, as it is characterized by high sulphur levels. Alternative energy sources such as marine gasoil; diesel and even LNG become interesting alternatives for the maritime sector. Whether or not these alternative bunker fuels could replace Rotterdam's fuel oil throughput is assessed in this research.

But the more specific threat to PoR is the anticipated upgrading program of the Russian oil refinery sector. This upgrading program is stimulated through a new Russian tax regime that incentivizes the production of lighter oil products, at the expense of fuel oil, in order to meet the requirements of the Russian domestic demand. Most of the Russian oil refineries have not been updated since the collapse of the Soviet Union. As a result they remained producing relatively heavy oil products such as fuel oil, whereas domestic demand did change to more refined oil products, partly because of the Russian economic upturn since the early 2000's (Fattouh & Henderson 2012). The abundant Russian fuel oil production created an important cargo flow for PoR, as the port is perfectly located between Russia and Singapore.

The threat of less Russian fuel oil exports to PoR is already known for several years. But so far the Russian market has proven to be very difficult to predict. According to previous expectations the production of fuel oil should have started to decline already. But based on the preliminary figures of 2015, this year again is expected to be a record year for the production of Russian fuel oil. The exceptional drop in oil prices spurred global refinery production, also resulting in additional fuel oil. But although Russia's production figures today don't show a decline in fuel oil production yet, the entire market is still expecting it to happen in the near future. And once it does, it will surely impact the transhipments in PoR. As the prospects for fuel oil diminish other oil products will emerge as potential alternatives, also to PoR. How this shift is expected to take place is researched in the second part of this thesis.

1.1 Research objectives

The objective of this research is to analyse the impact of Russia's refinery upgrade program on the throughput of fuel oil in Port of Rotterdam (PoR). In addition this research provides forecasts on the regional supply and demand balances for oil products. This second part of the research was deemed necessary as PoR's oil product throughput consists not only out of Russian fuel oil. And alternative throughput to the declining Russian fuel oil exports is probably found outside of the Russian market. By geographically mapping the regional developments in supply and demand balances it has been possible to identify a number of threats and opportunities to the oil product throughput in PoR.

The main research question this research aims to answer is:
What will be the impact of Russia's refinery upgrade program on the fuel oil throughput in Port of Rotterdam?

The unpredictability of Russian refinery throughput has been an important reason for wanting to understand the Russian refinery system first before further analysing the global developments in oil product demand and supply. The combined analysis of the Russian refinery system and the forecast results on regional supply and demand balances resulted in a more complete answer to the main research question.

1.2 Relevance

Rotterdam's total liquid bulk throughput consists for almost 25% of fuel oil throughput. The expected changes to the supply of fuel oil from Russia, due to refinery upgrades, make it a very relevant topic for PoR to investigate. Logically the topic for this research was set in collaboration with Port of Rotterdam. Qualitative research on the developments in the Russian refinery system allows for a better understanding of the developments in that region, and it provides an outlook for the Russian refinery output once the upgrades are completed. Secondly, the analysis of global supply and demand developments allows for the identification of both threats and opportunities to the oil product throughput in PoR.

1.3 Research Design and Methodology

The first part of this research consists of qualitative research of the Russian refinery market, the global fuel oil market, and an analysis of the fuel oil throughput in PoR. The second part of this research consists of a quantitative model that forecasts the regional supply and demand of light, medium, and heavy oil products. The model is developed by the author and relies on input data from the IEA energy statistics database as well as IEA Medium Term Oil Market Reports (MTOMR) and OPEC World Oil Outlook reports (WOO). There are certain supply and demand variables in the model that impact the original 2012 data in such a way that the model can forecast the regional supply and demand of the different oil product categories by 2020 and even up to 2025. A detailed description of the methodology can be found in section 4. Preliminary conclusions were drawn on the results of both the qualitative and quantitative research results. These results were then discussed in a meeting with PoR in order to gain further insights as well as test the validity of the results to the real life business environment of PoR.

1.4 Thesis structure

Chapter 2 provides an introduction to the global fuel oil market as well as the transhipment of fuel oil in PoR. The chapter then zooms in on the Russian production of fuel oil and the changes in Russian policy that are expected to severely impact the Russian fuel oil throughput. The chapter concludes with an analysis of different outlooks on the Russian refinery throughput by 2020. Chapter 3 provides preliminary conclusions on how the events, outlined in chapter 2, are likely to impact the fuel oil throughput in PoR. Chapter 4 introduces the methodology behind the model that is used to forecast the regional supply and demand balances for oil products. Chapter 5 presents the models results. Then, a regional analysis of the regional developments for supply and demand is presented in the same chapter. Secondly the impact of these supply and demand developments on the regional oil product balances is analysed and the potential impact of these new supply and demand balances on the international trade of oil products is discussed. Finally the chapter concludes by highlighting those global developments that will specifically impact the oil product throughput in PoR. Chapter 6 concludes by answering the original research question, highlights additional threats and opportunities to PoR, derived from the models results, and points out the limitations of this research as well as interesting areas for further research on this topic. Chapter 7 provides a short management advice to PoR for the oil product throughput based on the overall findings of this research.

2. Analyses of the Russian and Rotterdam Fuel oil market

Conversion rates

In this chapter the global fuel oil market is introduced. Throughout this research a number of abbreviations can be found that relate to oil product quantities. Emphasis is put on presenting throughput and production figures in million tonnes (Mt) but multiple sources communicate either in kilo tonnes (Kt.) or million barrels per day (mb/d). In some events these different numbers had to be converted. In case of fuel oil, 1 mb/d equals 54.39 Mt per year[1] (BP 2015). But this conversion rate differs for every oil product. As a rule of thumb the number 50 is used as a general conversion rate in case for other oil products or aggregated categories of oil products. For the models input data this has not been necessary.

Different historical data sources

The primary sources for historical data on Russian refinery throughput and global demand figures on fuel oil have been the BP Statistical review of World Energy 2015, the IEA Energy Statistics database and IEA's annual Medium Term Oil Market Reports (MTOMR) as well as OPEC's annual World Oil Outlook reports (WOO). Between these sources there was sometimes a diversion in historical figures. But instead of arguing which source comes closest to the actual figures, historical data from one source is only compared to present data from that same source. This prevents, to a large extent, the risk of irrelevant comparisons. Important to note is that all sources are consistent in displaying similar trends in the fuel oil market.

2.1 The global fuel oil market

The global fuel oil market is on a path of global decline. For more than 30 years the global demand for fuel oil has witnessed an almost uninterrupted year on year decline. From a peak of 877 Mt in 1979 global demand has dropped to 434 Mt in 2014. In 1979 the share of fuel oil in the global mix of oil products was 25%. By 2014 this share had dropped to only 8.6% (BP 2015). Demand has primarily declined in the OECD regions and was only partially offset by a more stable demand in the Non-OECD regions and an increasing demand in the Middle East (Figure 1).

[1] From barrels to tonnes is *0.149. From days to year is: 0.149 * 365 = 54.39 (BP) or 6.7 barrels per tonne (IEA)

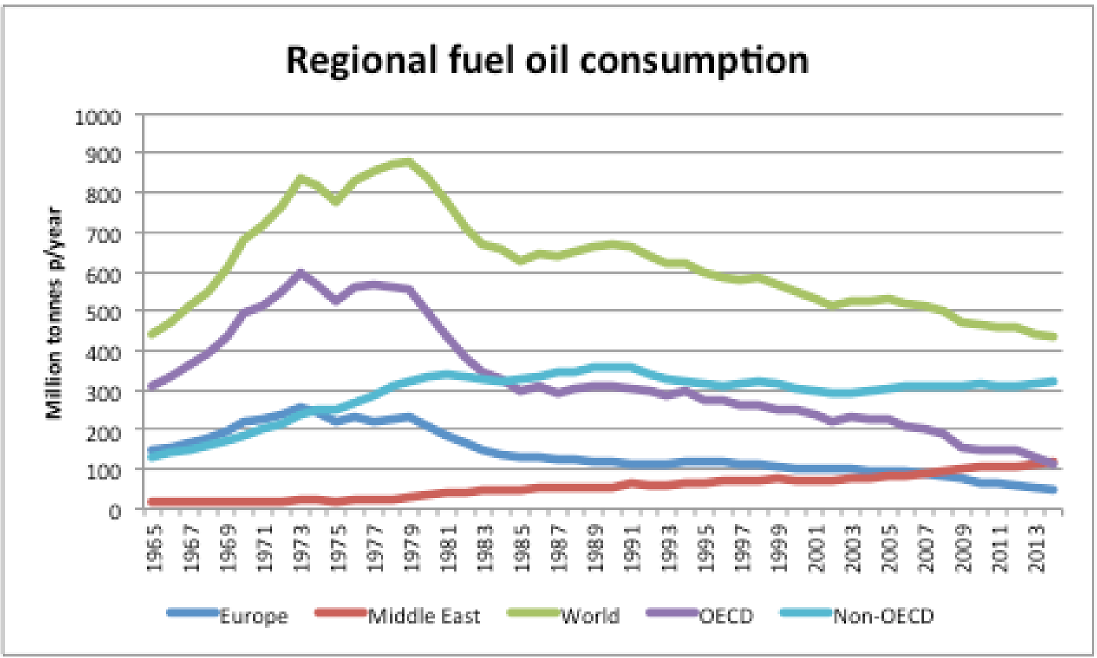

Figure 1: Global and regional fuel oil consumption 1965-2014
Source: Author via BP Statistical review of world energy 2015 workbook

The diversion between OECD and Non-OECD demand for fuel oil is partly explained by the function fuel oil still fulfils to the power sector in emerging regions such as the Middle East. In that region fuel oil is directly burned by the power-sector. And although the relative share of fuel oil is expected to decrease, as a result of fuel switching to natural gas and renewable energy sources, in absolute terms demand in the Middle East is expected to further increase until 2019 (IEA 2014c). In Europe, on the contrary, the power sector has almost entirely switched to coal and gas powered energy and heating plants or different forms of renewable energy.

There are two main reasons that help explain the global decline in fuel oil demand. First, cheaper fuels, such as coal and natural gas, have proven to be easy substitutes for fuel oil as a primary feedstock for heating and electricity plants. Secondly, fuel oil is relative pollutant product compared to other oils and certainly compared to natural gas. Increasing environmental awareness and resulting constraints served as another constraint for global fuel oil demand (Ramberg & Van Vactor 2014). The only real growth market for fuel oil over the last decades has been the international marine bunker market.

2.1.1 Fuel oil as marine bunker fuel

According to IEA (2014a) the global demand for marine bunkers in 2012 was 194 Mt, compared to 111 Mt in 1971. Out of these 194 Mt, fuel oil comprised 170 Mt. So in 2012 total demand for fuel oil consisted for 36% out of bunkers, compared to only 9.3% in 1971 (IEA 2014a; Ramberg & Van Vactor 2014). But this major market for fuel oil is anticipating the most severe changes by 2020. As of 2010 Emission Control Areas (ECA; North Europe, US and Canada) only allows for bunker fuels with sulphur content of 1% or less. Since January of 2015 this content level has been lowered even further to 0.1%. But these actions do not yet affect the majority of the bunker market as most fuel oil is used in international waters and once outside of the ECA zone vessels can use the high sulphur FO-380[2]. But by 2020, or latest 2025 (depending on an IMO assessment in 2018), IMO mandates globally that the sulphur level for maritime bunker fuels is maximized at 0.5% (Ramberg & Van Vactor 2014). At sulphur levels of 0.1% or 0.5% it is becoming increasingly difficult, and expensive, for refineries to desulphurize fuel oil in order to be compliant to these specifications (Stockle & Knight 2009). Rampberg & Vactor (2014) argue that distillates such as marine diesel (sulphur level between 0.3% and 2%) or marine gasoil (sulphur between 0.1% and 1.5%) are expected to partially replace fuel oil as a result. Lloyd's Register (2014) underlines this assumption and sees the share of fuel oil decline in favour of marine diesel oil and marine gasoil as well as LNG. According to IEA already 10 Mt in fuel oil demand will be lost in 2015 as a result of switching from heavy bunker fuels to marine gasoil. And if the global limitation of 0.5% comes in to force by 2020 another 130 Mt in annual fuel oil demand is expected to be lost. Marine gasoil (120 Mt) and LNG (10 Mt) are expected to be the replacement fuels according to IEA (IEA 2015a).

2.1.2 Fuel oil market outlook

The information in section 2.1.1 clearly indicates how the demand for marine bunkers will no longer be supportive to global fuel oil demand in the near future. In addition Ramberg & Vector (2014) argue that fuel oil demand in emerging markets is also set to decline as emerging economies will adopt environmental regulations similar to those in the OECD countries once their economies improve. In their 2015 Medium-Term Oil Market Report, IEA (2015) estimates that Non-OECD fuel oil demand will be 233 Mt in 2020 compared to 293 Mt in 2014. And if fuel oil bunker demand does decrease by 130 Mt by 2020, because of new sulphur regulations, IEA estimates that total, global fuel oil demand could plummet to numbers as low as 288 Mt by 2020 (5.4 mb/d). But in their 2014 World Energy Outlook IEA (2014c) actually displays a slightly more gradual picture in terms of the declining demand for fuel oil as a marine bunker. By using scrubbing technologies or fuel oil hydro treating technologies, fuel oil can remain compliant with the 2020 regulations. But these intermediate solutions don't come cheap. And even in a scenario where scrubber technologies are used as an intermediate solution a drop of 65 Mt in demand is estimated by 2040 compared to 2013.

It is clear that the two driving forces behind the demand for fuel oil are no longer sustainable. And if the supply of fuel oil is not falling in line with the declining demand for fuel oil a lot of volatility in the market is expected in the near future (Cameron & Statham 2015).

2.2. Rotterdam's relationship with Russian Fuel oil

Port of Rotterdam is the largest port in Europe and has a dominant position in the handling of containers and liquid bulk within Europe. The total throughput in 2014 was 444 Mt Liquid bulk accounted for 45% or 202.5 Mt out of the total cargo throughput (PoR 2015b). With a throughput of 48 Mt, fuel oil is the most important oil product within the liquid bulk segment, after crude oil. According to PoR there are a number of reasons why liquid bulk is such an important cargo type for the port. These reasons are summarized in three pillars; production, tank storage and trade. Within the port area there are five refineries including the Shell refinery, the largest

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[2] FO-380 is the cheapest fuel oil product output for a refiner and in order to be complient with current regulations contains less than 3.5% sulphur (Vermerie 2012).

refinery in Europe. Combined these refineries produce between 6-7 Mt of fuel oil per year. By pipe the port is connected to a total of 10 refineries and an even greater number of chemical plants. Another supportive factor for Rotterdam's position as a fuel hub is its large tank storage capacity; multiple companies such as Vopak and VTTI operate tank storage terminals in the port. As a result there is a diverse offering in storage facilities as well as competitive pricing through competition. The final pillar is trade. PoR serves as a price benchmark for a number of oil products, including heavy fuel oil (HFO). And with water depths up to 24 meters PoR is very suitable as a transhipment port (Assche 2014). In addition, Rotterdam is still the worlds third largest bunker port, after Singapore and Fujairah (PoR 2013). And fuel oil is by far the single most import bunker fuel accounting for 9.8 out of the total 10.6 million tons in 2014 (PoR 2014). These numbers clearly underline the importance of fuel oil to Port of Rotterdam.

2.2.1. Transhipment of Russian Fuel oil

In 2014 the total transhipment volume of fuel oil was 48 Mt. There was 28 Mt of incoming fuel oil and 20 Mt was exported that year. For many years Russia is the dominant source for fuel oil, as approximately 60% of the incoming fuel originates from that country. Singapore, on the other hand, is the dominant export destination, as 60% of the outgoing fuel oil is destined for Singapore (Levenswaard 2015). The Russia-Rotterdam-Singapore route is clearly the most important route for fuel oils within PoR. One practical reason for this transhipment of fuel oil destined for Singapore is the water depth in PoR. PoR has a water depth of 24 meters compared to 5-11 meters for the Port of St. Petersburg or 7 meters in case of the Port of Vysotsk. The tanker capacity for these important Russian fuel oil export ports is therefore limited to roughly 100,000 dwt. vessels compared to the large VLCC's that PoR can handle (approx. 300,000 dwt.) (Petersburg Oil Terminal n.d.; Levenswaard 2015). And although the relatively new terminal of Ust-Luga has one berth with a draft up to 17 meters the limited draft of the Danish straits pose another restriction to the vessel size in Russian ports (Ust-Luga Oil n.d.; EIA 2014). So as long as demand for fuel oil remains high in Singapore, PoR is located in a favourable, geographical position to function as a transhipment port for Russian fuel oil. In 2014 a total of 29 VLCC's and 41 Suezmaxes, carrying a total of 8.1 and 5.4 Mt of fuel oil respectively, set sail to Asia (Levenswaard 2015). The majority of the VLCC's delivers crude oil from the Middle East before and are then loaded with fuel oil destined for Singapore. In 2014 20 out of the 29 VLCC's that exported fuel oil in PoR discharged crude oil first (Backers 2015). The demand for crude oil in PoR is high thanks to the European refinery activity and in particular because of the refineries in the port.

2.2.2. Fuel oil trade

An important explanation for the dominant position of Singapore in Rotterdam's fuel oil exports is Singapore's importance as a bunker port. In 2012 Singapore delivered a total of 41.2 Mt of fuel oil as marine bunker fuel. In order to do so it imported 66.3 Mt of fuel oil, against a domestic production of only 7.5 Mt. Another 27.5 Mt of fuel oil was (re) exported that year (IEA 2014a). As stated earlier Rotterdam and Singapore are amongst the most important bunker locations in the world and their bunker prices serve as benchmarks for surrounding ports. An important reason for fuel oil exports from Rotterdam to Singapore is that there often is a beneficial price difference between the two regions (Smit & Faber 2011). This price difference allows for trading opportunities (arbitrage) of bunker fuels between Rotterdam and Singapore. This price difference has been as high as $64 per tonne for IFO 380 and

$41 per tonne for IFO 180 in early 2015. In week 8 of 2015 a tonne of IFO380 Cst. in Rotterdam was $312 compared to a price of $376 in Singapore (Bunker Index n.d.). Such price differences allow oil traders to sell fuel oil from Rotterdam in Singapore and charter a VLCC or a Suezmax in order to transport the fuel oil from North-West Europe to Asia. These exceptional high spreads in the beginning of 2015 were the result of strong bunker demand in Singapore and a spur in (Russian) refinery production resulting from declining oil prices. Oil prices started to fall dramatically in the second half of 2014. The additional fuel oil production from North-West Europe and Russia resulted in an increase of fuel oil throughput in PoR of 11 Mt, compared to the same period in 2014 (PoR 2015a; Ship and Bunker n.d.). Till April 2015, 21 VLCC's and 19 Suezmaxes set sail from Rotterdam to Singapore compared to 10 and 12 in the same period in 2014. In Singapore the extreme price spreads of early 2015 resulted in monthly fuel oil inflows of 7.5 Mt in May and 6.5 Mt in June 2015, compared to a monthly average of 5 Mt over January-April 2015 (Platts n.d.).

2.2.3. Fuel oil chain in PoR

The typical fuel oil trajectory in PoR is displayed in Figure 2. Both the imported fuel oil as well as the locally produced fuel oil is stored in one of the ports tank terminals. In these storage tanks, or in a refinery itself, the fuel oil can be blended into the desired specification through the addition of other fuels and chemicals. In case of bunkering, fuel oil is often loaded on a bunker-barge that sails to a larger vessel in order to deliver the bunker fuel. Another option for sea going vessels is to directly bunker via a jetty. Fuel oil destined for exports are also typically loaded by jetties (Smit & Faber 2011).

