Evaluating the competitive position of the Rotterdam Petrochemical Cluster

Bachelor Thesis

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Contents

ABSTRACT

The paper reviews literature from various sources in order to identify the leading factors affecting the competitive position of the contemporary petrochemical cluster, located at the port of Rotterdam. The study reveals that a mega-trend of an industry shift towards the East and a rapidly expanding production in the US are the two major pressure points for the cluster. The paper then proceeds to evaluate the potential impacts of these shifts and compare the Rotterdam cluster to other similar clusters in Europe. Conclusively, a scenario evaluation presents an array of possible future developments and their outcomes. The study concludes that the cluster is in a strong competitive position, as it enjoys good collaboration with other clusters under the ARRR label, and it benefits from unique geographic advantages, however immediate action and restructuring will be required in order to maintain the benefits of these advantages in the long run.

Introduction

The industrial cluster at the port of Rotterdam is part of one of the strongest interconnected chemical clusters worldwide, namely the Antwerp, Rotterdam, Rhine, Ruhr area cluster. It produces a vast array of products to satisfy demand both domestically and internationally. The cluster accounts for 55% of the revenue of the port of Rotterdam, which translates into around 20% of the added value to the Dutch industrial sector (Port of Rotterdam, 2010). Furthermore while the population of the Netherlands represents merely 0.2 percent of the global population, the cluster employs over 60.000 people indirectly, and its production amounts to 2% of total production worldwide (Deloitte, 2012). The port of Rotterdam industrial cluster, predominantly a supply chain-based cluster, is formed of 5 refineries, managed by international energy giants such as Koch, ExxonMobil, Shell, BP and Kuwait Petroleum, 6 refinery terminals (including Esso Nederland, which is also a part of ExxonMobil) and 11 storage terminals, with capacity of 19.2 million cubic meters: 12.7 million cubic meters for crude oil and 6.5 million cubic meters for oil products (Port of Rotterdam, 2014f). In light of its economic significance, it is expected that international developments in the field of petrochemical production and trading of the past decade are likely to have a significant impact on the performance of this enormous driver for the economy of the Netherlands.

In the near future megatrends are going to reshape the world of business as we know it and present new challenges and opportunities for the already established industries. Variables such as population growth, shifts in global balance of trade, resource scarcity, and climate change among others are going to tip the balance in favor of some, while taking away from others. The European chemical industry is already seeing a paradigm shift, with the majority of production and activities shifting towards the Middle East and Asia, as these countries offer at the very least a more favorable political environment, in terms of energy policy, better investment climate and larger pool of highly skilled labor, available for hire at competitive wages. In the other corner of the world, we also see the US sitting on vast amounts of until recently unexplored deposits of crude oil and shale gas. However technological developments of the past decade, have allowed Americans to extract crude, which was previously considered unreachable, in such quantities, that some reports from renowned energy sources see the US becoming the world's biggest producer by 2020.

Energy markets however are not only somewhat predictably influenced by megatrends however. As the world today becomes more globalized and interconnected, economic shocks in some countries have a direct impact on the global economy. Such shocks are often a consequence either of a natural disaster or a sudden disturbance in the political climate of a given country. A recent example is the conflict in Iraq, where the Islamic rebel group "ISIS" took control of the majority of the country by force and brought about the eventual establishment of a caliphate (or an Islamic state). In the process an oil refinery was seized. As this paper is being written, events are still unfolding and the crisis there continues, but already we observe a rise in the price of crude oil with 4% as a direct consequence (Greiner, 2014). Meanwhile political turmoil between Russia and the European Union, in regards to the newly annexed Crimean peninsula have been the cause for many direct and indirect sanctions imposed by both sides, most important of which is the stricter requirements for the export of Russian gas to Ukraine. The effects of these conflicts and political games are however beyond the scope of this paper and serve the purpose of illustrating the nature of factors, which might influence the competitive position of the European petrochemical industry directly or indirectly.

The goal of this paper is to identify the most important current developments in the landscape of petrochemicals worldwide and based on the data gathered, evaluate the future competitive position of the industrial cluster at the port of Rotterdam.

Problem statement and Methodology

The petrochemical cluster at the port of Rotterdam is facing the reality and dynamics of the contemporary world. New technological developments are made available at a higher rate than ever before and it is of critical importance to make the right investment choices for the future, when expanding current capacity or shutting down uneconomic facilities. Therefore this paper will seek to evaluate the future competitive position of the cluster at the Rotterdam port, by answering the following research question:

How is the competitive position of Rotterdam's industrial cluster affected by balance shifts in production and consumption of petrochemicals internationally?

In order to arrive at an answer to this question, we will first give rise to a number of sub-questions, which will help us formulate the specifics around the aforementioned shifts in balance and put the industrial cluster's competitive position in a defined framework. Thus we would like to know the following:

1) What are the basics behind the observed shifts in the balance of trade of petrochemical markets worldwide?

2) What are the observed and expected effects of these shifts on the chemical industry in Europe?

3) What is the nature of clusters, and what are the theoretical and practical advantages (and/or disadvantages) of their formation?