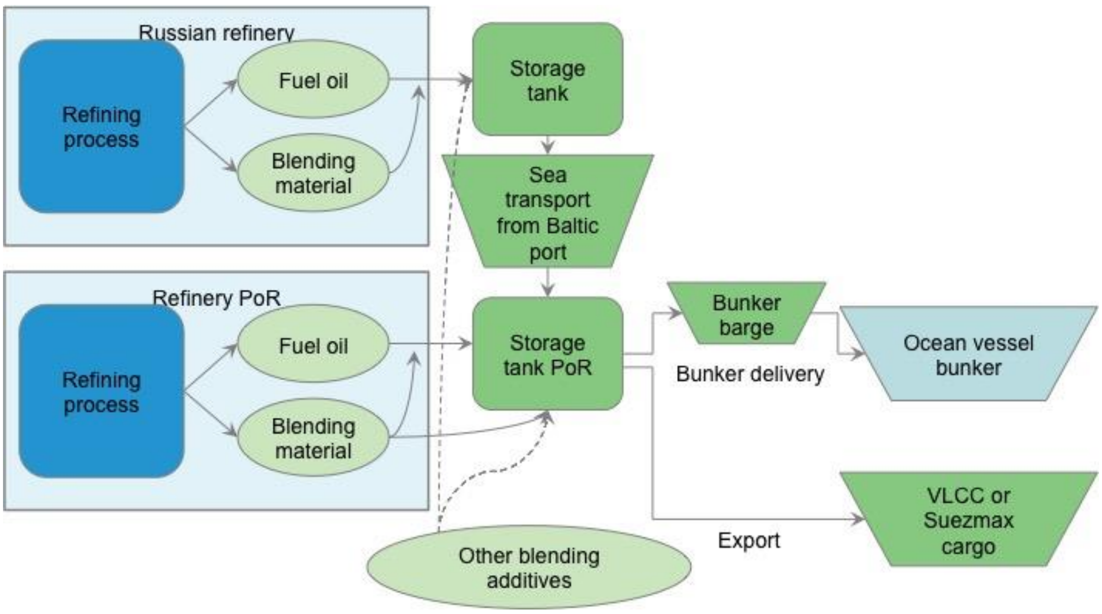

Figure 2: Flow chart of Russian Fuel oil in PoR
Source: Author via Smit & Faber (2011)

But another way of transhipping fuel oil are ship-to-ship (sts) transfers. In this operation fuel oil is transhipped directly from a smaller vessel to a Suezmax or VLCC, without the intervention of a tank storage facility. PoR estimates that it's share in the sts North Sea market for (fuel) oil is around 55%. And in order to strengthen this position another €20 million is invested in new sts infrastructure. This new infrastructure is expected to become operational by the end of 2015 (Levenswaard 2015). An important strategic notion with sts transfers is that it is no longer logical to blend fuel oil in PoR prior to exporting it to Asia. And according to multiple industry players, such as Shell and Vopak, it are precisely the favourable blending conditions in PoR that represent an important reason for Rotterdam's hub position in the transhipment of fuel oil from Russia to Asia (Sijbers 2015). Background information on the refinery process, including blending, is provided in Appendix 1.

2.3 Russia's refinery sector

Even today the Russian oil refining industry is characterized by the history of the Soviet Union. Russia's refining capacity ranks third after the US and China (Kostanian et al. 2012). By 2012 there were 28 refineries operating in present day Russia (Konończuk 2012). All but two of them were constructed throughout the 1950s and 1960s and were built primarily to service the Soviet's vast industrial complex and military operation, these sectors relied heavily on fuel oils (Fattouh & Henderson 2012). In addition, fuel oil was the source for heating in the Soviet Union. As a result, fuel oil accounted for almost 45% of the total Russian refinery output at the end of the Soviet Union (EY 2014).

2.3.1. Russia's refinery system

After the collapse of the Soviet Union in 1991, the refining throughput of the Former Soviet Union (FSU) also tumbled. In 1999 the FSU had a total throughput of 222 Mt compared to a peak of 484 Mt in 1987. The actual refinery capacity in the FSU and the new Russian federation also dropped in the aftermath of the Soviet Union. Russian refinery capacity declined from 358 Mt in 1991 to 264 Mt in 2003 (BP 2015) (Figure 3). In that same time period the utilization rate of the Russian refineries dropped to 60%, (EY 2014). Fattouh & Henderson (2012) even mention that refineries were operating below 50% of their capacity. In this same period hardly any investments were made in upgrading the Russian refineries to alter the product mix. So even though capacity and throughput numbers declined, the relative share of fuel oil in the refineries' product mix was still around 40% by the year 2000 (Fattouh & Henderson 2012).

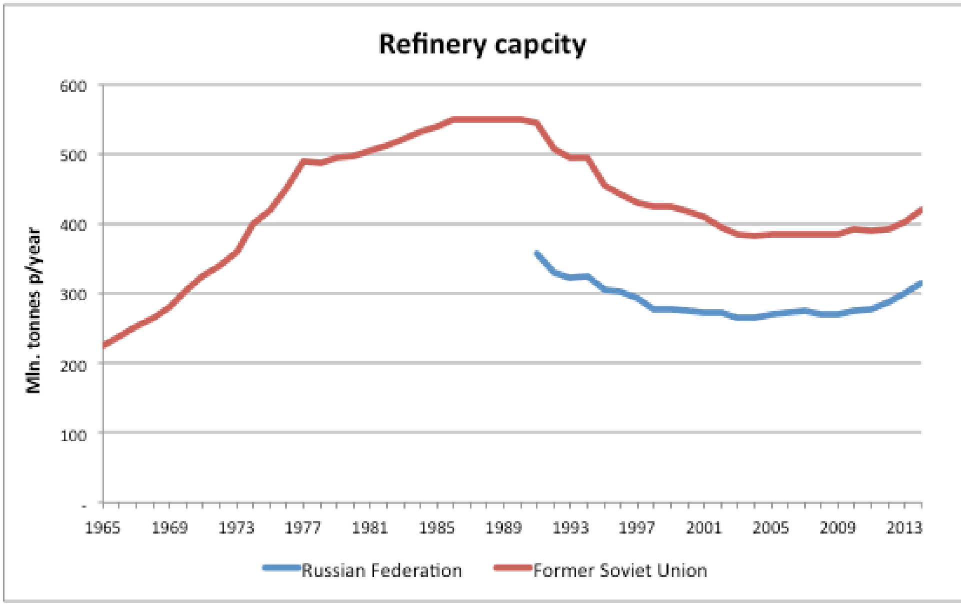

Figure 3: Russian and FSU refinery capacity 1965-2014
Source: Author via BP Statistical review of world energy 2015 workbook

At first the effects of declining refining capacity and the lack of upgrade investments were hardly felt throughout the 1990's in Russia. The economy itself was in decline and the country was still relying on lower quality oil products for their Soviet-era vehicles that used low-octane gasoline. But as the Russian economy finally started to grow again at the end of the economic crisis in 1998/99, the imbalance between demand for, and supply of oil products started to become apparent. The industries in demand for fuel oil, the Russian industrial complex and military, remained in decline whereas the demand for lighter fuel oil products started to increase. This product imbalance became especially apparent for high-octane gasoline, used by more modern, western cars imported into Russia. The Russian refineries were actually able to produce these lighter oil products but due to a technical characteristic of the refining process in older refineries, for every tonne of lighter oil product to be produced there is also an extra tonne output of fuel oil[3]. So as domestic demand for fuel oil declined the Russian refineries were facing a though dilemma in the late 1990's and early 2000's. Either they produced light oil products and accept losses on fuel oil exports, as a result of high export tax on fuel oil, or they had to decrease the amount of fuel oil produced but therefore also fail to meet domestic demand.

2.3.2. Russian Supply and Demand mismatch

The changing Russian demand, in favour of lighter oil products, has been in sharp contrast to the lack of change in refinery complexity. Between 2007 and 2012 the demand for lighter oil products, such as motor gasoline, increased by 22% whereas the refinery output for motor gasoline increased by only 9% during that same period. At the same time fuel oil output remained stable at 30% of the total annual refinery output. In nominal terms fuel oil output increased to 75 Mt in 2012 whereas domestic demand was only 18 Mt by 2012. And out of this 18 Mt only 2.3 Mt was

[3] In a straight run refinery fuel oil output is roughly 50% of the crude feed input (Vermerie 2012). See Appendix 1 for a introduction to the refinery process.

actually destined for final consumption [4] (IEA 2014a). Figure 4 shows the increasingly abundant production of fuel oil from the early 2000's while at the same time the production of motor gasoline was struggling to meet the increasing domestic demand (Figure 5).

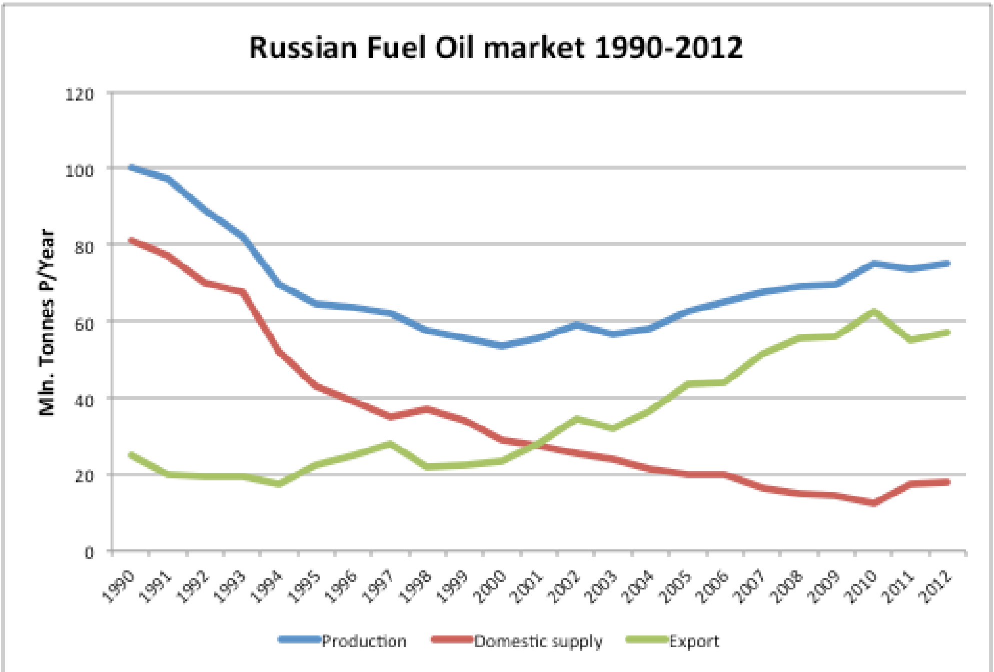

Figure 4: Russian Fuel oil production, demand and export 1990-2012
Source: Author via IEA Energy statistics of Non-OECD Countries

The increase in fuel oil production, starting in the early 2000's, combined with the decreasing domestic demand for fuel oil has spurred the Russian exports of fuel oil. In 2012 Russia exported 57 Mt of fuel oil, i.e. 76% of total production, compared to 23 Mt in the year 2000.

[4] Final consumption includes deliveries to consumers, industry and transport but excludes energy used for transformation processes and for own use of the energy producing industries.

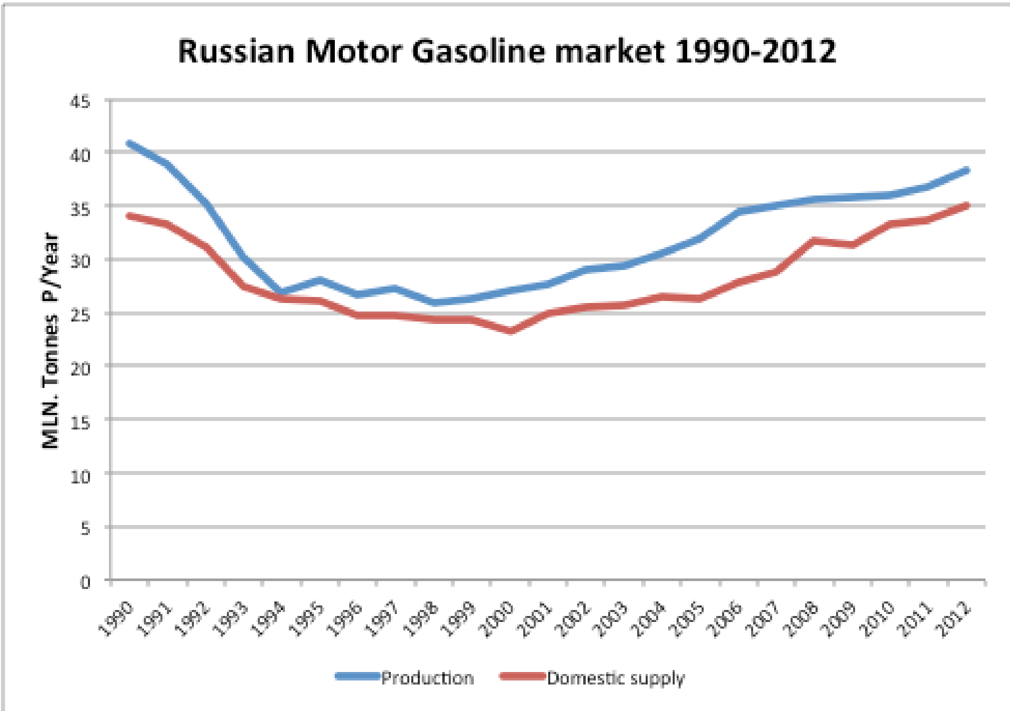

Figure 5: Russian motor gasoline production and demand 1990-2012
Source: Author via IEA Energy statistics of Non-OECD Countries

In 2012 the total Russian refinery throughput was 253 Mt (Figure 6). Fuel oil accounted for 30% of total throughput or 75 Mt and motor gasoline was only 15% of total throughput or 38 Mt Compared to the throughput estimates for an average, modern oil refinery these numbers should have been 19% for fuel oil and 26% for gasoline (Deutsche Bank 2013).

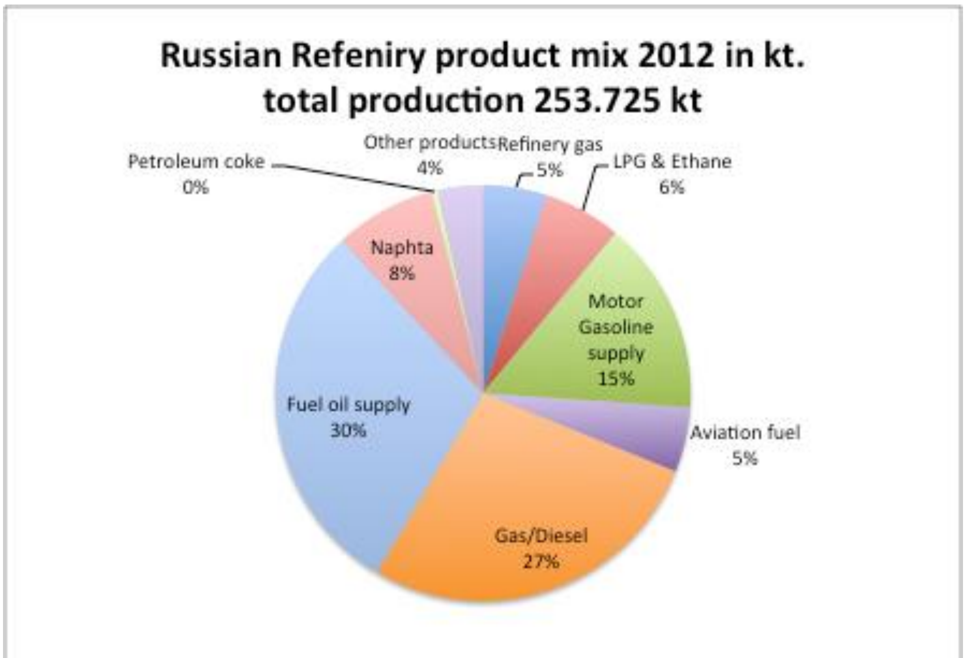

Figure 6: Russian refinery throughput 2012
Source: Author via IEA Energy statistics of Non-OECD Countries 2014

The domestic energy demand is displayed in two separate pie charts in Appendix 3. Although the Russian refineries are capable of meeting the Russian domestic demand in actual numbers the figures clearly indicate a mismatch between Russian production and consumption from a relative perspective. Russian demand for fuel oil is for instance only 13% of the total Russian oil product demand whereas the relative share of motor gasoline demand is 25% (Figure 8 & 9, Appendix 3). In addition, Figure 5 already illustrated how Russian refineries are actually struggling to keep up with the growing demand for motor gasoline in actual terms.

Recent publications indicate that, up until 2015 not much has changed in the refinery product mix. IEA's 2014 Energy Statistics only provide Russian fuel oil figures until 2012. But multiple sources indicate that Russian fuel oil production was 78 and 80 Mt in 2013 and 2014 respectively. Originally 2015 was actually expected to be the year that would herald the decline of Russian fuel oil production (Ruderman 2015). But due to the low oil price Russian refineries are actually on their way to, again, set a new fuel oil production record in 2015. A further outlook on Russia's refinery throughput will be discussed in the section 'Russia's fuel oil market by 2020'.

2.4 The impact of Russian regulations

The increasing mismatch between Russian demand for and supply of refined oil products has not gone unnoticed by the Russian policy makers. From the late 1990's multiple initiatives have been introduced in order to alter the refinery product mix in Russia. This section discusses these actions as well as the (un) desired results.

2.4.1 Tax and regulatory initiatives to change supply

In 1999, the Russian government linked the export tax rate for oil products to the export rate for crude oil. The export coefficient on fuel oil was about 50% of the export tariff on crude oil, whereas the tariff for lighter oil products ranged between 80-120% to that of crude oil. Between 2003 and 2005 the export tariff on all oil products, including fuel oil, was formalised at a rate of 90% of the export tariff on crude oil. This resulted in loss making fuel oil exports for the Russian refineries and a severe negative impact on the industries profitability. In order to concede to the struggling Russian refineries and their production dilemma the Russian government decided to change their export tariff regime again in 2005 (EY 2014).

A new differential export tariff regime was introduced. Table 1 shows how the export of crude oils was taxed up until 2011. As mentioned, the exports of refined oil products were given a differential tax export rate compared to crude oil exports. Table 2 shows the export coefficients for the exports of refined oil products. The export coefficient for Gasoline was set at 90% of that of the crude oil export tariff. This was done in order to retain the lighter oil products for the growing domestic market, whereas the 46.7% tax rate on fuel oil clearly provided a profitable export outlet for this oil product (EY 2011). The intention of the Russian administration was two fold. First, it wanted to provide a profitable outlet for the abundant fuel oil production and second, it aimed at incentivizing the Russian oil industry to export refined oil products (with a higher added value) instead of directly exporting crude oil and consequently have refineries use these additional revenues in order to invest in refinery upgrades (Fattouh & Henderson 2012).

Actual price per barrel (US$)	General duty rate per barrel (US$) 2011
Up to $15	0%
Between $15 and $20	35% x (actual price - $15)
Between $20 and $25	$1.75 + 45% (actual price - $20)
More than $25	$4.00 + 65% (actual price - $25)

Table 1: Crude oil export tariff based on the price per barrel
Source: Author via Author via EY Oil and Gas Tax Alert Sept. 2011

Export duty coefficient until 1 October 2011	
Diesel and jet oil	67%
Fuel oil	46.7%
Oil and Lubricants	46.7%
Gasoline	90%

Table 2: Export coefficients for refined oil products compared to the crude oil export tariff
Source: Author via EY Oil and Gas Tax Alert Sept. 2011

But although the new tax regime certainly helped to improve the refineries profitability it did not lead to any serious investments in refinery upgrades. Most investments were directed towards primary processing capacity and not to secondary processing units that allow for further processing in to lighter oil products (Six 2015). As a result the Nelson Complexity index[5] for Russian refineries only increased from 4.4 in 2005 to 5.1 in 2011, compared to a European average of 6.5 and a US average of 9.6 by 2011 (Fattouh & Henderson 2012; Canadian Fuels Association 2013; Six 2015). Instead the refineries were optimizing their production output in order to benefit in the most optimal way from the export duty coefficients. As a result exports of oil products increased by 109% between 2000 and 2011 (Konończuk 2012). And by 2012 fuel oil still accounted for 30% of total refinery throughput and 53% of the total oil product exports (IEA 2014a).

2.4.2 A new fiscal policy

The previous sections of this paper have shown how today's Russian refinery mix remains out-dated, compared to both the changing domestic demand as well as international standards. Contrary to the original intentions of the Russian government, the tax export system that commenced in 2005 actually supported this out-dated product mix.

So in order to finally initiate a serious upgrade program amongst the Russian refineries a new tax export regime came in to force on the 1st of October 2011. The new export tax system, also known as the 60-66-90-100 system, lowered the maximum export rate on crude oil to 60% (previously 65%) while simultaneously equalizing the export coefficient for light and heavy oil products at 66%. In addition the export duty on gasoline was increased to 90% of that of crude oil exports (EY 2014). The new tax manoeuvre intended to reduce the export of low quality products such as fuel oil, while simultaneously increasing the availability of lighter

[5] The most recognized method to classify a refinery's complexity is the Nelson Complexity Index (NCI). See Appendix 1 for further details.

products (gasoline) to the domestic market. At the introduction of the new tax regime it was already announced that further changes in export duties were to be expected. Table 3 shows how further changes to the tax export tariff have developed over the recent years and how they are expected to be by 2017. Late 2014 a new ‘tax manouvre’ was signed that drastically dropped the export coefficients on lighter oil products. Simultaneously the export coefficient on fuel oils will increase annually up to 100% of the crude oil export rate by 2017. In this same manoeuvre the export duty on crude oil was also lowered further in a drastic manner (from 60% in 2014 to 42% in 2015, down to 30% by 2017). One reason for a lower export duty on crude oil was to be more aligned with the export duty of Kazakhstan and Belarus, countries with whom Russia is forming a united economic zone (Rodova 2014).

Export duty rate	Till Sept. '11	From Oct. '11	2014	2015	2016	2017
Diesel	67%	66%	65%	48%	36%	30%
Fuel oil	46.7%	66%	66%	76%	82%	100%
Motor Oil and Lubricants	46.7%	66%	66%	48%	40%	30%
Gasoline	90%	90%	90%	78%	61%	30%

Table 3: Overview of oil export coefficients according to new legislation
Source: Author via EY Global oil and tax guide 2012, 2013, 2014, 2015

2.4.3 Refining margins

The extreme export discount on fuel oil till September 2011, compared to the export tariff on crude oil resulted in situations in which fuel oil was priced at a discount to crude oil in foreign markets but at the same time the export netback price[6] for fuel oil in Russia was higher compared to crudes. For example fuel oil sold at a $9 per barrel discount to Urals in the Mediterranean in 2010 but the export netback price in Russia for fuel oil was still $12 per barrel higher compared to Urals (Reed 2014). For long the Russian refining margins exceeded the margins of European peers as a result of the old Russian tax regime. The average refining margin in Russia in 2010 was almost $20 per barrel whereas the margins in North West Europe were just $3 per barrel. By 2013 the Russian margins had already dropped to an average of $7 per barrel due to the new tax regime and less favourable market conditions. But maybe more importantly, in a hypothetical scenario of zero export duty on crude oil, EY (2014) calculated that the actual Russian refining margin would have been $14 per barrel negative. So in order to maintain positive refining margins under the changing tax regime Russian refineries will have to shift their production output to the products that now have a more favourable export duty, i.e. the middle and lighter oil products and away from heavy fuel oil.

2.4.4 New product requirements

Another way to enforce refinery upgrades is by altering product requirements. Already in 2008 the Russian government introduced new requirements to oil products such as marine fuel, gasoline, kerosene and car fuels. Through a gradual transition, motor fuels have to meet the most stringent standards by 2016 (EY 2014). This means that by 2016 only the Euro 5 product specifications are allowed for both gasoline and diesel (Nesmelov 2014). But especially higher standards for bunker fuel are expected to have their effect on Russian refinery output. As

[6] Netback price = Price on international market – costs associated to bringing the oil (products) to that market; Transport, Export duty, Cost of loading. Russian taxes are added to the netback price (Argus 2013).

mentioned in section 2.1.1, IMO mandates a maximum sulphur level of 0.5% by 2020 globally. Producing fuel oil with a sulphur level of 0.5% or below will almost certainly require additional residue upgrading or desulphurisation steps (secondary processing units) (Stockle & Knight 2009).

2.4.5 Direct agreements

In 2011 the Russian Government also signed direct agreements with the countries largest 'vertically integrated oil companies' (vioc). In these agreements the viocs took on the obligation to upgrade their existing refining capacity before the year 2020 (Kostanian et al. 2012). These were signed between the 'viocs' and a number of governmental divisions; the Russian Federal Anti-monopoly Service, the Federal Service for Environmental, Technical and Nuclear Oversight, the Federal Agency for Technical Regulation. At the heart of these agreements is a program that oversees the renovation and construction of 124 secondary processing units amongst the Russian refineries (EY 2014).

2.5 Russia's fuel oil market by 2020

Throughout this section an overview is provided of different outlooks for the Russian fuel oil market by 2020. The year 2020 is chosen, as by that time most of the current refinery upgrades will be completed. First the Russian fuel oil production by 2020 is assessed on a company level, secondly the total Russian fuel oil throughput is estimated and thirdly the resulting export figures are presented.

The combination of Russia's tax export manoeuvres combined with more stringent product requirements and direct agreements with 'viocs' is starting to have its effect on upgrading investments in the Russian refinery sector. According to EY (2014) annual investments in Russian refineries have increased from $1.4 billion in 2005 to $10 billion in 2013. All of the countries major refineries are in the process of, or just finalized, major upgrading programs. Overall the sectors Nelson Complexity Index is expected to increase to 7 once the current programs are finished (Fattouh & Henderson 2012). Prior to the tax reforms of 2011 the oil industry invested approximately 20% of their total capital in refineries, by 2013 this number had increased to 25%. This increase in refinery capital expenditure (ie. more secondary processing units are added) will certainly have its impact on Russia's product mix. Lukoil, Rosneft, GazpromNeft, Bashneft and TNK-BP all see their relative share of light oil throughput increase and are all unanimous about the crumbling share of fuel oil production in the upcoming years. Table 4 provides an estimate overview on the relative fuel oil production amongst the largest refineries in Russia. The estimates are based on analyst forecasts, reports, and the companies' own estimates.

Oil company	% Fuel oil	Year	Source
LUKOIL	0%	2015	Fattouh & Henderson (2012)
Rosneft	5%	2020	Khudainatov (2012)
Gazpromneft	0%	2020	Fattouh & Henderson (2012)
Bashneft	1%	2019	Korsik (2014)
Surgutneftegas	5%	2020	Fattouh & Henderson (2012)
TNK-BP	10%	2020	Fattouh & Henderson (2012)

Table 4: Overview of oil export coefficients according to new legislation

2.5.1 Total Russian fuel oil throughput by 2020

In its Global Trends & Outlook to 2025, Lukoil (2013) estimates that the share of fuel oil in the total Russian product mix will drop to just under 10% by 2020 and down to 5% by 2025 (compared to 30% in 2012). In a recent presentation from Rosnefts' Maxim Nesmelov (2014) he estimates that by 2020 40 Mt of fuel oil is produced in Russia (compared to 75 million in 2012). Rosneft expects that the increase in conversion units (refinery upgrades) will change the product mix (lighter oils over heavy oil) but will not increase overall refinery throughput. By 2020 the total refinery throughput will still be around 254 Mt (compared to 253.7 in 2012). A recent analysis from Natixis (2014) shares the same vision on the total Refinery throughput by 2020. In the analysis of Natixis fuel oil accounts for 15% of total production by 2020. The share of Diesel will be well over 30% and the share of Gasoline has increased to 20% of total production by 2020 (Deshpande & Brown 2014).

EY (2014) estimates that by 2020 fuel oil production will account for 15% of total refinery throughput. Production of gasoline will increase from 15% to 18% and production of diesel is expected to increase most, by 7% up to a total of 33%. At the 2014 World Fuel Oil Summit in Athens Mr Antipov and Mr Montefiori, both from Rosneft, estimated the Russian fuel oil output to be 35.5 Mt by 2020 (Axelrod Energy Projects 2014). At the 2015 World Fuel Oil Summit Ruderman (2015) presented an estimate of 22.1% (or 61 Mt.) fuel oil yield by 2018 against a total refinery throughput of roughly 285 Mt From 2015 the year on year decrease in Rudermans' fuel oil production projection is 6 Mt This suggests a 49 Mt fuel oil production by 2020, assuming the y.o.y. decline can be extrapolated for another two years. From all projections Rudermans' appears to be on higher side, both in terms of fuel oil production as well as total Russian refinery throughput. In their 'Global and Russian Energy Oultook to 2040' The Energy Research Institute of the Russian Academy of Sciences & The Analytical Center for the Government (ERI RAS & ACRF) estimated a fuel oil production of roughly 35 Mt against a total refinery throughput of just over 260 Mt (ERI RAS & ACRF 2014). Longer term outlooks to 2035 and 2040 suggest a fuel oil production of 19 and 20 Mt respectively (ERI RAS & ACRF 2014; Grushevenko et al. 2015).

Fattouh & Henderson (2012) provide the most negative outlook in terms of fuel oil production figures by 2020. In their analysis fuel oil throughput could be as low as 12 Mt by 2020. They estimate domestic demand to be 8 Mt by 2020 leaving only 4 Mt available for export by that time. The impact of these different outlooks on the Russian fuel oil exports will be discussed in the next section.

In order to make the percentage estimates absolute we assume a stable, total, refinery throughput of 255 Mt by 2020. In 2011 the Russian Ministry of Energy also stated that they consider the current refinery output levels, of approximately 255 Mt per year, optimal (Konończuk 2012).

Source	Estimate as % of total throughput	Absolute estimates (Mt)
Lukoil (2013)	10%	**25 Mt**
Maxim Nesmelov (2014)		**40 Mt**
Deshpande & Brown (2014)	15%	**37,5 Mt**
EY (2014)	15%	**37,5 Mt**
Axelrod Energy Projects (2014)		**35,5 Mt**
Kostanian et al. (2012)		**37 Mt (2016)**
Ruderman (2015)		**61 Mt (2018)** **49 Mt (2020/author)**
ERI RAS & ACRF (2014)		**35 Mt**
Fattouh & Henderson (2012)		**12 Mt**

Table 5: Estimate overview of Russian fuel oil throughput by 2020

2.5.2 Russian fuel oil exports by 2020 vs. Russian domestic demand

The previous section outlined a projected Russian fuel oil production between 12 to 49 Mt by 2020. How much fuel oil will actually be exported highly depends on the Russian domestic demand by 2020. In section 2.3.2 it was outlined that in 2012 Russia exported 57 Mt of its 75 million tonne production and domestic demand was 18 Mt In this section export estimates are derived from domestic demand and production outlooks.

Kostanian et al. (2012) estimate that, already by 2016, fuel oil exports can drop to 16 Mt against a production of 37 Mt, suggesting a domestic demand of 21 Mt Rosneft expects domestic demand to be 14 Mt by 2020 against a production of 40 Mt This suggests that roughly 26 Mt are available for export by 2020 (Nesmelov 2014). IEA (2015) estimates that by 2020 the Former Soviet Union still exports about 0.4 mb/d (roughly 21.7 Mt per year), down from 70 Mt in 2012. Since 2000 Russian fuel oil production and exports represented anywhere between 70% and 82% of the Former Soviet Union (FSU) fuel oil production and exports (IEA Energy statistics). Assuming a 75% share in the IEA estimates, suggests roughly 16 Mt[7] of Russian fuel oil exports by 2020. In the previous section the export of estimate of 4 Mt by Fattouh & Henderson (2012) was already presented.

Source	Production	Demand	Export
Fattouh & Henderson (2012)	12	8	4
Kostanian et al. (2012)	37 (2016)	21 (2016)	16 (2016)
Nesmelov (2014)	40	14	26
IEA (2015)			16

Table 6: Estimates of Russian fuel oil export capacity by 2020

[7] 21.6 Mt (IEA FSU estimate) x 75% = Russian fuel oil export estimate

3. Impact of fuel oil developments to fuel oil throughput in PoR

The qualitative analysis in section 2, on developments in the global fuel oil market, and the Russian market in particular, allow for preliminary conclusions on the impact of these developments on the fuel oil throughput in PoR.

With a share of 60% in the total incoming fuel oil, Russia represents almost 17 Mt out of the 28 Mt of fuel oil that came into PoR last year. That means that roughly 30% of all Russian fuel oil exports are shipped to PoR. Although a wide range of outlooks on the Russian fuel oil market provide an equally wide range of production estimates to the year 2020, they all agree on the fact that Russian fuel oil production in 6 years time will be considerably less than it is today. The most recent outlooks seem to suggest a Russian fuel oil production between 35 Mt and 40 Mt by 2020. The export estimates of fuel oil, associated with these production outlooks, range from 16 to 26 Mt.

In the optimistic scenario that Russian fuel oil exports would be 26 Mt by 2020, this would leave PoR with roughly 7.8 Mt of incoming Russian fuel oil, compared to 17 Mt today. This calculation assumes that PoR maintains its relative share of 30% in Russian fuel oil exports. If PoR wants to maintain today's level of 17 Mt of incoming Russian fuel oil, PoR should increase its relative share in Russian fuel oil exports to 65% by 2020. The latter is considered unrealistic as roughly 50% of Russian fuel oil is exported through ports in the black sea (Ruderman 2015). Shipments from that region don't go to Rotterdam before reaching their final destination in Asia. If, by 2020, the division between exports from Baltic ports and Black sea ports is still 50/50, this suggests a maximum of 13 Mt of fuel oil that could potentially go through PoR. Based on this qualitative research it is a realistic expectation that the supply of Russian fuel oil to PoR will decline dramatically by the year 2020.

The most important export destination for fuel oil in PoR is Singapore. The primary purpose for the exported fuel oil to that region is to serve as bunker fuel. To date the maritime bunker sector has been the only sector that showed a stable growth in demand for fuel oil. But either by 2020, or 2025, this is expected to change drastically thanks to new IMO sulphur regulations. A potential switch of 130 Mt of annual fuel oil demand to gasoil will almost entirely phase out the need in Singapore for fuel oil imports. And even if scrubber technologies would emerge as an intermediate solution to the 0.5% sulphur cap, an estimated 65 Mt of bunker demand for fuel oil is still expected to disappear. So either way, support from the maritime sector for fuel oil throughput in PoR will severely decline by 2020.

The year on year decline in global demand for fuel oil, in addition to the declining support from the maritime sector, is also not supporting the prospects for Rotterdam's' fuel oil throughput. With yearly records for fuel oil throughput in PoR it can be difficult to believe that dramatic changes in supply and demand of fuel oil are only a few years away from becoming a reality. Nevertheless there is large consensus about the negative forecasts on both the supply and demand for fuel oil. The forecasts only seem to diverge between how much decline and when.

With much consensus on the prospects for fuel oil it is vital for PoR to search for alternative throughput opportunities in different oil products and regions. The next section of this research puts the fuel oil developments for PoR in a broader perspective and allows for the potential identification of these opportunities.

4. Methodology and data

The previous section provided a qualitative analysis on the Russian refinery market and its impact on the fuel oil throughput in PoR by 2020. From this section on, the changes in Russian fuel oil throughput are placed in a broader perspective. This is done in order to identify potential oil products for PoR that can replace the declining throughput of fuel oil. This section introduces the quantitative tools that are used in order to estimate the global changes in supply and demand for oil products. In section 5 and 6 the estimated changes, and the impact of these changes on the throughput in PoR, are further evaluated.

In order to estimate the global changes in supply and demand of oil products a, self-designed model by the author is used. Based on actual 2012 figures, the model is able estimate the developments in the supply and demand for oil products up to 2025. In order to do so the model relies on certain input variables that affect supply and demand. The methodology behind these variables is described in detail in sections 4.2 and 4.3. The variables used by the model in order to produce estimates up to 2020 are compiled by qualitative research. Then the model extrapolates the relative difference between the actual 2012 figures and the 2020 estimates in order to estimate the regional supply and demand of oil products up to 2025. This last step is primarily used as a tool to magnify certain, regional developments, in terms of supply and demand. By doing so it is easier to identify potential 'tipping points' at which a region could for instance switch from being a net exporter of a certain oil product into a net importer of an oil product.

Section 4.1 introduces the methodology behind the 2012 regional supply and demand figures. In addition this section explains the categorization of countries into regions and different oil products into three main categories.

4.1 IEA Energy Statistics database

The IEA Energy Statistics Database provides the input data for the model. This source provides the most detailed information on regional production, consumption, exports, and imports of oil products. The most recent, complete dataset was available for the year 2012. First the available data is categorized; secondly the variables impacting future supply and demand are introduced.

The country specific supply and demand of oil products is ordered in a total of eight regions; Europe, Asia, China, FSU, Africa, Middle East, South America, and North America. An overview of the countries per region is provided in Appendix 4. The IEA Energy statistics database provides detailed information on 17 different oil products. For this research they have been structured into three categories; light, medium and heavy. An overview of the oil products per category is presented in Table 7. Fuel oil and other products, such as bitumen, are grouped in the same category heavy distillates. All products are displayed in kilo tonnes (Kt). Light, medium and heavy are the three typical categories in which individual oil products are segregated (MathPro 2011).

Light distillates	Medium distillates	Heavy distillates
Refinery gas (kt)	Other kerosene (kt)	Fuel oil (kt)
Ethane (kt)	Kerosene type jet fuel excl. biofuels (kt)	Lubricants (kt)
Liquefied petroleum gases (LPG) (kt)	Gas/diesel oil excl. biofuels (kt)	Bitumen (kt)
Aviation gasoline (kt)		Paraffin waxes (kt)
Gasoline type jet fuel (kt)		Petroleum coke (kt)
Naphtha (kt)		Other oil products (kt)
White spirit & SBP (kt)		
Motor gasoline excl. biofuels (kt)		

Table 7: Oil product categories
Source: Mathpro 2011, Author

The relevant factors for determining the regional supply of oil products are; Production, Transfers, Stock changes and statistical differences. Transfers can result from reclassification of oil products, for instance through blending. But transfers can also represent oil products that are further processed and therefore serve as feedstock for another oil product. Stock changes represent the difference between opening stock levels at the years opening and closing. Statistical difference can arise from the use of different national data sources (IEA 2014b). The formula used to calculate final supply per region is:

$$Supply = production + transfers + stock\ changes + statistical\ differences$$

Transformation processes, Energy industry own use, losses, final consumption, international marine bunkers and international aviation bunkers determine the regional demand in this model. The supply to the international marine and aviation sector is taken into account on a regional level as these deliveries do affect the countries import and export balance. The formula is:

$$Demand = transformation\ processes + Energy\ ind.own\ use + losses + final\ consumption + intl.marine\ bunkers + intl.aviation\ bunkers$$

The regional import/export balance should be equal to the result of ‘regional supply’ – ‘regional demand’. An example for the Netherlands is provided in Table 8.

Netherlands 2012

Production	8696		Imports	33207
Transfers	-1053		Exports	-28190
Stock changes	-244			
Statistical differences	0			
Domestic supply	**7399**			
Transformation	0			
Energy Ind. Own use	-8			
Losses	0			
Final consumption	-71			
Intl. Marine bunkers	-12337			
Intl. Aviation bunkers	0			
Total demand	**-12416**			
Supply/Demand balance	**-5017**		**Import/Export balance**	**5017**

Table 8: Dutch fuel oil balance 2012 (Kt)
Source: IEA Energy statistics 2012, Author

The actual 2012 supply and demand data, constructed according to the described methodology is presented on the next page.

2012											
	Supply				**Demand**				**Supply/Demand Balance**		
	supply light	*supply medium*	*supply heavy*	*supply total*	*demand light*	*demand medium*	*demand heavy*	*demand total*	*export light*	*export medium*	*export heavy*
Europe	223.847	301.697	134.352	659.896	195.072	349.524	130.543	675.139	28.775	-47.827	3.809
Asia (excl. China)	298.952	376.939	150.453	826.344	369.136	326.782	188.438	884.356	-70.184	50.157	-37.985
China	167.487	190.709	71.705	429.901	167.984	197.362	106.534	471.880	-497	-6.653	-34.829
FSU	108.131	108.042	105.778	321.951	98.957	65.027	41.047	205.031	9.174	43.015	64.731
Africa	47.303	46.145	34.818	128.266	56.548	82.861	38.338	177.747	-9.245	-36.716	-3.520
Middle East	181.282	143.539	96.938	421.759	107.634	131.285	93.359	332.278	73.648	12.254	3.579
South America	122.552	112.226	105.746	340.524	148.377	143.895	89.969	382.241	-25.825	-31.669	15.777
North America	471.979	331.993	142.876	946.848	480.147	281.806	105.672	867.625	-8.168	50.187	37.204

Table 9: 2012 Regional Supply, Demand and Balance of oil products (Kt)
Source: Author IEA Energy Statistics Database 2012

2012								
	Supply				**Demand**			
	supply light	*supply medium*	*supply heavy*	*supply total*	*demand light*	*demand medium*	*demand heavy*	*demand total*
Europe	34%	46%	20%	100%	29%	52%	19%	100%
Asia (excl. China)	36%	46%	18%	100%	42%	37%	21%	100%
China	39%	44%	17%	100%	36%	42%	23%	100%
FSU	34%	34%	33%	100%	48%	32%	20%	100%
Africa	37%	36%	27%	100%	32%	47%	22%	100%
Middle East	43%	34%	23%	100%	32%	40%	28%	100%
South America	36%	33%	31%	100%	39%	38%	24%	100%
North America	50%	35%	15%	100%	55%	32%	12%	100%

Table 10: 2012 relative mix Supply and Demand for oil products in %
Source: Author IEA Energy Statistics Database 2012

4.2 supply variables

In order to determine the effect of regional supply changes three relevant variables have been identified; Refinery Capacity, Refinery Utilization Rate and Refinery Complexity. Qualitative research was conducted in order to assess the changes of these variables between 2012 and 2020. Multiple sources were used for projections of future refinery capacity, utilization and complexity. For all three variables only the relative changes, from actual 2012 levels to projected 2020 levels, are used. This method minimizes the risk of differences in actual figures between multiple sources. Simultaneously it maintains the projected direction of a certain source. The relative change from these sources is then used to impact the original 2012 data from the IEA Energy Statistics Database. Section 5.6 provides a detailed explanation for the changes in the different supply variables per region.