4) What are the inherent strengths and weaknesses of the industrial cluster at the port of Rotterdam?

5) In the unfolding of current events, how does the Rotterdam cluster compare against other competitor clusters in Western Europe?

6) Given the findings thus far, what are possible future scenarios and their outcomes for the cluster?

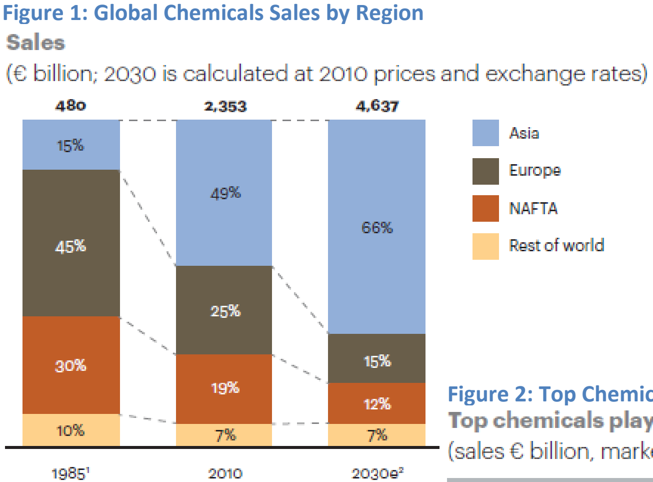
The answers to these six questions will build upon each other to inherently give an answer the research question of this research paper. Furthermore the materials reviewed in order to contribute to these answers will come from various sources, such as scientific articles, reports on global energy markets and news reports and will constitute knowledge from both leading experts in the field and renowned researchers.

Part 1: A Changing World: Identifying the major shifts, that will determine the competitive environment for the European chemical industry.

The petrochemical industry, production and consumption worldwide have been subjected to the influence of a variety of market determinants, which have been gradually changing the landscape for players all around the globe, introducing new opportunities and challenges for the sector along the way. Two major factors stand out in the modern day, which are likely to have the largest impact on the European petrochemical industry in the near future. The first one is the megatrend of an industry shift from Europe towards the Middle East and Asia.

For the past decades the Asian Tigers have attracted significant technological and infrastructural investments in energy and chemical markets. This comes predominantly in response to their free and open markets, the relative perceived stability of the governmental systems and the vast labor pool, rich on highly skilled work force. The environmental and social issues that often arise with heavy industries, such as the petrochemical industry, are subjected to looser controls and bureaucracy in the East, in that way opening their doors to larger and more profitable investors at a possibly higher environmental cost. This is where the paradigm of Western Europe often diverges from the one of Middle East and Asia and it is probably one of the factors that lie at the forefront of the industrial shift eastward. Europe's scarcities for land, especially in the case of the Netherlands, and the high degree of environmental concern in the region, have created a political climate, striving for more regulation and sustainability. This in turn strangles the industry, hampers raw economic growth and pushes the bigger players on the market towards alternative geopolitical environments, where they can achieve their potentials for profit and growth. In a statistical perspective, the majority of the growth in the past 25 years has been driven by Asia, which at the present day owns 49% of the chemical sales internationally (Kearney, 2012). Figures 1 and 2 are taken from the "Chemical Vision 2030: A European Perspective" by A.T. Kearney, a renowned consultancy firm, operating in various fields among which the chemical markets. It reports that by 2030 it is forecasted that over 66% of global sales worldwide will be owned by Asian companies. Furthermore 5 or more of the top 10 companies in the chemical industry internationally are expected to be of an Asian or Middle Eastern origin.

Figure 1: Global Chemicals Sales by Region



Source: (Kearney, 2012)

Figure 2: Top Chemical Players by Region

Top chemicals players
(sales € billion, market share in %)

1985				2010			
1	Bayer	14	2.8%	1	BASF	48	2.0%
2	BASF	13	2.8%	2	Dow Chemical	41	1.7%
3	Hoechst	13	2.6%	3	ExxonMobil	40	1.7%
4	ICI	10	2.1%	4	SABIC	35	1.5%
5	Dow Chemical	8	1.7%	5	Sinopec	33	1.4%
6	DuPont	8	1.7%	6	Royal Dutch Shell	30	1.3%
7	Ciba-Geigy	7	1.5%	7	DuPont	24	1.0%
8	Montedison	7	1.4%	8	LyondellBasell	24	1.0%
9	Rhône-Poulenc	6	1.2%	9	Ineos Group	21	0.9%
10	Monsanto	5	1.0%	10	Mitsubishi Chemical	21	0.9%

Number of players by region

2030e
Europe 2-3
NAFTA 1-2
Middle East 2-3
Asia 3-5

Source: (Kearney, 2012)

The petrochemical industry has shown very strong and stable growth in the past decade, at the forefront of which have been the developing economies. It has grown by 95% in value during the period from 2001 to 2011.