4.2.1 Refinery Complexity

The changes in refinery complexity are primarily based on outlooks from IEA's Medium Term Oil Market Reports (MTOMR). In their 2013 MTOMR, IEA provided a detailed overview of the secondary processing capacity per region. The report also provides an outlook for the changes to the capacity of secondary refining processes up to 2018. An example is provided in Table 44, Appendix 5. The different refinery processes for which the IEA provides this outlook are: Reforming, Isomerisation, Alkylation, FCC/RFCC, Hydrocracking, Cocking, Thermal Crack/VBU (IEA 2013). In order to use this information for the model all these processes were assigned to one of three different refinery configurations. The three refinery configurations are: a Topping/Hydro skimming refinery, a Conversion Refinery, and a Deep Conversion Refinery (MathPro 2011). These categories are simplified representations of real refinery configurations, and in case of Topping/Hydroskimming a combination of two different refinery configurations (topping + hydroskimming). Appendix 1 provides a more detailed introduction into the different refinery processes and the associated product mixes.

Table 11 shows how the different processes are assigned to the three refinery configurations.

Refinery Process per category		
Topping/HS	*Conversion*	*Deep Conversion*
Topping/HS capicity: Total CDU - (Conversion capacity + Deep Conversion capacity)	Reforming	FCC/RFCC
	Isomerisation	Hydrocracking
	Alkylation	Coking
		Thermal Crack./VBU

Table 11: Overview of different refinery processes per refinery configuration
Source: MTOMR 2013, Author

As mentioned the different refinery processes are categorized into three main refinery configurations: Topping/Hydroskimming, Conversion and Deep Conversion. This is very important as each configuration has a different output mix in terms of light, medium, and heavy oil products. In reality the exact product mix is also dependent on other factors such as the crude oil quality that is used as a feedstock. For the purpose of this research an average output mix for every process is used. Table 12 provides an overview of relative light, medium, and heavy output for a simple Topping/Hydro skimming refinery, a refinery with standard conversion capacity, and a refinery with deep conversion capacity (MathPro 2011).

% Distillates extracted from Refinery Configuration			
	% Light	% Medium	% Heavy
Topping/HS	30%	31%	39%
Conversion	44%	32%	24%
Deep Conversion	47%	42%	11%

Table 12: Relative throughput mix per refinery configuration
Source: Mathpro 2011, Author

The next step is to determine the regional refinery product mix based on the throughput capacity per different process in 2012 based on the information form the MTOMR 2013. First the 2012 processing capacity (mb/d) per region and configuration is provided in Table 13. It must be mentioned that globally Hydro skimming and Topping Refineries only represent roughly 12% of global refinery capacity (Hauge n.d.). Unfortunately, reconstructing this percentage based on the available data from the MTOMR proved to be impossible. But using the relative change in capacity per refinery process helped to circumvent this issue.

Refinery Capacity per Process 2012			
	Topping/HS	Conversion	Deep Conversion
Europe	6,20	3,03	5,88
	41%	20%	39%
Asia (excl. China)	10,48	3,03	6,30
	53%	15%	32%
China	6,34	0,80	6,27
	47%	6%	47%
FSU	4,76	1,58	2,07
	57%	19%	25%
Africa	2,45	0,56	0,46
	71%	16%	13%
Middle East	4,93	1,22	1,82
	62%	15%	23%
South America	3,31	0,54	2,30
	54%	9%	37%
North America	2,54	6,64	12,11
	12%	31%	57%

Table 13: Refinery capacity per different process (mb/d)
Source: MTOMR 2013, Mathpro, Author

The theoretical refineries product mix for 2012 is now calculated by multiplying the regional 2012 refinery configuration, according to MTOMR 2013, by the theoretical output per refinery configuration provided in Table 12. The results are displayed in Table 14.

Supply Product Mix 2012			
	% Light	*% Medium*	*% Heavy*
Europe	39%	35%	25%
Asia (excl. China)	38%	35%	28%
China	39%	36%	25%
FSU	37%	34%	29%
Africa	35%	33%	33%
Middle East	36%	34%	30%
South America	38%	35%	27%
North America	44%	38%	18%

Table 14: Theoretical refinery product mix 2012
Source: author

Now the same procedure is repeated for the expected refinery configuration by 2018. The configuration estimates from the MTOMR 2013 for the year 2018 are assumed to also represent the configurations by 2020. Global delays in the commissioning of refinery upgrades have been persistent over the last couple of years due to changing economical prospects (China) and technical delays (Latin America) (IEA 2014c; IEA 2015a). A more elaborate explanation of this assumption is provided in section 5.6. Table 15 provides an overview of the expected 2018 configuration according to MTOMR 2013.

Refinery Capacity per Process 2018			
	Topping/HS	*Conversion*	*Deep Conversion*
Europe	5,94	3,01	6,05
	40%	20%	40%
Asia (excl. China)	10,20	3,17	7,05
	50%	16%	35%
China	8,58	1,36	7,77
	48%	8%	44%
FSU	4,44	1,67	2,88
	49%	19%	32%
Africa	2,64	0,65	0,56
	69%	17%	15%
Middle East	5,56	1,71	3,22
	53%	16%	31%
South America	3,71	0,73	3,02
	50%	10%	40%
North America	2,39	6,64	12,46
	11%	31%	58%

Table 15: Projected refinery configurations by 2018
Source: MTOMR 2013

The theoretical product mix for 2018/2020 is now again calculated by multiplying the estimated refinery configuration for 2018/2020 with the theoretical output provided in Table 12. The results are presented in Table 16.

Supply Product Mix 2020			
	% Light	*% Medium*	*% Heavy*
Europe	40%	36%	25%
Asia (excl. China)	38%	35%	27%
China	39%	36%	26%
FSU	38%	35%	27%
Africa	35%	33%	32%
Middle East	38%	35%	28%
South America	38%	36%	26%
North America	44%	38%	18%

Table 16: Theoretical refinery product mix 2020
Source: Author

Now the relative change between the theoretical 2012 and theoretical 2020 output for light, medium, and heavy products is calculated. The results are presented in Table 17.

Relative Change in Supply Product Mix			
	Light	*Medium*	*Heavy*
Europe	0,62%	0,44%	-1,59%
Asia (excl. China)	1,32%	0,87%	-2,87%
China	-0,64%	-0,83%	2,20%
FSU	3,35%	2,40%	-6,99%
Africa	0,94%	0,46%	-1,44%
Middle East	4,10%	2,60%	-7,75%
South America	1,77%	0,99%	-3,73%
North America	0,33%	0,31%	-1,44%

Table 17: Relative change in refineries product mix 2012-2020
Source: Author

The second to last step is calculating the new, regional output for light, medium and heavy products (in Kt) based on the relative change per region and product from table17 and the actual 2012 supply figures from the IEA Energy Statistics database (Table 9). These intermediate results are presented in Table 18 and are used in order to determine the new relative share for light, medium, and heavy oil products in the actual 2020 supply estimate.

Expected 2020 Product Mix based on individual product categories				
	Light	*Medium*	*Heavy*	*Total*
Europe	225.227	303.025	132.214	660.467
Asia (excl. China)	302.892	380.222	146.141	829.256
China	166.407	189.129	73.282	428.818
FSU	111.750	110.638	98.387	320.775
Africa	47.746	46.356	34.317	128.420
Middle East	188.706	147.268	89.422	425.397
South America	124.720	113.340	101.804	339.864
North America	473.546	333.036	140.823	947.406

Table 18: Theoretical 2020 product mix (Kt)
Source: Author

Finally these intermediate 2020 supply estimates from Table 18 are used to determine the relative share of light, medium, and heavy oil products by 2020. The results are presented in Table 19. The actual supply estimates for 2020 are presented in chapter 5.

Expected Relative Supply Product Mix 2020				
	Light	*Medium*	*Heavy*	*Total*
Europe	34%	46%	20%	*100%*
Asia (excl. China)	37%	46%	18%	*100%*
China	39%	44%	17%	*100%*
FSU	35%	34%	31%	*100%*
Africa	37%	36%	27%	*100%*
Middle East	44%	35%	21%	*100%*
South America	37%	33%	30%	*100%*
North America	50%	35%	15%	*100%*

Table 19: Estimated relative refinery product mix by 2020
Source: Author

4.2.2. Refinery Capacity

The growth or decline in refinery capacity is primarily based on outlooks from the MTOMR reports. The MTOMR 2013 report provides the actual refinery capacity in 2012; the MTOMR 2015 report provides an outlook for the regional refinery capacity by 2020. The relative change of these estimates is then calculated. This relative change in refinery capacity is taken into account in order to calculate the actual production estimate by 2020. Again, the relative change between the MTOMR 2012 and 2020 figures is used, not the actual difference in production numbers from the outlook. This prevents situations in which the actual 2012 numbers from the IEA Energy Statistics differs significantly from the MTOMR figures. For some regions, such as Africa, a detailed outlook was only available until 2018. A detailed, qualitative, analysis of the regional changes in refinery capacity is presented in chapter 5.

4.2.3. Refinery Utilization

The final variable that determines the actual regional product supply by 2020 is the refinery utilization rate. The primary source for assessing the relative, regional change in refinery utilization rates is OPECS World Oil Outlook 2013 (WOO) and WOO 2014. The relative change is calculated between the actual 2012 refinery utilization rates from WOO 2013 and the estimated utilization rates for 2020 from WOO 2014. A detailed analysis on the regional developments in utilization rates is provided in chapter 5.

Combined, the relative change in capacity and utilization rate determine the overall, relative change in regional supply. The formula used is:

$$\begin{aligned} &Relative\ \%\ change\ in\ regional\ supply \\ &\qquad = (1 + \%change\ in\ regional\ refinery\ capacity) \\ &\qquad * (1 + \%change\ in\ refinery\ utilization\ rate) \end{aligned}$$

The relative change in supply per region between 2012 and 2020 is presented in the Table below. As mentioned the estimates will be discussed in section 5.6.

% Change in throughput 2012-2020			
Region	% Change in Refinery Capacity	% Change in Refinery Utilization Rate	% Change in throughput
Europe	-4,7%	-10,0%	85,8%
Asia (excl. China)	4,0%	-4,5%	99,3%
China	15,0%	-3,0%	111,6%
FSU	5,8%	1,2%	107,1%
Africa	11,0%	4,0%	115,4%
Middle East	30,0%	6,3%	138,2%
South America	21,0%	3,9%	125,7%
North America	4,7%	2,3%	107,1%

Table 20: Total % change in refinery throughput 2012-2020
Source: Author

The final step to determine the actual 2020 supply estimate per region and product category is to multiply the relative change in total throughput (Table 20) by the original 2012 total supply per region (Table 9). This new total supply is then segregated into light, medium, and heavy products by using the results from Table 19 (Estimated relative refinery product mix by 2020). The final results are presented in section 5.1.

4.3 Demand variables

The variables affecting regional demand are; oil product demand and the product mix demand. Again the relative changes between 2012 actual numbers and 2020 projections are used. This allows for the use of different sources while minimizing the risk of different base year data from these sources compared to the figures from the IEA database.

4.3.1 Oil product demand mix

The relative share for light, medium, and heavy oil products in total demand is estimated in a similar manner as for the relative share of the different oil products in total supply (4.2.1). OPEC's WOO reports provide a detailed overview on how the oil product demand is distributed over the different categories per region. They also provide an outlook for the year 2020 for this distribution. The numbers for the base year 2012, come from the WOO 2013 report. And the 2020 outlook is derived the WOO 2014 report. In section 5.6 the composition of these numbers will be explained in more detail, per region. The steps below describe how the WOO data is used in order to determine the product mix demand by 2020.

First the product demand mix for 2012, according to OPEC's WOO 2013, is categorised into light, medium, and heavy oil products. The data is presented in Table 21. The numbers are presented in mb/d.

OPEC Actual Demand 2012			
	Light	*Medium*	*Heavy*
Europe	4,7	7,5	2,5
Asia (excl. China)	7,9	6,7	4,5
China	3,6	3,8	2,4
FSU	1,9	1,4	0,9
Africa	1,3	1,8	1
Middle East	2,5	2,2	2,1
South America	4	3	1,8
North America	12,7	6	2,6

Table 21: 2012 Oil product demand per category according to WOO (mb/d)
Source: WOO 2013, Author

The same is done for the 2020 estimates from OPEC's WOL 2014 report (Table 22).

OPEC Demand Estimation 2020			
	Light	*Medium*	*Heavy*
Europe	4,3	7,6	2,1
Asia (excl. China)	8,8	7,8	4,6
China	4,6	5,3	2,7
FSU	2,1	1,4	0,9
Africa	1,6	2	1,5
Middle East	3,1	2,9	2,4
South America	4,5	3,6	1,7
North America	13,3	6,3	1,9

Table 22: 2020 Oil product demand per category according to WOO (mb/d)
Source: WOO 2014, Author

The next step is to determine the relative change in regional product demand for every separate category (Table 23).

OPEC Relative Change Per Product			
	Light	*Medium*	*Heavy*
Europe	-8,5%	1,3%	-16,0%
Asia (excl. China)	11,4%	16,4%	2,2%
China	27,8%	39,5%	12,5%
FSU	10,5%	0,0%	0,0%
Africa	23,1%	11,1%	50,0%
Middle East	24,0%	31,8%	14,3%
South America	12,5%	20,0%	-5,6%
North America	4,7%	5,0%	-26,9%

Table 23: Relative change 2012-2020 in oil product demand per category
Source: Author

The second to last step is to multiply every individual regional change per product category with the original corresponding demand from the IEA 2012 database as presented in Table 9. This is an intermediate step in order to determine the expected, relative product demand mix by 2020.

Expected 2020 Product Mix (bsaed on individual product growth + Database 2012)				
	Light	Medium	Heavy	Total
Europe	178.470	354.184	109.656	642.311
Asia (excl. China)	411.189	380.433	192.626	984.248
China	214.646	275.268	119.851	609.765
FSU	109.374	65.027	41.047	215.448
Africa	69.598	92.068	57.507	219.172
Middle East	133.466	173.058	106.696	413.220
South America	166.924	172.674	84.971	424.569
North America	502.831	295.896	77.222	875.949

Table 24: Expected 2020 product mix based on WOO estimates Kt.
Source: Author

Finally the results from Table 24 are used to calculate the new relative product mix for every region by 2020. The results are presented in Table 25.

Expected Demand Product Mix 2020				
	Light	Medium	Heavy	Total
Europe	27,79%	55,14%	17,07%	100%
Asia (excl. China)	41,78%	38,65%	19,57%	100%
China	35,20%	45,14%	19,66%	100%
FSU	50,77%	30,18%	19,05%	100%
Africa	31,75%	42,01%	26,24%	100%
Middle East	32,30%	41,88%	25,82%	100%
South America	39,32%	40,67%	20,01%	100%
North America	57,40%	33,78%	8,82%	100%

Table 25: Estimated 2020 relative product demand
Source: Author

4.3.2 Oil product demand

The overall, regional change in oil product demand is primarily based on OPEC's WOO 2013 and WOO 2014 reports. The 2013 WOO report provides actual demand figures for 2012. The WOO 2014 report is used for its outlook on oil product demand through 2020. Again the relative change in actual 2012 demand and projected 2020 demand is used to determine the total regional oil product demand by 2020. The relative change per region is presented in Table 26.

Product Demand Change 2012 - 2020	
Region	Product Demand % Change
Europe	-4,08%
Asia (excl. China)	10,00%
China	25,60%
FSU	7,30%
Africa	21,43%
Middle East	18,57%
South America	12,50%
North America	1,42%

Table 26: Relative change in product demand 2012-2020
Source: WOO 2013, 2014

The regional development in oil product demand is analysed in further detail in chapter 5. The final step is to multiply the 2012 IEA statistics data with the regional demand growth. Finally the relative product mix demand from Table 25 is applied to total product demand. The results are presented in chapter 5.

4.4 2025 estimates

The calculations in the outlined methodology rely for a large part on inputs from IEA's MTOMR en OPEC's WOO outlooks. The resulting, estimated supply and demand for 2020, suggest a trend compared to the original 2012 data. The relative change between 2012 actual data and the 2020 estimated data is extrapolated through 2025. As mentioned at the introduction of section 4 this step is primarily executed as a tool for easier identification of potential tipping points in regional surpluses or deficits. The results of this final step come with great reservations. The compound annual growth rate (CAGR) for the regional change is calculated for both supply and demand using the following formula:

$$CAGR\ regional\ demand = \left(\frac{regional\ demand\ 2020}{regional\ demand\ 2012}\right)^{\left(\frac{1}{8\ (\#years)}\right)} - 1$$

$$CAGR\ regional\ supply = \left(\frac{regional\ supply\ 2020}{regional\ supply\ 2012}\right)^{\left(\frac{1}{8\ (\#years)}\right)} - 1$$

Based on the CAGR the developments in demand and supply are extrapolated until 2025. The results, including estimated supply and demand balances per region, are presented in section 5.1 to section 5.5. Section 5.6 and 5.7 provide a more qualitative analysis of these results. In the qualitative analysis the estimates up to 2025 are also assessed against other sources.

5. Results & Data analysis

Based on the methodology described in chapter 4, changes in the regional demand and supply for oil products, divided into light, medium, and heavy products, for 2020 is calculated and then extrapolated until 2025. The results are presented from section 5.1 to section 5.5. The results are presented in tables that provide information on the actual change in product demand and supply, as well as the change in regional supply and demand balances (section 5.1-5.5). Section 5.5 provides an overview of changes in the relative product mix in terms of supply and demand between 2012 and 2020.

Section 5.6 provides a regional analysis of the developments in supply and demand. Section 5.7 assesses the changes in regional supply and demand balances and provides preliminary conclusions on the effect of these balance changes. The input data from the MTOMR and WOO is also reviewed in these two sections.

Section 5.8 translates the regional developments in oil product balances into the potential impact on the oil product throughput in PoR.

5.1 2020-2025 Light distillates: supply, demand and balances estimates

Supply light distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	223.847	193.011	189.468	185.990	182.575	179.224	175.934
Asia (excl. China)	298.952	299.776	299.880	299.983	300.086	300.189	300.293
China	167.487	186.096	188.563	191.062	193.595	196.162	198.762
FSU	108.131	120.089	121.674	123.280	124.907	126.555	128.226
Africa	47.303	55.052	56.106	57.180	58.275	59.391	60.528
Middle East	181.282	258.543	270.275	282.539	295.359	308.761	322.771
South America	122.552	157.102	162.055	167.165	172.436	177.873	183.482
North America	471.979	506.908	511.452	516.037	520.663	525.330	530.039

Table 27: Estimated 2020-2025, and actual 2012 supply light distillates (Kt)
Source: Author

Demand light distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	195.072	179.938	178.131	176.342	174.570	172.817	171.081
Asia (excl. China)	369.136	406.403	411.319	416.294	421.329	426.425	431.583
China	167.984	208.632	214.361	220.247	226.295	232.509	238.893
FSU	98.957	111.684	113.386	115.113	116.867	118.648	120.456
Africa	56.548	68.539	70.206	71.914	73.664	75.456	77.292
Middle East	107.634	127.253	129.944	132.692	135.499	138.365	141.291
South America	148.377	169.068	171.849	174.676	177.550	180.471	183.440
North America	480.147	505.125	508.337	511.570	514.823	518.097	521.392

Table 28: Estimated 2020-2025, and actual 2012 demand light distillates (Kt)
Source: Author

Estimated 2020-2025 supply/demand balance for light distillates and actual 2012 balance (Kt.)

Supply/Demand balance light distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	28.775	13.073	11.337	9.648	8.005	6.407	4.853
Asia (excl. China)	-70.184	-106.627	-111.439	-116.311	-121.243	-126.236	-131.290
China	-497	-22.537	-25.799	-29.185	-32.700	-36.347	-40.131
FSU	9.174	8.405	8.288	8.166	8.039	7.907	7.769
Africa	-9.245	-13.486	-14.100	-14.734	-15.389	-16.066	-16.764
Middle East	73.648	131.291	140.331	149.846	159.860	170.397	181.480
South America	-25.825	-11.966	-9.794	-7.511	-5.114	-2.598	42
North America	-8.168	1.783	3.115	4.467	5.840	7.233	8.648

Table 29: Estimated 2020-2025, and actual 2012 supply/demand balance for light distillates (Kt)

Source: Author

5.2 2020-2025 Medium distillates: supply, demand and balances estimates

Supply medium distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	301.697	259.680	254.857	250.124	245.479	240.920	236.445
Asia (excl. China)	376.939	376.310	376.232	376.154	376.075	375.997	375.918
China	190.709	211.506	214.261	217.051	219.877	222.741	225.641
FSU	108.042	118.894	120.324	121.773	123.238	124.721	126.222
Africa	46.145	53.449	54.440	55.450	56.477	57.524	58.591
Middle East	143.539	201.769	210.543	219.698	229.252	239.220	249.622
South America	112.226	142.766	147.127	151.621	156.252	161.024	165.942
North America	331.993	356.498	359.686	362.902	366.147	369.421	372.725

Table 30: Estimated 2020-2025, and actual 2012 supply medium distillates (Kt)
Source: Author

Demand medium distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	349.524	357.097	358.055	359.016	359.979	360.945	361.914
Asia (excl. China)	326.782	376.005	382.657	389.428	396.318	403.330	410.467
China	197.362	267.556	277.929	288.704	299.896	311.523	323.600
FSU	65.027	66.401	66.574	66.748	66.923	67.098	67.274
Africa	82.861	90.667	91.693	92.731	93.781	94.842	95.915
Middle East	131.285	165.001	169.783	174.704	179.768	184.978	190.340
South America	143.895	174.891	179.209	183.632	188.165	192.810	197.570
North America	281.806	297.246	299.235	301.237	303.252	305.281	307.323

Table 31: Estimated 2020-2025, and actual 2012 demand medium distillates (Kt)
Source: Author

Estimated 2020-2025 supply/demand balance for medium distillates and actual 2012 balance (Kt.)

Supply/Demand balance medium distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	-47.827	-97.417	-103.198	-108.892	-114.501	-120.026	-125.468
Asia (excl. China)	50.157	306	-6.425	-13.274	-20.243	-27.334	-34.548
China	-6.653	-56.050	-63.668	-71.653	-80.019	-88.782	-97.959
FSU	43.015	52.493	53.750	55.024	56.315	57.623	58.949
Africa	-36.716	-37.218	-37.253	-37.282	-37.303	-37.317	-37.324
Middle East	12.254	36.769	40.760	44.994	49.484	54.242	59.282
South America	-31.669	-32.125	-32.082	-32.012	-31.914	-31.786	-31.627
North America	50.187	59.252	60.451	61.666	62.895	64.141	65.402

Table 32: Estimated 2020-2025, and actual 2012 supply/demand balance for medium distillates (Kt)
Source: Author

5.3 2020-2025 Heavy distillates: supply, demand and balances estimates

Supply heavy distillates							
	2012	2020	2021	2022	2023	2024	2025
Europe	134.352	113.302	110.914	108.577	106.289	104.048	101.856
Asia (excl. China)	150.453	144.638	143.927	143.220	142.516	141.815	141.118
China	71.705	81.953	83.332	84.736	86.162	87.613	89.088
FSU	105.778	105.729	105.723	105.717	105.711	105.704	105.698
Africa	34.818	39.569	40.206	40.854	41.513	42.182	42.861
Middle East	96.938	122.516	126.155	129.903	133.761	137.734	141.826
South America	105.746	128.236	131.364	134.569	137.852	141.215	144.660
North America	142.876	150.745	151.758	152.778	153.806	154.840	155.881

Table 33: Estimated 2020-2025, and actual 2012 supply heavy distillates (Kt)
Source: Author

Demand heavy distillates							
	2012	2020	2021	2022	2023	2024	2025
Europe	130.543	110.558	108.285	106.059	103.879	101.744	99.652
Asia (excl. China)	188.438	190.383	190.628	190.873	191.118	191.364	191.610
China	106.534	116.493	117.802	119.125	120.463	121.816	123.185
FSU	41.047	41.914	42.024	42.134	42.244	42.354	42.465
Africa	38.338	56.632	59.462	62.434	65.554	68.830	72.270
Middle East	93.359	101.729	102.826	103.936	105.057	106.191	107.337
South America	89.969	86.062	85.586	85.112	84.641	84.172	83.707
North America	105.672	77.574	74.634	71.805	69.084	66.465	63.946

Table 34: Estimated 2020-2025, and actual 2012 demand heavy distillates (Kt)
Source: Author

Supply/Demand balance heavy distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	3.809	2.744	2.629	2.517	2.409	2.305	2.203
Asia (excl. China)	-37.985	-45.745	-46.701	-47.653	-48.602	-49.548	-50.491
China	-34.829	-34.540	-34.469	-34.389	-34.301	-34.203	-34.096
FSU	64.731	63.815	63.699	63.583	63.467	63.350	63.233
Africa	-3.520	-17.064	-19.256	-21.580	-24.042	-26.649	-29.409
Middle East	3.579	20.787	23.329	25.967	28.704	31.544	34.489
South America	15.777	42.174	45.779	49.457	53.211	57.043	60.954
North America	37.204	73.170	77.124	80.973	84.722	88.374	91.935

Table 35: Estimated 2020-2025, and actual 2012 supply/demand balance for heavy distillates (Kt)

Source: Author

5.4 2020-2025 total supply, demand and balances estimates

Supply all distillates							
	2012	2020	2021	2022	2023	2024	2025
Europe	659.896	565.993	555.236	544.684	534.333	524.178	514.216
Asia (excl. China)	826.344	820.725	820.025	819.326	818.628	817.930	817.232
China	429.901	479.555	486.152	492.839	499.619	506.492	513.460
FSU	321.951	344.712	347.668	350.649	353.656	356.688	359.747
Africa	128.266	148.070	150.752	153.482	156.261	159.091	161.972
Middle East	421.759	582.829	606.877	631.917	657.991	685.140	713.409
South America	340.524	428.103	440.528	453.314	466.470	480.009	493.940
North America	946.848	1.014.151	1.022.893	1.031.711	1.040.605	1.049.576	1.058.623

Table 36: Estimated 2020-2025, and actual 2012 total supply (Kt)
Source: Author

Demand all distillates							
	2012	2020	2021	2022	2023	2024	2025
Europe	675.139	647.593	644.230	640.884	637.556	634.245	630.951
Asia (excl. China)	884.356	972.792	984.451	996.249	1.008.189	1.020.272	1.032.500
China	471.880	592.681	609.811	627.435	645.568	664.226	683.423
FSU	205.031	219.998	221.944	223.908	225.889	227.887	229.903
Africa	177.747	215.838	221.141	226.574	232.140	237.843	243.687
Middle East	332.278	393.982	402.460	411.121	419.969	429.006	438.239
South America	382.241	430.021	436.399	442.872	449.440	456.106	462.871
North America	867.625	879.945	881.498	883.053	884.610	886.171	887.734

Table 37: Estimated 2020-2025, and actual 2012 total demand (Kt)
Source: Author

Supply/Demand balance all distillates							
	2012	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Europe	-15.243	-81.601	-88.994	-96.200	-103.223	-110.067	-116.735
Asia (excl. China)	-58.012	-152.067	-164.425	-176.923	-189.562	-202.343	-215.268
China	-41.979	-113.127	-123.659	-134.595	-145.949	-157.734	-169.963
FSU	116.920	124.713	125.723	126.741	127.767	128.802	129.844
Africa	-49.481	-67.768	-70.389	-73.092	-75.879	-78.752	-81.715
Middle East	89.481	188.847	204.416	220.796	238.022	256.133	275.171
South America	-41.717	-1.918	4.129	10.442	17.030	23.902	31.069
North America	79.223	134.206	141.396	148.659	155.995	163.405	170.889

Table 38: Estimated 2020-2025, and actual 2012 supply/demand balance for total distillates (Kt)
Source: Author

5.5 Relative changes in the oil product mix

Supply								
	light		medium		heavy		total	
	2012	*2020*	*2012*	*2020*	*2012*	*2020*	*2012*	*2020*
Europe	33,92%	34,10%	45,72%	45,88%	20,36%	20,02%	100,00%	100,00%
Asia (excl. China)	36,18%	36,53%	45,62%	45,85%	18,21%	17,62%	100,00%	100,00%
China	38,96%	38,81%	44,36%	44,10%	16,68%	17,09%	100,00%	100,00%
FSU	33,59%	34,84%	33,56%	34,49%	32,86%	30,67%	100,00%	100,00%
Africa	36,88%	37,18%	35,98%	36,10%	27,15%	26,72%	100,00%	100,00%
Middle East	42,98%	44,36%	34,03%	34,62%	22,98%	21,02%	100,00%	100,00%
South America	35,99%	36,70%	32,96%	33,35%	31,05%	29,95%	100,00%	100,00%
North America	49,85%	49,98%	35,06%	35,15%	15,09%	14,86%	100,00%	100,00%
Total Regions	40%	41%	40%	39%	21%	20%	100%	100%

Table 39: Relative supply oil product mix 2012/2020
Source: Author

Demand								
	light		medium		heavy		total	
	2012	*2020*	*2012*	*2020*	*2012*	*2020*	*2012*	*2020*
Europe	28,89%	27,79%	51,77%	55,14%	19,34%	17,07%	100%	100%
Asia (excl. China)	41,74%	41,78%	36,95%	38,65%	21,31%	19,57%	100%	100%
China	35,60%	35,20%	41,82%	45,14%	22,58%	19,66%	100%	100%
FSU	48,26%	50,77%	31,72%	30,18%	20,02%	19,05%	100%	100%
Africa	31,81%	31,75%	46,62%	42,01%	21,57%	26,24%	100%	100%
Middle East	32,39%	32,30%	39,51%	41,88%	28,10%	25,82%	100%	100%
South America	38,82%	39,32%	37,65%	40,67%	23,54%	20,01%	100%	100%
North America	55,34%	57,40%	32,48%	33,78%	12,18%	8,82%	100%	100%
Total Regions	41%	41%	40%	41%	20%	18%	100%	100%

Table 40: Relative demand oil product mix 2012/2020
Source: Author

5.6 Regional analysis of supply and demand developments

Throughout this section the models results are analysed. This section also assesses the input data from the WOO and MTOMR reports. In some occasions the input data from these sources was slightly adjusted. If it was decided to do so this section will explain why.

5.6.1 Europe

Supply

The recent revival of the European refinery throughput is expected to be short lived. Due to the recent, low oil prices refinery utilization rates were up to 85% in April 2015, compared to 79% in 2012 (IEA 2015b; BP 2015). Nevertheless the combination of falling regional demand and high labour and production costs will ensure Europe's position as the 'sick man' of the global refining industry. Adding to that, the export-geared refineries from the Middle East, the US and Russia increase competition for the European refineries. The regulatory pressure is also expected to have its impact on the industries utilization rate. IEA's (2015b) projection of an utilization of 71% by 2020 is therefore considered realistic. A drop from 79% to 71% represents a decline of roughly 10% this is taken into account by the model. In WOO 2014; OPEC estimates European refinery rates to be 83% by 2020. Priority is given to IEA's estimates, as their publication is more recent and therefore more up to date with today's reality.

In terms of capacity the EU refining industry has been following a path of refinery closures. Between 2008 and 2014 Europe closed over 2 mb/d in refinery capacity, down to 14.2 mb/d by 2014 (IEA 2015a). Some further closures of smaller European refineries are expected up to 2020. Nevertheless the largest chunk of closures is expected to already have taken place. The capacity decline for the model builds on the percentage change between 2012's capacity (15.11 mb/d) and the 2020 outlook estimate of 14.4 mb/d (IEA 2013; IEA 2015a). This represents a 4.7% decline. Resulting from these variables the model estimates a total European supply of 566 Mt by 2020 and 514 Mt by 2025 when the models results are extrapolated. Total supply in 2012 was 660 Mt (Table 36).

European refineries face tough competition from foreign competitors, so where some refineries close, others are battling competition by increasing their investments. In Antwerp and Norway a number of large modernization investments by Exxon and Total are underway in order to convert heavy oil outputs into gasoil or diesel outputs (IEA 2015a). Nevertheless the model output doesn't indicate a change in the refineries product mix. The relative share of light, medium and heavy distillates by 2020 are 34%, 46% and 20% respectively (Table 39).

Demand

Similar to the supply of oil products, the European demand is declining for some years now. The European economic environment is not supporting any severe growth in product demand. But the most structural reasons for Europe's declining demand are technological improvements and stricter environmental regulations (IEA 2015a). OPEC estimates European demand to be 14.1 mb/d by 2020, compared to 14.7 mb/d in 2012. This represents a drop of 4% in total demand. IEA has doubled their estimate for the falling European demand from 0.3% per annum in their 2014 MTOMR to 0.7% per annum in their 2015 MTOMR. When extrapolated over an eight-year period, the latter represents a total decline of 5.7%, (2012-2020). The fluctuation in the estimates, and the fact that OPECS estimate falls right in the middle of IEA's 2014 and 2015 estimates makes that the model relies on OPECS 4% decline estimate. Resulting from these variables the model estimates a total European demand of 648 Mt by 2020 and 631 Mt by 2025 when the models results are extrapolated. Total demand in 2012 was 675 Mt (Table 37).

In terms of demand distribution Europe always has had the highest share of middle distillate demand. Global average for middle distillates is just 35%, compared to over 50% for Europe. Because of an almost eliminated demand for fuel oil by 2020, the relative share for middle distillates is estimated to increase to 55% by 2020. Even in actual terms the demand for middle distillates will increase, despite the overall decline in demand. The share for light and heavy distillates is estimated at 28% and 17% respectively (Table 40).

5.6.2 China

Supply

In 2012 the planned upgrades in Chinese refinery capacity were rather ambitious, especially compared to the economic reality by 2015. In 2012 IEA estimated a refinery capacity of 17.71 mb/d by 2018, compared to a capacity of 13.41 in 2012. In the 2015 MTOMR the outlook until 2020 is adjusted to 14.4 mb/bd. This still represents a 7.5% increase compared to 2012 figures (IEA 2013; IEA 2015a). OPEC maintains a more optimistic outlook on the actual capacity growth in China. According to the WOO 2014 capacity grows to 14.44 mb/d in 2020 compared to 11.6 mb/d in 2012. This results in a 24.5% growth. This divergence in estimates is resolved by using a (rather arbitrary) 15% growth rate for the model. A political reason that supports a more optimistic expectation is the fact that China is not keen on relying on neighbouring countries such as Korea and Japan for spare refinery capacity (Janssens & Fitzgibbon 2015). In addition Chinese government officials still maintain a capacity growth up to 16.3 mb/d (3.4 mb/d + 12.9 mb/d 2012) by 2020. And further plans for additional growth up untill 2025 are being drafted. But Chinese companies such as PetroChina and Sinopec currently seem to take a more cautious stance that resembles the adjusted economic growth path of China. The difficulty in forecasting Chinese refinery capacity is an important remark to the models results. The difference between 15% and 30% capacity growth can make the difference between China being a net importer or a net exporter for oil products. In the longer term (post 2020) the later seems to be the more realistic scenario.

The changing growth path of the Chinese economy has also affected the Refinery utilization rates. From an 83% utilization rate in 2012 the Chinese refinery rate is down to 77% in 2015 (BP 2015; Sharma n.d.). With the commissioning of additional capacity these substantially lower rates are expected to be persistent. A relative change from 83% to 77% would indicate a drop in utilization rate of 7%. The WOO 2013 actually shows a Chinese utilization rate of 81% for 2012, and estimates a utilization rate of 81% by 2020 in the WOO 2014 (OPEC 2013; OPEC 2014). The WOO figures seem less aligned with todays reality. Therefore an intermediate decline of 3%, from the 2012 utilization rate is estimated as input for the model. Resulting from these variables the model estimates a total Chines supply of 479.5 Mt by 2020 and 513.5 Mt by 2025 when the models results are extrapolated (Table 36).

In terms of refinery upgrades, which impact the product mix, no dramatic changes are expected according to IEA (2014). In addition, the Chinese product mix is already relatively modern as the heavy distillates represented only 17.1% of total throughput in 2012 (Xianghong 2011; IEA 2015). For the model no change in refinery complexity is estimated. The relative share for light, medium and heavy oil products is the same for 2020 as it was in 2012 (Table 39).

Demand

Chinese energy demand is expected to grow by almost 30% between 2012 and 2020 according to OPEC's WOO 2014. This growth is perfectly in line with the MTOMR outlook of 2014, which was 3.3% per year. But in the 2015 MTOMR this annual growth is revised down to just 2.6% per year for the period 2014 to 2020 (IEA 2015a; IEA 2014c). As the 2015 MTOMR is a more recent publication than the 2014 World Oil Outlook, the yearly growth rate for the model input has been revised down to 2.9%. This results in an estimated total growth of 25.6% for oil products in China.

In 2012 medium distillates represented almost 42% of total Chinese oil product demand. By 2020 this share has increased to 45.1% according to the models results (Table 40). Although the results do not specify medium distillates into gasoil and kerosene it is expected that kerosene is the driving force behind the growth of middle distillates demand. Aviation fuels are expected to grow significantly, by as much as 4% per year (IEA 2014c). And with only 54 out of every 1000 Chinese people owning a car it is easy to understand how gasoline is going to represent the largest part of the growth in lighter oil product demand. But, on the opposite side, both gasoil/diesel and fuel oil demand are subject to (forced) product switching as the Chinese government puts more and more emphasis on the environmental impact of energy uses (IEA 2015a).

Overall Chinese energy demand is estimated to grow to 592.65 Mt by 2020 and up to 683.4 Mt by 2025 (Table 37).

5.6.3 Other Asia

Supply

Within the other Asia region there is a clear distinction in capacity developments between the OECD countries (Australia, Korea, Japan and New Zealand) and the other countries. The Non-OECD Asia region is expecting some substantial additions to its current refinery capacity through 2020. But the commissioning of multiple refineries in India are constantly delayed (IEA 2015a). Throughout the rest of Non-OECD Asia a similar trend of delays is apparent. But once completed, India, Malaysia, Pakistan and Vietnam will be the countries providing the majority of the increase in capacity (IEA 2013). Compared to the 2013 MTOMR production figures, capacity in Non-OECD Other Asia' is expected to grow by 12.4%, from 11.33 mb/d in 2012 to 12.7 mb/d by 2020 (IEA 2013; IEA 2015a). On the other hand the OECD countries in the region have witnessed a decline in refinery capacity over the last couple of years and that is not expected to change before 2020. The closure of inefficient refineries will result in an expected refinery capacity of 7.9 mb/d by 2020 for the OECD countries within the region, compared to 8.48 mb/d in 2012 (IEA 2015a; IEA 2013). So for the entire region 'Other Asia' an overall increase from 19.81 mb/d to 20.6 mb/d represents a growth estimate of 4%. Although the capacity increase will first result in worsening utilization rates, several outlooks also see a reversion of this trend before 2020 as the pace in which new capacity is added will adjust to the low utilization rates (Janssens & Fitzgibbon 2015). By 2020 an overall utilization rate for other Asia of 78% is estimated. This is a 4.8% decrease from

2012. WOO 2013 and WOO 2014 suggest a similar trend from 88% in 2012 to 84% by 2020 (OPEC 2013; OPEC 2014). The model assumes a decline of 4.5% in utilization rates. As a result the model estimates a total production of 820.7 Mt in 2020 and 817.2 Mt by 2025 (Table 36).

The combination of investments in new refinery capacities and upgrades on the one hand and closure of inefficient refineries on the other will only slightly affect the regions throughput mix. The throughput share of heavy distillates drops from 18.2% in 2012 to 17.6% in 2020 according to the models results. Medium distillates represent 45.9% of the total throughput and light distillates account for the remaining 38.8% (Table 39).

Demand

The Asian region, China excluded, will see an increase of roughly 10% in total product demand between 2012 and 2020 (OPEC 2013; OPEC 2014). With Japan cautiously returning to nuclear energy this will negatively impact the demand growth for the entire Asian region. But strong demand gains in countries such as India lift the entire regional demand by a substantial number nevertheless (IEA 2014c). The model results estimate a total demand of 972.8 Mt by 2020 and 1,032.5 Mt by 2025(Table 37). The relative share of middle distillates grows to 38.7% (from 37%) and demand for heavy distillates drops to 19.6% (from 21.3%) of total demand (Table 40). Another important explanation for this redistribution can be found in Singapore. The 2020 IMO sulphur regulations will seriously affect the demand for fuel oil in favour of gas oil.

5.6.4 Middle East

Supply

Percentage wise the ME will, without a doubt, develop the most additional refinery capacity to 2020. Capacity is expected to increase from 7.97 mb/d in 2012 to 10.3 in 2020, an increase of almost 30% (IEA 2013; IEA 2015a). Saudi Arabia is responsible for almost 50% of this capacity increase. A lot of emphasis is put on increasing the refineries yield, mainly benefitting the output of middle distillates (gasoil/diesel). The growth in the ME is driven by both an increasing regional demand as well as efforts that try to add value domestically instead of exporting only the less valuable crude oils. In terms of adding secondary processing units the ME is ahead of China and Other Asia in actual terms (OPEC 2014). By 2020 OPEC (2014) forecasts ME utilization rates to be at 84%. Compared to the 79% level of 2012 this represents a 6.3% increase (OPEC 2013). The increase of 6% is the estimate used for the model. The total output will grow from 421.8 Mt in 2012 to 582.8 Mt in 2020 and to 713.4 Mt by 2025 according to the models estimates (Table 36).

The product mix in the Middle East seems to remain broadly the same according to the estimates from the model. The lighter crude oil feedstock results in light distillates representing the largest share of oil product outputs with 44.4% by 2020. 34,6% of refineries output is represented by middle distillates and the remaining 21% consists of heavy distillates (Table 39). The model only indicates a very small change in the refineries product mix.

Demand

This region shows an above average growth in oil demand for the period up to 2020. OPEC estimates the total product demand to grow by more than 18% between 2012 and 2020 (OPEC 2013; OPEC 2014). In its 2015 MTOMR, IEA (2015) appears to show an even higher estimate for demand growth of roughly 20% (7.8 mb/d to 9.4 mb/d). Nevertheless IEA also stresses how the recent, low oil price pose a risk to the demand outlooks for the region. In addition countries such as Saudi Arabia undertake a lot of efforts to encourage efficient use of energy, such as stricter building standards that will decrease energy use of air conditions as well as restricting the use of inefficient, old vehicles (IEA 2015a). The model therefore relies on OPECS estimate of 18%. Based on this estimate the total oil product demand for the region is expected to be 394 Mt by 2020 and 438.2 Mt by 2025 (Table 37).

IEA and OPEC share the same outlook for the changing product mix. The actual demand for fuel oil will remain stable throughout the period (2012-2020) because of the energy and industry sectors. But real growth takes place for gasoil, and diesel. This growth is fuelled by a growing number of trucks and buses as well as the anticipated shift in maritime bunkers from fuel oil to gasoil. Gasoline growth will also show an increase because of the fast growing number of consumer cars, though not as impressive as middle distillates (OPEC 2014). The relative share of medium distillates grows from 39.5% in 2012 to 41.9% by 2020. And although demand for fuel oil remains consistent in actual terms, the relative share drops from 28.1% to 25.8%. The model estimates the relative demand for light oil product to be the same between 2012 and 2020 (Table 40). Based on the previous qualitative analysis this share should probably rise slightly over the forecasted period.

5.6.5 Africa

Supply

Although Africa is a large producer of crude oil it was a net importer of light, medium and heavy oil products in 2012 due to the lack of adequate refining capacity. But there are concrete plans for new refineries in Nigeria (400 kb/d), and in Angola construction of a 120 kb/d refinery is already underway (IEA 2015a). But ever-imminent delays in construction make it difficult to forecast the actual capacity by 2020, but an increase is forecasted nevertheless. In 2013 IEA estimated the African refinery capacity to be 3.85 mb/d by 2018. More recent MTOMR reports no longer publish growth estimates specifically on the African refinery capacity. Due to the uncertainty of delays the model prolongs the original 2018 outlook to 2020. Compared to a capacity of 3.47 mb/d in 2012, the 2018 projections are an 11% increase (IEA 2013). The Utilization rate is expected to improve considerably, from 61% in 2012 to 67% by 2020 (OPEC 2013; OPEC 2014). This 10% increase is also used as the models input data. As a result total African supply will increase from 128.3 Mt in 2012 to 148.1 Mt by 2020 and 162 Mt by 2025 (Table 36).

There is no serious indication that Africa's refinery complexity is about to change in the reported period. The models results underline this as the product mix only shifts marginally to middle and light distillates to the detriment of heavy products (Table 39).

Demand

African demand for oil products is expected to increase by more than 21% between 2012 and 2020 (4.2 mb/d to 5.1 mb/d). The largest increase in demand is found for gasoil and diesel (OPEC 2014). Important reasons for this serious increase in oil product demand are the relatively strong macroeconomic outlooks as well as the fact that Africa has one of the lowest per capita uses of energy. In their 2014 MTOMR, IEA (2014) had even a slightly more optimistic expectancy towards the increase in overall demand for Africa. But out of cautionary considerations the model relies on OPECS estimates of 21%.

Africa is the only region in which the relative share of heavy distillates will increase. It changes from 22% in 2012 to 26% by 2020 (Table 40). Increasing demand for bitumen, better known as asphalt, causes the increase. The underlying reason is the strong need to expand road infrastructure (OPEC 2014). Total oil product demand is set to increase from 177.7 Mt in 2012 to 215.8 Mt in 2020 and 243.7 Mt by 2020 (Table 37). As the divergent growth rates for supply and demand suggested Africa will stay a significant importer for oil products.

5.6.6 FSU

Supply

The Russian refineries will primarily develop in terms of upgrades. The overall refinery capacity within both Russia as well as its former FSU partners is not expected to increase dramatically. IEA estimate a capacity increase of 5.8% to 2020 (from 8.41 mb/d in 2012 to 8.9 mb/d) (IEA 2015a; IEA 2013). This is in line with previous research on the Russian refinery sector. Russian refineries already have one of the highest utilisation rates (only US refineries have a higher utilization rate) and there are no signs that this will change negatively. The model input for a change in refinery utilization is 1.2% as OPEC expects rates to slightly improve from 83% in 2012 to 84% by 2020 (OPEC 2013; OPEC 2014). The models results suggest a total FSU oil product supply of 344.7 Mt by 2020 and 359.7 Mt by 2025 (Table 36).

The complexity of FSU refineries, and those in Russia in particular, is expected to show a severe change. Prior analysis of outlooks in this paper suggests heavy oil products represent just 15% of the total refinery throughput by 2020, compared to over 30% today. For the entire FSU region the model results nevertheless show a 30% share of heavy distillates by 2020 compared to 32.86% in 2012 (Table 39). This can partly be explained by the fact that heavy distillates also include other products. But the models results in terms of changes in the refineries product mix seem (a bit) of track compared to the qualitative analysis earlier in this thesis. A relative share of fuel oil below 20% seems highly realistic based on previous research.

Demand

Between 2012 and 2020 the demand in Russia and the Caspian Sea region is expected to increase from 4.1 mb/d to 4.4 mb/d, a total increase of 7.3% (OPEC 2014). Earlier IEA (2014) projections suggested an annual growth rate of 2.1% for the period 2013-2019. Given the trade barriers between Russia and the EU, combined with the thereof resulting economic challenges, the more modest estimate of 7.3% from OPEC is chosen as input data for the model. The demand forecasts resulting from the model are 220 Mt in 2020 and 229.9 Mt by 2025 compared to 205 Mt in 2012 (Table 37).

In terms of demand distribution the IEA and OPEC data differ substantially for the base year 2012. For 2012, OPEC (2013) sees a distribution of 41%, 29% and 29% for light, medium and heavy product demand respectively; whereas the FSU distribution based on the IEA/OECD energy statistics data suggest a demand distribution of 48%, 32% and 20%. The IEA/OECD data is clearly most in line with the qualitative analysis on the Russian domestic supply for 2012. Strangely the demand distribution from WOO 2012 and WOO 2014 are again similar to the actual 2012 demand distribution. The irregularity in the 2012 figure appears to be caused by the 0.8 mb/d demand for 'other products'. Other products demand was 0.5 in 2013 and 0.4 in 2010 (OPEC 2012; OPEC 2013; OPEC 2014). Assuming there is a irregularity, the model uses the WOO 2013 data as base year figures in order to calculate the change in the product demand mix by 2020.

The model results show the share of light product demand increase from 48.3% in 2012 to 50.8% by 2020 (Table 40). The results indicate that light distillates increase at the expense of both medium and heavy oil products. The relative share of medium oil products drops from 31.7% to 30.2% and heavy products drop from 20% to 19%. Part of the explanation can be found in new (private) car registrations that increase the share for gasoline demand (OPEC 2014).

5.6.7 North America

North America, and the US in particular, have witnessed a revival of its oil production and refinery industry thanks to the so called 'shale oil revolution'. Contrary to Europe the US is expected to witness a small increase in total refinery capacity, from 21.29 mb/d in 2012 to 22.3 mb/d by 2020 (IEA 2013; IEA 2015a). This increase of 4.7% is used as input for the model. Utilization rates in the US remain very strong and outlooks even expect a slightly further increase. OPEC expects a utilization rate of 89% by 2020, compared to 87% in 2012. For the model the increase in utilization rate is estimated at 2.3% (OPEC 2014; OPEC 2013). The results for total supply for North America is 1.014 Mt in 2020 and 1059 Mt by 2025 compared to 946.8 Mt in 2012 (Table 36).

The important, underlying reason for this growth in production of oil product is the availability of cheap crude oil as a feedstock. The combination of the shale revolution together with US legislation banning crude exports has resulted in lower crude prices within the US compared to the rest of the world (Janssens & Fitzgibbon 2015).

The North American region already experiences a modern supply of oil products as heavy oil products only represent 15% of total supply against 50% light and 35% medium distillates (Table 39). The lighter crude oil from the shale fractions is likely to result in even a lighter product mix in the future. Other changes in the Americas have to do with redistribution between medium and light oil products. For instance efforts are undertaken to reduce gasoline output in favour of medium distillates such as diesel (IEA 2015a). But the models results show no sign though of this potential redistribution between light and medium distillates. According to the model, the relative product mix by 2020 is expected to be the same as it was in 2012 (Table 39).

Demand

Again contrary to Europe, North America does also see a small increase in the oil product demand up to 2020. Stronger economic growth, compared to Europe and, thereto related, falling unemployment rates support product demand through the period up to 2020 (IEA 2015a). OPEC estimates a total growth of 1.4% between 2012 and 2020 (21.2 mb/d to 21.4 mb/d). But in their longer term outlook up to 2040 OPEC does expect the total oil product demand to decrease to 17.8 mb/d by 2040, largely because of increased energy efficiency (OPEC 2014). For the 2020 estimates the model nevertheless uses the 1.4% increase for the period 2012-2020. The resulting demand by 2020 is 879.9 Mt and 887.7 Mt in 2025, compared to 867.6 Mt in 2012 (Table 37).

North American demand for gasoline is hardly increasing in actual terms anymore up to 2020. Energy efficiency and switching to alternative fuels, for instance to diesel fuelled vehicles, are the most important reasons highlighted by OPEC. Gasoil demand will increase until 2020, partly because of IMO regulation, and partly because of an increase in truck traffic and busses. The relative share of heavy distillates is expected to drop severely between 2012 and 2020 as the remaining fuel oil demand is replaced by either natural gas or diesel (OPEC 2014).

The models results underline OPECS outlook for heavy distillates as the share drops from 12.2% to 8.8% (Table 40). In return both medium and light distillates see their relative share increase compared to 2012 figures.

5.6.8 South America

Supply

As with Africa, no more specific outlooks on South America are provided in the MTOMR 2014 and 2015 editions. In 2013 IEA still estimated an additional 1.31 mb/d CDU capacity by 2018, compared to 6.15 mb/d in 2012. This was primarily based on planned projects in Brazil, Colombia and Venezuela. But prevailing allegations of corruption in Brazil in combination with mismanagement has severely altered these expectations (IEA 2013; IEA 2014c; IEA 2015a). Given the delays and the lack of more specific projections, the 7.46 mb/d capacity is put forward to 2020. This suggests an estimated growth in production of 21%. In terms of product mix not much is expected to change up to 2020. Although some upgrading programs are underway, for instance in Colombia, expected commissioning of these programs is no sooner than 2020. Refinery utilization was relatively low in 2012 due to technical issues in Venezuela and bad weather in Brazil that year (IEA 2013). OPEC estimates the utilization rate climbs from 77% in to 2012 to 80% by 2020 (OPEC 2014; OPEC 2013). The model incorporates this 3.9% increase.

The results are a total oil product demand of 428.1 Mt in 2020 and 493.9 Mt by 2025, compared to 340.5 Mt in 2012 (Table 36). The relative share of heavy distillates drop from 31% to 30% and both medium and light distillates increase slightly (Table 39).

Demand

Overall demand for oil products in South America is expected to increase by 12.5% for the period 2012-202 (From 8.8 mb/d to 9.9 mb/d) (OPEC 2014; OPEC 2013). This growth is primarily driven by the increase in private cars (gasoline), as well as growing demand for medium- and heavy-duty vehicles (gasoil/diesel). Declining use of fuel oil in the maritime sector and the industry sectors result in a slightly lighter share of for heavy distillates in the 2020 product mix (OPEC 2014). The IEA energy estimate a similar growth path based on their 2014 MTOMR, with an average growth rate of 1.5% per annum. This is a sharp readjustment to earlier IEA projections (2% in 2013, and 3.7% for 2007-2013). Important reasons to do so are the changed macroeconomic outlooks as well as the lower oil price. The current oil price makes it impossible for oil exporting regions, such as Venezuela, to balance their budget. This in turn will have an impact on further economic growth as well as growth in product demand (IEA 2015a; IEA 2014c). The input demand growth rate for the model is 12.5%.

Results are a total demand of 430 Mt in 2020 compared to 382.2 Mt in 2012. By 2020 demand is estimated at 462.9 Mt (Table 37). As expected from the qualitative analysis from IEA and OPEC reports, the relative share of heavy distillates will decline. According to the results heavy distillates drop from 23.5% to 20% by 2020. Medium distillates increase from 37.7% to 40.7% and light distillates increase slightly from 18.8% to 39.3% (Table 40).

5.7 Regional analysis of 2020-2025 supply/demand balances

The developments in supply and demand per region can result in some regions seeing their oil product deficit turning into a surplus while other regions are likely to experience the opposite. This can also differ between the different oil products. In this section the developments in the regional supply and demand balance, per product, is discussed, as well as the (potential) implications of these changes towards the international trade of oil products. The world maps that display the geographical overview of the regional supply and demand balances per oil product category are presented in Appendix 6.

5.7.1 Europe

In 2012 Europe was already a severe net importer of middle distillates (47 Mt). Throughout the forecasted period this net deficit on middle distillates is expected to increase to 97 Mt by 2020 and up to 125 Mt by 2025 (Table 32). Over the same period the surplus on both light and heavy distillates will gradually decline from 28 Mt to 4.8 Mt (Table 29) and 3.8 to 2.2 Mt (Table 35) between 2012 and 2025 respectively. The declining refinery activity as well as the demand deficit shifting even further to middle distillates will seriously affect the European oil product trade. The declining surplus on light distillates will affect the export position of Europe for this product group. Especially when noticing that the North Americas will turn their deficit on light products in 2012 into a surplus by 2020 and see this further increasing to 8.6 Mt by 2025 (Table 29).

A number of realistic implications of the European developments are:

- Decreasing European refining activity results in less crude oil demand as a feedstock affecting crude oil imports from Russia, Middle East, Africa and even the North Americas
- The increasing deficit on Middle distillates results in Europe fully absorbing middle distillates imports from the North Americas, FSU, and ME, hardly allowing for any transhipments of middle distillates to Asia, including China, and Africa
- The light distillate balance for North America is changing into a surplus. This makes the region the obvious supplier to the South American deficit on light distillates. Combined with a declining light distillate surplus in Europe it is easy to understand how the European exports to South America will be impacted negatively.
- The transhipment of fuel oil will be heavily affected by a declining output of Fuel oil in Europe, Less supply of Fuel oil from the FSU, and a decreasing demand for fuel oil in Asia, and in particular Singapore, because of marine bunker switching. In addition the opening up of crude imports in China for smaller refineries lowers Asian demand for fuel oil even further.

5.7.2 China

According to the models forecasts China will become the second largest importer of oil products with a deficit of 113 Mt by 2020, coming second after the rest of Asia. This deficit is growing further through 2025 up to 170 Mt (Table 38). The growing deficit between 2020 and 2025 deserves a lot of reservation though, as the Chinese government is still pushing towards extensive increases of refinery capacity. If all expansion plans are commenced this could even turn China into a net exporter of oil products in the longer term. The large, projected deficit by the model on middle distillates is probably not realistic. Chinese demand growth for middle distillates is cooling of while production of middle distillates will remain as the majority of the refineries output. In addition the Chinese desire to obtain independency, especially from surrounding nations as Korea, make it very likely that the total deficit by 2025 turns out to be considerably lower than the estimated 170 Mt Nevertheless the growing deficit until 2020 will already have its implications on oil product trade for the region. And in the case of light oil products China could very well see a growing deficit in its supply and demand balance. In 2012 China had an almost balanced supply and demand for light oil products, but by 2020 it is estimated to have a 22 Mt deficit, and potentially a 40 Mt deficit by 2025 (Table 29). The 6.6 Mt deficit for medium distillates turns into a 56 Mt deficit by 2020 and potentially 98 Mt by 2025 (Table 32). The deficit on heavy distillates shows almost no change in the projected period and remains at 34 Mt (Table 35). The summarized implications below do take into account a less extreme development of the Chinese product balance deficit.

- The Middle East is already the dominant supplier for naphtha to the Asian region. In case of a growing Chinese deficit for light oil products, such as naphtha, it is realistic to expect that the Middle East will become the primary supplier to China.
- Part of the Chinese demand for fuel oil existed because independent Chinese oil refineries had to use fuel oil as a feedstock, because they were prohibited to directly import crude oil feedstocks. Recent changes to Chinese regulation now allow more companies to directly import crude oil. This will most likely intensify Chinese crude imports from the Middle East and FSU and even South America.
- If China would see an increasing deficit on their trade balance for light, medium and heavy distillates, the Middle East again appears to be the region that could cover the potential deficits.
- The FSU, with stable surpluses on heavy and medium distillates, remains another important source for imports into China in case of deficits on the Chinese product balance. But the supply of medium distillates will likely be jeopardized by the enormous deficit in Europe.
- Demand for Naphta, which is primarily used as a feedstock, is actually a product for which China could turn to the US. But until now oil product trade between these two regions is minor.

The models results on China rely on input variables that suggest a Chinese demand growth that outpaces the Chinese growth in production. Over the course of a 10-year period we could realistically see capacity growth catching up with, or even surpassing, demand again. There are a couple of effects that could result from that:

- A Chinese surplus on light, medium and heavy distillates make it an outstanding supplier to the product balance deficits in Africa.
- The other Asia region too is a logical region to export Chinese surpluses to.

- From a geopolitical perspective China is probably the preferred trading partner to South America, compared to the US. With lower transport costs (thanks to low oil prices and a new canal in Nicaragua) the geographical distance between the two regions becomes less of a barrier.

5.7.3 Asia

The Asia region sees its overall balance deficit grow from 58 Mt in 2012 to 152 Mt in 2020 up to 215 Mt by 2025 (Table 38). The events of growing demand in the Non-OECD countries in the region combined with refinery closures in the OECD countries and delays of newly built refineries in the non-OECD region seem to underline these results. Relatively, the deficit for medium distillates shows the biggest increase, from a 50 Mt surplus in 2012 to a 34 Mt deficit in 2025 (Table 32). But the majority of the regions imbalance is represented by the 131 Mt deficit for light distillates by 2025 (Table 29). How oil product trade in the region will develop is also dependent on the refinery developments in China and whether that country actually has a balance surplus or deficit. Preliminary conclusions from the models results are:

- The projected deficit for medium distillates can be fulfilled from both the Middle East region as well as the North Americas. Oil product trade between Korea, Japan and the west coast of the US has already been strong over the years. The direction of trade will depend on specific product imbalances. Together with Singapore these countries can serve as hubs within the Asian region.
- India, the other large exporter in the region, is also an export candidate for the European deficits on medium oil products. Already India has exported products to Europe, in situations of favourable price conditions compared to the competing regions in the Middle East.
- Within the region only India has a severe surplus on light distillates (15 Mt in 2012). Together with the Middle East, India is expected to deliver these light oil products to the rest of the region which witnesses increasing deficits on its product balances.

5.7.4 Middle East

The Middle East will experience a huge increase in surpluses on their product balance for all three product categories. The increasing refinery capacity is the foremost reason for these higher surpluses. It's geographical position make that the region can export globally and that no continent is out of economic distance. On the other hand this does also mean that for almost every potential export market the Middle East is at least facing one other competitor. The surplus on light distillates is expected to grow from 73 Mt in 2012 to 131 Mt by 2020 and up to 181 Mt by 2025 (Table 29). The surplus for middle distillates is considerably lower through the same period. It increases from 12 Mt in 2012 to 36 Mt by 2020 and 59 Mt by 2025 (Table 32). Due to its vast refinery expansion the Middle East will also see a severe increase in heavy distillate surplus from 4 Mt in 2012 to 34 Mt by 2025 (Table 35). The potential implications on the product trade are outlined below.

- The medium distillate export market in Europe for the ME is facing competition from the FSU and US. But with the ever increasing European deficit the European market is most likely to be the dominant export market for middle distillates out of the ME.
- Geographically the Middle East has an advantage over the US and the FSU for medium distillate deliveries to the African market. As the African deficit on

medium distillates remains persistent over the forecasted period it is likely that the same will apply for ME exports to Africa.

- On light distillates the ME seems to become the primary supplier to all regions that are experiencing deficits on their light product balance. Only minor competition is expected on these products from the North Americas or the FSU, especially because the ME surplus in actual terms is the most considerable.
- In case of regional deficits in the Asian and Chinese markets, the Middle East is a logical supplier. But the developments in these regions could also turn into regional surpluses or only minor deficits, especially for middle distillates. The extent to which the ME will actually have an outlet for its surpluses in the Asian region is therefore difficult to estimate.

5.7.5 FSU

In 2012 the FSU was undoubtedly the largest product exporter in the world. Throughout the forecasted period it will primarily start to face competition from the Middle East region. The overall production of the FSU will only increase incremental and so will the overall product balance surplus of the region. The surplus in medium distillates will see the largest increase from 43 Mt in 2012 to 52.5 Mt in 2020 and 59 Mt in 2025 (Table 32). The logical destination for this surplus is Europe as it is in dire need of medium distillates and already the most important region for Russian oil product exports today. The impact of Russia's changing oil product balances on its international trade is shortly outlined below.

- Competition on the European market is increasing for its medium distillates exports. North America and the ME are the most important competitors for this market. The European deficit seems large enough though to not have exporting regions fight severely for the European market.
- The up rise of North America and the ME as exporters of middle distillates to Africa is probably a bigger threat to current exports from Russia. The ME has a favourable location for the Eastern part of Africa and North American distillates are already shipped to Africa, often via transhipment in Europe.
- Africa, together with Asia, will remain important export markets for Russian fuel oil throughout the period, as long as bunkers don't switch all together to gasoil.
- If bunkers switch from fuel oil to gasoil this opens up a new opportunities for Russian gasoil exports to the Asian region. Nevertheless transhipment is expected to happen in European ports or waters. The shallow waters of the Baltic sea are an important reason for this expectation.

5.7.6 Africa

The combination of increasing demand and an underdeveloped refinery system make that Africa will see its import demand grow throughout the forecasted period. The largest imbalance can be found for middle distillates. By 2025 the deficit for middle distillates is estimated at 37.3 Mt (Table 32). But the deficit on heavy distillates increases the most, from 3.5 Mt in 2012 to 29.4 Mt by 2020 (Table 35). An important notion is that this mostly concerns heavy oil products other than fuel oil.

- For imports on medium distillates Africa can rely on a number of regions, the FSU, North America and ME. In addition Indian refinery output is also a potential supplier although it is more likely for this region to export surpluses to the rest of the Asian region, because of its geographical proximity.
- The FSU will probably remain an important source for the deficit on heavy distillates.

5.7.7 North Americas

In North America total surplus is estimated to increase from 79.2 Mt in 2012 to 171 Mt by 2025 (Table 38). The primary drivers of this increase are the heavy distillates. Demand for heavy distillates is expected to decline further whereas US refinery capacity slightly increases. The model output though doesn't take the crude quality into account. The light shale oil in North America will have a different output than average crude oil quality. Refining shale oil is in favour of medium and light distillates. This needs to be taken into account when interpreting the US surplus developments. The model output indicates an increase in heavy distillate surplus from 37 Mt in 2012 to 92 Mt by 2025 (Table 35). The surplus on medium distillates remains more stable and increases from 50 Mt in 2012 to 65 Mt by 2025 (Table 32). The real interesting change is noticeable for light distillates. North America will see a 8 Mt deficit in 2012 turn into a 8 Mt surplus by 2025 (Table 29). The latter is expected to have a serious impact on the international trade of light oil products.

- In terms of light distillates North- and South America used to be reliant on exports from Europe and the Middle East. As North America will see its deficit turn into a surplus it will actually become a competitor to the South American market.
- The fact that Europe sees its light distillate surplus decline could suggest an export opportunity for the US to Africa too, certainly when the South American deficit on lighter oil products indeed decreases, as projected by the model.
- The increasing surplus on medium distillates, combined with the increasing European deficit, will reinforce the North American position as a supplier to the European market.
- Exports to Asia, through South Korea, Japan, and Singapore is likely to increase in case the regional deficits in Asia turn out as is estimated by the model outputs.
- Exports to Africa for Light, medium and heavy distillates can increase as African deficits are persistent and European competition fades.
- New competition for Asian, African and European markets, from the emerging ME on middle distillates is expected.

5.7.8 South Americas

By 2020 the total expected deficit of South America is just 1.9 Mt compared to 41.7 Mt in 2012. And by 2025 the deficit could have turned into an overall surplus of 31.1 Mt (Table 38). This potential switch is mainly driven by an increasing surplus on heavy distillates, from 15.8 Mt in 2012 to 61 Mt in 2025 (Table 35). The deficit on medium distillates remains stable throughout the forecasted period, at 31.6 Mt by 2025 (Table 32). And by 2025 light distillates still face a deficit of 12 Mt compared to a deficit of 25.8 Mt in 2012 (Table 29). The model results estimates a perfect balance for light distillates by 2025. In terms of light and medium product imports the up rise of North America, especially on light products, and the ME, especially on medium distillates, has already been discussed. The increasing surplus of heavy distillates can shipped to Asia as long as bunker markets remain important clients for fuel oil. But it is expected to become increasingly difficult to find profitable outlets for fuel oil surpluses globally. This fact could urge refining companies to speed up their upgrading programs and thereby shifting the product mix to the more valuable

5.8 Impact of the new global supply/demand balances on PoR

In chapter 5.7 the changing regional supply and demand balances have been assessed and the first conclusions were drawn on how these new balances affect the global trade of oil products. This section specifically aims at outlining how these global changes relate to the throughput of oil products in PoR. The conclusions in this section also draw on earlier results from the qualitative research in section 2 and the preliminary conclusions from section 3. The geographical illustration of the developments in supply and demand balances in Appendix 6 help are a useful tool in order to visualize the information in this section.

The declining refinery production within Europe is expected to have multiple consequences for PoR. On the one hand there will be less need for feedstocks, i.e. lowering crude oil imports from the ME and FSU. And on the other hand the declining refinery throughput will result in less oil products being available for exports. For the route Rotterdam-Singapore-ME-Rotterdam this is an extra worrying development. Less VLCC's are expected to call in PoR to deliver crude oil and simultaneously there will be less, locally produced, fuel oil available to bring back to Singapore.

The changing product balance in the FSU will affect the current transhipment of fuel oil in PoR. As the FSU surplus balance shifts from heavy to medium distillates, less fuel oil will arrive in PoR and logically less fuel oil is therefore available for further transhipment to Asia, and Singapore specifically. On the upside PoR is likely to see more medium distillates arrive from the FSU. But contrary to fuel oil, Europe itself is in dire need for medium distillates. So where fuel oil imports from the FSU boosted the international transhipment on to VLCC's, the import of medium distillates is likely to result in more throughputs bound for European destinations. Diesel and gasoil are typically transhipped onto barges, for distribution throughout Europe via the rivers, or short sea shipping for the UK ports. The increasing European deficit on medium distillates, together with increasing medium distillate surpluses in the FSU will support an increase of middle distillate products going through PoR.

The uprise of the ME as a region with surpluses on medium distillates is likely to increase European imports from that region through PoR. Nevertheless Asia, Africa and even South America are regions competing with Europe for these increasing exports from the ME. The same is true for the surpluses on medium distillates in India. Another, very important, issue with the increasing European demand for medium distillates is the increasing fight over these imports amongst European ports. Contrary to fuel oil, gasoil and diesel hardly require any further processing before final use. Therefore the required port infrastructure for the transhipment of diesel and gasoil is less demanding than, for instance fuel oil transhipments that require (some) additional blending. As a result, even more European ports can compete for the European imports of gasoil and diesel compared to the transhipment of fuel oil. This issue will be discussed further in section 7.

Africa is the only region that sees their deficits increase on light, medium and heavy distillates. This creates additional opportunities for PoR as it could see an increase in transhipments to Africa. This will most likely concern light and medium distillates from North America, the FSU as well as the ME. Deliveries to the west coast of Africa still create the opportunity for additional transhipment of ME oil products to Africa.

The estimate that the US becomes a net exporter of light distillates is also likely to affect the throughput of light oil products in PoR going to South America. The European surplus on light distillates resulted in steady exports to South America. With a North American surplus these European exports will have to compete with US exports, and they have a favourable geographical position compared to Europe. But the huge ME increase in its surplus on light distillates does probably still leave Europe, and PoR, in a relative good position for transhipments of light oil products to South America.

6. Conclusions

The original research of this thesis focused on the impact of the Russian refinery upgrades on the fuel oil throughput in PoR. With the original scope only focussing on Russia and Rotterdam this question could be answered, to a large extent, with qualitative research alone. But in order to understand the full impact on the throughput in PoR, the developments in Russia have been placed in a global perspective. And from this global perspective the expected changes in Rotterdam's throughput of heavy, medium and light distillates were analysed. As a final step potential opportunities for PoR in these developments were identified. Section 6.1 presents a summary of the key findings from the qualitative research in section 2, which were also presented in section 3, and key findings from the quantitative research from section 5. Section 7 zooms in on the potential opportunities for PoR.

6.1 Key findings

In 2014 the throughput volume of fuel oil in PoR was 48 Mt. 28 Mt was incoming volume and another 20 Mt was (re) exported that year. The primary origin of the fuel oil was Russia, accounting for 60% of all imports or roughly 17 Mt. Between 2012 and 2014 the net fuel oil export volume in Russia was between 57 Mt and 60 Mt per year, against an annual production of roughly 80 Mt. Rotterdam's share in Russian fuel oil export has been roughly 30%. Due to the current refinery upgrades and changes to the export tariffs, Russia is expected to see its fuel oil production decline to volumes of 35 to 40 Mt by 2020. With no severe change in Russian domestic demand for fuel oil (roughly 18 Mt) it is easy to understand how the influx of Russian fuel oil in PoR will be affected severely negative by the Russian refinery upgrades. In section 3 it was explained how, even under an optimistic estimate of 26 Mt of Russian fuel oil exports by 2020, only 13 Mt will potentially flow through PoR. This is a result of the division of fuel oil exports between Baltic ports and Black sea ports. Exports from the Black sea don't go through PoR. So even in a situation that PoR manages to seize 100% of this 13 Mt it will still mean in a severe decrease from today's numbers. In addition to declining Russian fuel oil throughput, the decline in European refinery activity will also result in less fuel oil being available for exports from PoR.

The main export region for Rotterdam's fuel oil throughput has been Singapore, as that country is the major bunker port in the world and marine bunkers account for 36% of global fuel oil demand. This export flow will also suffer a major blow once the global sulphur cap of 0.5% will come into force, either by 2020 or 2025. As a result fuel oil demand in Singapore can drop to insignificant numbers as demand for marine bunkers switches from fuel oil to gasoil. Based on these findings, the most important oil product route for PoR today is expected to be only of minor importance by 2020.

Forecasting the global demand and supply of all oil products per region, categorizing them into light, medium and heavy oil products, allowed for further assessment of the changing oil product throughputs in PoR. The declining Russian fuel oil production is replaced by additional Russian production, and exports, of medium distillates, such as gasoil. But as Europe will see its deficit on medium distillates increase from 47 Mt in 2012 to 97 Mt by 2020 and potentially even to 125 Mt by 2025 it is unlikely that much of these medium distillate oil products will be transhipped further to Asia. More likely Europe absorbs these incoming oil products.

So it is not very likely that gasoil can replace the FSU-PoR-Singapore fuel oil route. The increasing demand for gasoil in Singapore, resulting from the sulphur cap, is more likely to be serviced from ME exports. And Europe itself will also see an increase of medium oil product imports from the ME, as the surplus on the ME product balance increases from 12 Mt in 2012 to 36 Mt by 2020 and possibly even 59 Mt by 2025.

But although the increasing imports of medium distillates create additional intra European transhipment opportunities for PoR, the transhipment of diesel and gasoil is also a more straightforward procedure. With 5 refineries and a great number of tanker storage facilities PoR has a very competitive position amongst European ports when it comes to processing and blending oil products up to certain specifications before they are shipped out again. But the imported diesel and gasoil hardly require any further processing. PoR will therefore have to compete with a greater number of European ports that are able to receive and tranship medium distillates.

The increasing African product balance deficits, together with increasing product balance surpluses in North America and the ME create a potential growth area for PoR. Especially on the light and heavy distillates, because Europe encounters surpluses on those two product categories and therefore doesn’t fully absorb the incoming volumes from different regions in the world. Even North American exports to Africa are often transhipped via Europe before reaching their final destination in Africa. But, simultaneously the future net export position of North America on light distillates creates a threat to exports of light oil products from PoR to South America. North America is in a favourable geographical position to service the South American region.

Although today’s fuel oil throughput numbers might suggest otherwise, it is very likely that by 2020 fuel oil throughput in PoR is marginalized. Finding the alternative oil product and trade flow to replace this loss in fuel oil throughput is less obvious. But the increasing European deficit assures steady flows of incoming medium distillates to the region. Therefore medium distillates should be the foremost product category for which PoR needs to create additional strengths in order to maintain its position as a global fuels hub. Section 7 provides a strategic advice to PoR on this subject.

6.2 Limitations of the research

The first part of this research was based on a qualitative analysis of the Russian refinery system. The outlook on Russian fuel oil production in that section was based on a combination of market reports, and papers written by a diverse set of stakeholders, ranging from Russian oil companies to independent researchers. A large limitation to this part of the research is the pace by which certain reports become out-dated. From the moment new Russian regulation, aimed at incentivizing refinery upgrades, was announced a decrease in the output of Russian fuel oil was expected. Reports from 2011 and 2012 expected 2014 to be the first year in which Russian output of fuel oil would decline. But 2014 actually turned out to be another record year and to date, 2015 also seems on track to match, or even surpass last year’s output. This shows just how unpredictable the short-term refinery output can be. Nevertheless most of the current refinery upgrades are now underway and expected to be finalized by 2018. And the Russian export tax on fuel oil will be 100% of the crude oil exports tax by 2017. Although this still leaves room for arbitration on the exact year that heralds the decline of Russian fuel oil production, it does make it very, very likely that by 2020 the impact of changes to the Russian refinery system are very much apparent in the countries' fuel oil production figures.

The model that is used in order to forecast global demand and supply of oil products per region comes with its own set of limitations. The model relies on 2012 data, as this is the most recent year for which the necessary data was available. As a result, the sources for estimating the demand and supply variables relied on market reports from different years. Mostly reports, published in 2013 for base year 2012 figures and the more recent reports in order to obtain the most up to date outlook and forecasts to 2020. Although it wasn't encountered, there is always the risk of changes to the methodology in these reports, potentially affecting the relative changes used as variables to the model.

Another limitation to the model is its categorization, both in terms of regions as well as oil products. Limiting the categories to light, medium and heavy distillates allows for a clear overview on the regional developments. But it doesn't show for instance any differences in demand and supply of the different products within such a category. It could very well be that differences within such a category allow for additional opportunities and/or threats to PoR. The same holds for the regional consolidation of demand and supply. Primarily for Asia this is a limitation as that region shows a lot of divergence in demand and supply balances between developing regions and the OECD countries within the region. But to assess PoR's position this limitation is slightly off set as the primary regions for oil product trade for PoR are the FSU, the Americas, Africa and the ME. This notion is also important with regards to the actual results of the model as the estimates for Asia come with the most reservations. The large, estimated Chinese deficit on oil products can disappear, and even turn into a surplus if the projected increase in refinery capacity matches or surpasses the demand for oil products again. It is unlikely that the situation of lagging refinery growth will persist throughout the forecasted period.

Another limitation is the methodology used in order to estimate regional demand and supply balances up to 2025. The variables used to estimate up to 2020 are compiled by qualitative research. However, in order to estimate further to 2025 the CAGR for the regional demand and supply growth was calculated and extrapolated further. The benefit of this very practical approach is that it magnifies certain developments, which helps to identify potential tipping points in regional balances. On the down side this method develops linear results, not taking into account trend breaking developments such as the 2020 IMO regulation.

A final limitation worth noticing is the standardized refinery configuration used in order to assess the impact of refinery upgrades on a regions refinery product mix. Table 12 presents a highly simplified refinery output mix, depending on the refineries configuration. Nevertheless this method was opted for, as it was also a pragmatic approach to a very technical area of the model. The results do show that the potential effect of a change in refinery configuration is softened by this approach. Russia is a good example for this when comparing the models results to the original, qualitative research.

6.3 Area's for further research

This research has geographically mapped the regional developments in supply and demand of oil products. The assumed impact of these developments on the international trade of oil products is based on qualitative analysis. It is very relevant to quantify the current, global trade of oil products between the different regions based on actual trade data. This allows for a more precise analysis of the potential impact on regional oil product balances as they can now be related to hard trade data.

Another potential area for further research is the international trade in medium distillates. Historically gasoil and diesel are mostly grouped under one product category. But in terms of production and use there is a lot of distinction between the two products. For example, Rotterdam's imports almost as much gasoil from the US as it exports gasoil to the US. This sounds illogical knowing the enormous European deficit on medium distillates and the US surplus. Quick research learned that the US mainly exports diesel and that the vessels sailing from PoR to the US mainly carry gasoil. As gasoil is most likely to become the new dominant maritime bunker it is very valuable to globally map the supply and demand of gasoil.

7. Management advice to Port of Rotterdam

It is clear that the fuel oil throughput in PoR will be affected negatively by a number of developments; Russian Refinery upgrades, declining European refinery throughput, persistent declines in global fuel oil demand, and the switch from fuel oil to gasoil as maritime bunker. As fuel oil loses its importance as a major cargo flow for PoR, the port has to look out for alternative products that can replace the loss in fuel oil throughput. Diesel and gasoil are the most logical options. Supply from the FSU, North America and ME is growing and so is the European deficit. But grasping this market comes with fierce competition from other European ports. Gasoil and diesel hardly require any further processing before reaching their final market. And even if they require final blending, for instance into biodiesel, it is preferred to do this in a later stadium, closer to the final market. This postponement ensures the products remain homogenous as long as possible, therefore ensuring a larger market. This explains the difficulty of offering distinctive services for the transhipment of medium distillates within a port.

A large part of the gasoil and diesel transhipment will concern transfers for further distribution via barges on inland waterways for mainland Europe. The UK is another destination, reached through coaster vessels. The greatest competitor to sts transfers in PoR is probably sts transfers at open sea. This is for instance true for fuel oil transfers from 80.000 dwt. vessels to Suezmaxes or VLCC's, destined for Singapore. Sts transfers on open sea can still be done for gasoil or diesel destined for the UK, which are transhipped onto coaster vessels. But barges are not designed for sts transfers at open sea. So here is a very important reason for vessels to call at European port in order to discharge their medium distillate cargo. PoR has already commissioned a €32 million investment program for additional sts transfer facilities, expected to be completed by 2016 (Lalkens 2015). But at the moment these investments are primarily targeted at sts transfers of fuel oil. Large new poles, costing €400,000 each, are currently installed in anticipation of vessels with Russian fuel oil that needs to be transhipped on to large VLCC's.

But in order for these investments to remain valuable under declining fuel oil throughput, emphasis should be placed on optimizing these sts transfer facilities for multiple purposes. Probably the most important purpose in the future should be the sts transfer of diesel and gasoil onto barges. This is considered a prerequisite for grasping the market for intra European gasoil and diesel transhipments. With this premise of multipurpose sts transfer facilities; it is vital to find additional services that PoR can offer, surrounding the transfer of diesel and gasoil. The general assumption is that imported diesel and gasoil hardly require further processing before final use. But it is important to remain critical towards this assumption. PoR has 5 refineries within its port area combined with a large number of storage facilities. It should be assessed, together with the refineries, trading companies, and storage facilities, how these distinctive characteristics of PoR can add value to the imports of gasoil and diesel.

This final part, that incorporates refineries, trading houses and storage facilities, is the critical part for PoR in order to maintain a competitive advantage over competing ports such as Antwerp or Amsterdam. At the moment PoR is an important partner to these stakeholders. PoR needs to leverage on this position today in order to remain an important partner in the future.

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Appendix 1: General introduction into the refinery process

This section introduces the basic fundamentals of refinery processing. This is essential in order to understand the potential impact of Russian refinery upgrades on the fuel oil throughput in Port of Rotterdam.

In essence a petroleum refinery transforms crude oil into finished oil products. The most known and common oil products are LPG, Motor Gasoline, Naphta, Kerosene (Jet fuel), Gas oil/Diesel, and Fuel oil. These products can be divided into three main categories; light distillates (LPG, Gasoline, Naphta), middle distillates (Kerosine, Gasoil/Diesel) and heavy distillates and residuum (Fuel oil and asphalt). In general, the lighter oil products have a higher value than the heavier oil products such as fuel oil (Deutsche Bank 2013). In general, there are four common steps how crude oil is converted into the different oil products mentioned before. Figure 7 shows a schematic overview of this refinery process, including the temperatures at which crude oil is separated into light gas and refinery fuel. The first step is 'distillation', in which the crude oil is heated. This is also known as the primary processing unit. The lighter oil products rise and the heavier products remain at the bottom. Lighter products are recovered at the lowest temperatures whereas fuel oil is separated at a temperature of approximately 400 C. The second step in the refinery process is 'conversion/cracking'. Contrary to distillation, cracking changes the size and/or structure of the hydrocarbon molecules into a size and structure that is suitable for blending it into lighter oil products such as gasoline. But before blending can take place the products need to be treated. This third step, treatment, serves two important purposes: to obtain product specifications such as low sulphur content and to protect the refinery equipment from impurities. The final stage in every refinery is product blending. In this stage fractions from the different streams within a refinery are blended into final products that comply with industry and regulatory standards (MathPro 2011; Deutsche Bank 2013).

Refinery complexity

The extent to which a refinery is able to add value to the crude oil input is referred to as the refinery complexity. Lighter products and products subdue to stringent specifications (such as ultra-low sulphur fuel oil) add most value. A refinery with a low complexity is characterized by the lack of conversion (cracking) units. More conversion units allow for the production of the lighter, more valuable, oil products while simultaneously reducing the output of the less valuable fuel oil. The most recognized method for classifying a refinery's complexity is the Nelson Complexity Index (NCI) (Deutsche Bank 2013). "1" is assigned to refineries with a primary distillation unit. Hydroskimming refineries typically rank between "2" and "6", refineries with a conversion configuration rank between "6" to "9" and refineries with a deep conversion (coking) configuration receive a complexity of "9" or higher (Table 41). A Hydroskimming refinery is one of the simplest configurations whereas a coking configuration is able to convert even the least valuable residual oil fraction into an additional feedstock. This feedstock is then used again in the conversion process for lighter oil products.

Configuration	Complexity	
	Ranking	Range
Topping	Low	<2
Hydroskimming	Moderate	2 - 6
Conversion	High	6 - 9
Coking	Very high	>9

Table 41: Nelson Complexity Index ranking for refinery configurations
Source: Author via (Deutsche Bank 2013; MathPro 2011)

Table 42 shows the differences in product yields between a simple and a more complex refinery configuration. It clearly indicates the difference in the output of light (gasoline) and heavy (fuel oil) oil product outputs. A more complex refinery produces, on average, only 19% fuel oil compared to 35% in a simple refinery.

Product	Simple refinery	Complex refinery
LPG	4%	6%
Naphta	10%	10%
Gasoline	14%	26%
Kerosene	17%	16%
Gasoil/Diesel	20%	23%
Fuel Oil	35%	19%

Table 42: Average refinery output for simple and complex configuration
Source: Author via (Deutsche Bank 2013)

Appendix 2: Schematic overview of the refinery process

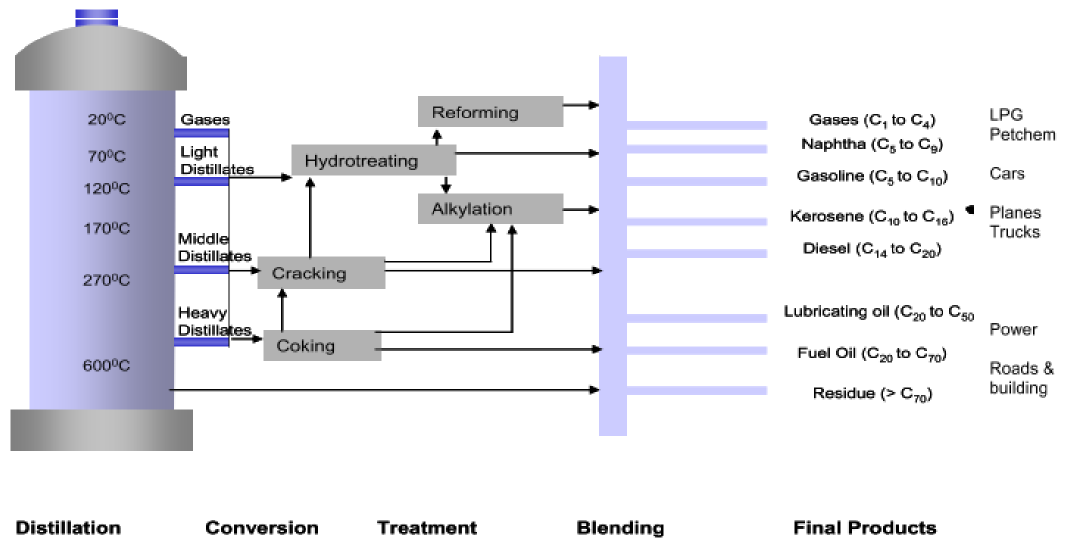

Figure 7: Schematic overview of refinery process
Source: Deutsche Bank 2013; The Oil refinery distillation process

Appendix 3: Russian fuel oil demand

'Russian domestic supply' includes the energy demanded by the Russian industry for electricity plants, 'combined heat and power plants' as well as the energy used by the energy industry itself. The final consumption reflects deliveries to consumers as well as the industry consumption wherefrom the energy industry is excluded (IEA 2014a).

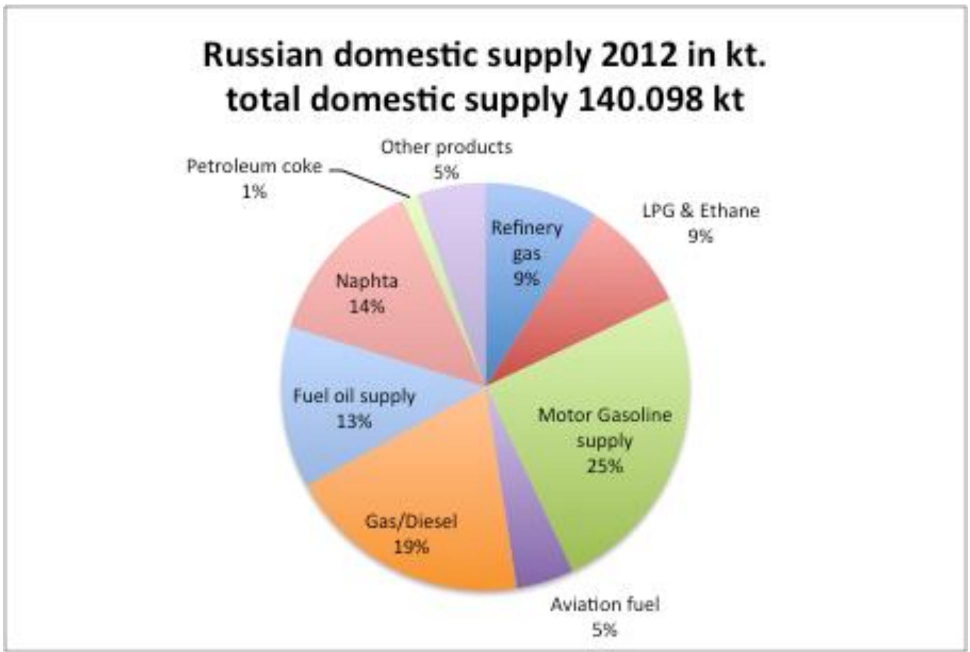

Figure 8: Russian domestic supply 2012
Source: Author via IEA Energy statistics of Non-OECD Countries 2014

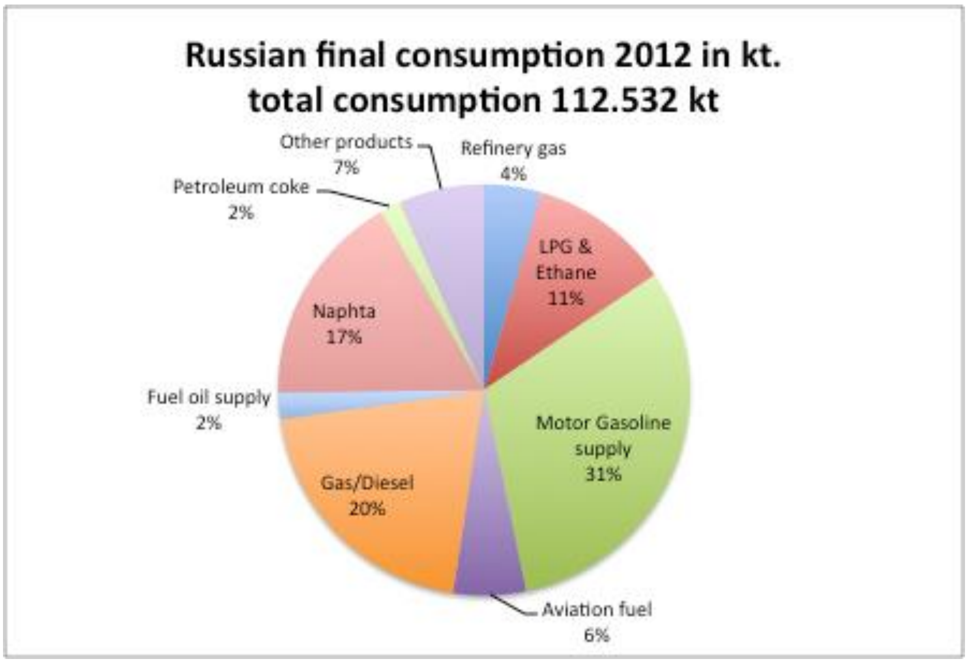

Figure 9: Russian final consumption 2012
Source: Author via IEA Energy statistics of Non-OECD Countries 2014

Appendix 4: Regional aggregation of countries

Region	Country
Africa	Algeria
Africa	Angola
Africa	Benin
Africa	Botswana
Africa	Cameroon
Africa	Congo
Africa	Democratic Republic of Congo
Africa	Côte d'Ivoire
Africa	Egypt
Africa	Eritrea
Africa	Ethiopia
Africa	Gabon
Africa	Ghana
Africa	Jamaica
Africa	Kenya
Africa	Libya
Africa	Mauritius
Africa	Morocco
Africa	Mozambique
Africa	Namibia
Africa	Nicaragua
Africa	Nigeria
Africa	Senegal
Africa	South Africa
Africa	Sudan
Africa	United Republic of Tanzania
Africa	Togo
Africa	Tunisia
Africa	Zambia
Africa	Zimbabwe
Africa	Other Africa
Asia (excl. China)	Australia
Asia (excl. China)	Bangladesh
Asia (excl. China)	Brunei Darussalam
Asia (excl. China)	Cambodia
Asia (excl. China)	India
Asia (excl. China)	Indonesia
Asia (excl. China)	Japan
Asia (excl. China)	Korea
Asia (excl. China)	Democratic People’s Republic of Korea

Asia (excl. China)	Malaysia
Asia (excl. China)	Mongolia
Asia (excl. China)	Myanmar
Asia (excl. China)	Nepal
Asia (excl. China)	New Zealand
Asia (excl. China)	Pakistan
Asia (excl. China)	Philippines
Asia (excl. China)	Singapore
Asia (excl. China)	Sri Lanka
Asia (excl. China)	Chinese Taipei
Asia (excl. China)	Thailand
Asia (excl. China)	Viet Nam
Asia (excl. China)	Other Asia (excl. China)
China	People's Republic of China
China	Hong Kong, China
Europe	Albania
Europe	Austria
Europe	Belgium
Europe	Bosnia and Herzegovina
Europe	Bulgaria
Europe	Croatia
Europe	Cyprus
Europe	Czech Republic
Europe	Denmark
Europe	Finland
Europe	France
Europe	Germany
Europe	Gibraltar
Europe	Greece
Europe	Hungary
Europe	Iceland
Europe	Ireland
Europe	Italy
Europe	Kosovo
Europe	Luxembourg
Europe	Malta
Europe	Republic of Moldova
Europe	Montenegro
Europe	Netherlands
Europe	Norway
Europe	Poland
Europe	Portugal

Europe	Romania
Europe	Serbia
Europe	Slovak Republic
Europe	Slovenia
Europe	Spain
Europe	Sweden
Europe	Switzerland
Europe	Turkey
Europe	United Kingdom
FSU	Armenia
FSU	Azerbaijan
FSU	Belarus
FSU	Estonia
FSU	Former Yugoslav Republic of Macedonia
FSU	Georgia
FSU	Kazakhstan
FSU	Kyrgyzstan
FSU	Latvia
FSU	Lithuania
FSU	Russian Federation
FSU	Tajikistan
FSU	Turkmenistan
FSU	Ukraine
FSU	Uzbekistan
Middle East	Bahrain
Middle East	Islamic Republic of Iran
Middle East	Iraq
Middle East	Israel
Middle East	Jordan
Middle East	Kuwait
Middle East	Lebanon
Middle East	Oman
Middle East	Qatar
Middle East	Saudi Arabia
Middle East	Syrian Arab Republic
Middle East	United Arab Emirates
Middle East	Yemen
North America	Canada
North America	Dominican Republic
North America	Haiti
North America	United States
South America	Argentina

South America	Bolivia
South America	Brazil
South America	Chile
South America	Colombia
South America	Costa Rica
South America	Cuba
South America	Ecuador
South America	El Salvador
South America	Guatemala
South America	Honduras
South America	Mexico
South America	Netherlands Antilles
South America	Panama
South America	Paraguay
South America	Peru
South America	Trinidad and Tobago
South America	Uruguay
South America	Venezuela
South America	Other Non-OECD Americas

Table 43: Overview countries per region
Source: Author via IEA Energy statistics database

Appendix 5: Chinese Refining Capacity 2012-2020

mb/d	**end 2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Light Oil Processing							
Reforming	0,76	0,88	0,91	1,05	1,21	1,21	1,24
Isomerisation	0,01	0,02	0,02	0,02	0,07	0,07	0,08
Alkylation	0,03	0,03	0,03	0,04	0,04	0,04	0,04
Bottom of the barrel processing							
FCC/RFCC	3,12	3,35	3,39	3,44	3,46	3,46	3,46
Hydrocracking	1,2	1,4	1,45	1,5	1,77	1,77	1,81
Coking	1,82	1,85	1,87	1,97	2,31	2,31	2,37
Thermal Crack/VBU	0,13	0,13	0,13	0,13	0,13	0,13	0,13
Hydroprocessing	4,18	4,98	5,12	5,45	6,3	6,3	6,46

Table 44: Chinese Refining Capacity per refinery process 2012-2020 (mb/d)
Source: Author via MTOMR 2013, page 98

Appendix 6: Geographical overview of supply/demand balances

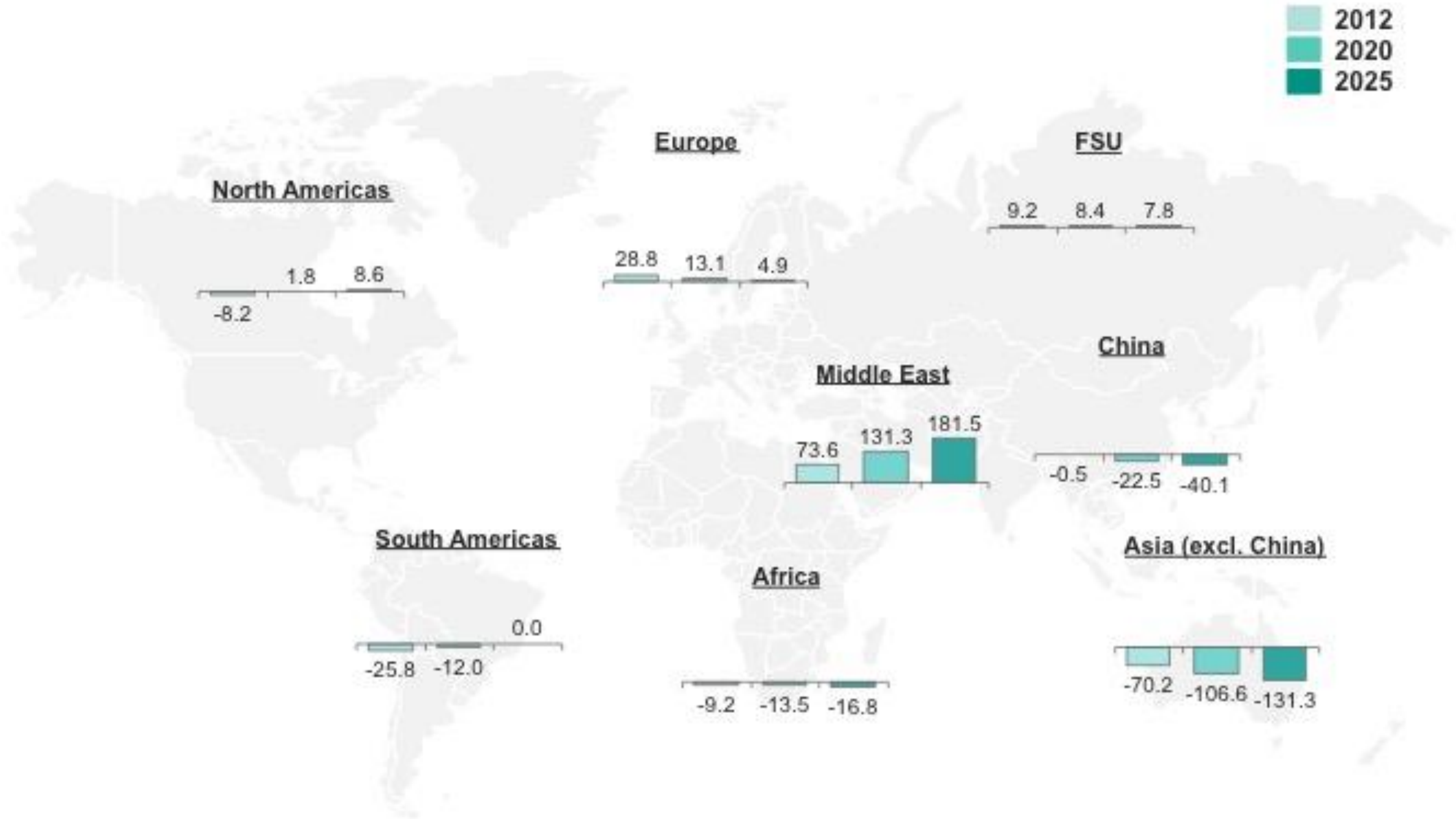

Figure 10: Supply and demand balance for light oil products (Mt)

Figure 11: Supply and demand balance for medium oil products (Mt)
Source: Author

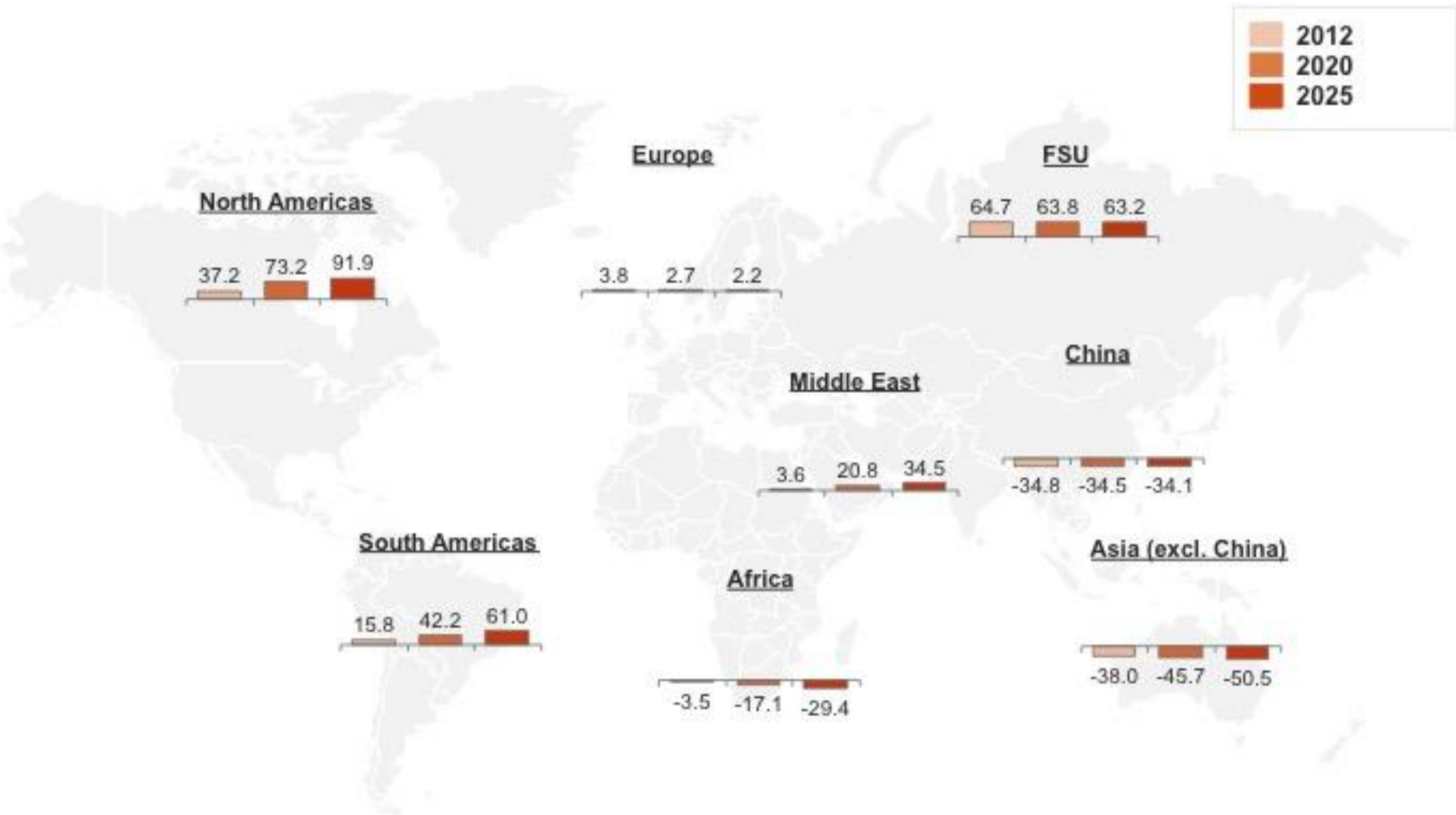

Figure 12: Supply and demand balance for heavy oil products (Mt)
Source: Author

Figure 13: Supply and demand balance for all oil products (Mt)
Source: Author