Further investigation into market data, produced by the European chemical industry council (CEFIC), reveals that global sales of chemicals worldwide were valued at €2744 billion in 2011. Figure 3 exhibits a breakdown of worldwide sales by producing country. We see that Asia is in the lead with a volume of €1147 billion in sales, where Europe trails behind nearly at half of that volume, at €578 billion.

Figure 3: World Chemical Sales by Region

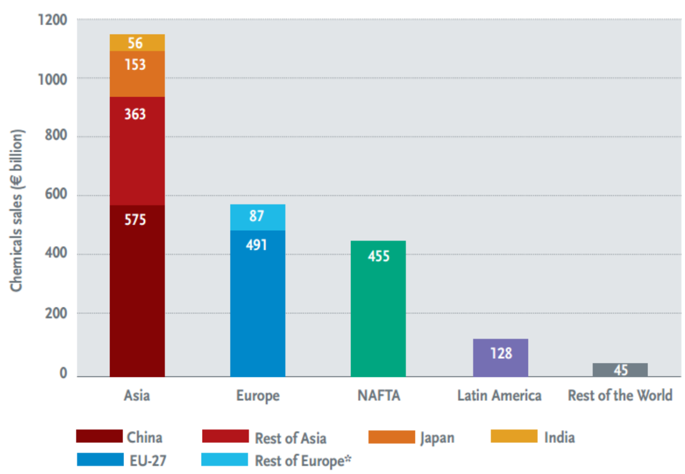
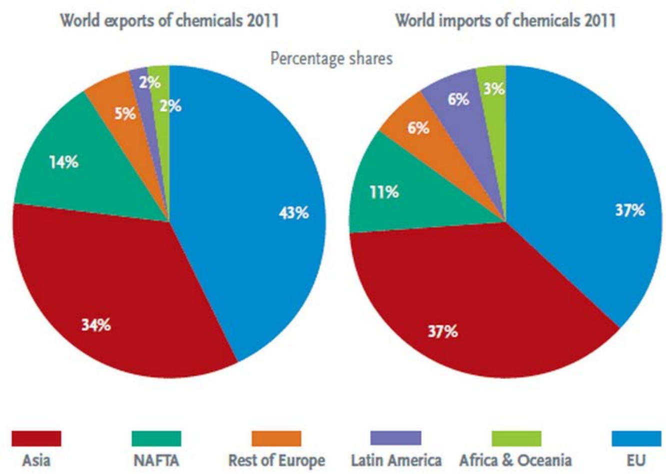


Figure 4: World Exports and Imports of Chemicals by Regional Shares

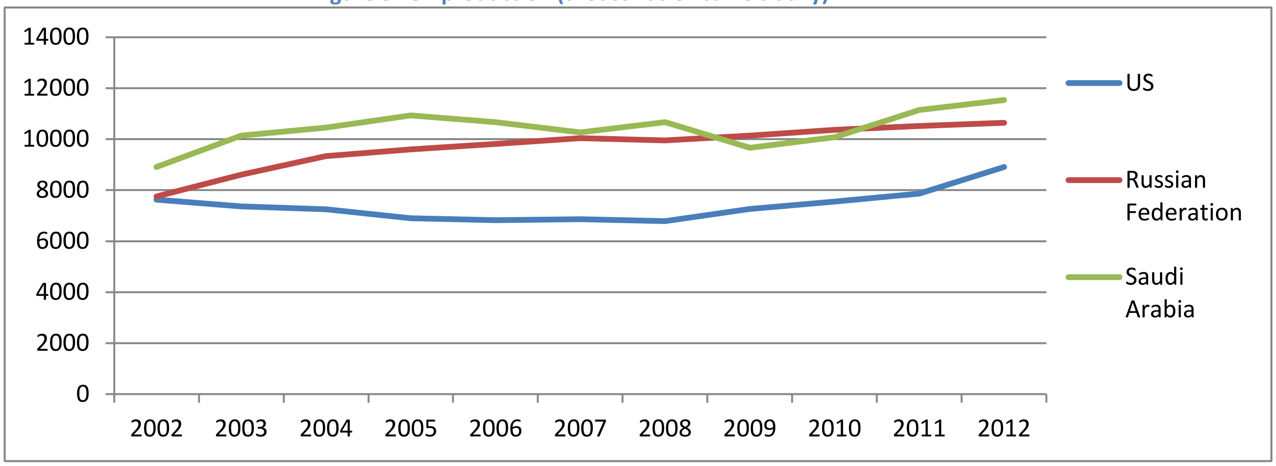


Source: (CEFIC, 2014)

Another valuable insight from the CEFIC report is a chart of the activity in exports and imports of the key regions internationally and is represented in Figure 1. It shows that even with half the operational volume in sales, Europe remains very competitive and at the heart of the trade, with a share of 43% of worldwide exports, larger than that of Asian economies, which lies at 34%. Moreover Europe is also tied with Asia at 37% of global imports of chemicals for that same year.

The second important shift in production, which we want to have a look at in this part of the paper, and this is primarily focused on raw production of crude oil, is a current development in the United States. The United States has seen a spiking increase in the use of hydraulic fracturing, or fracking in short, combined with horizontal drilling as a way to extract otherwise impossible to reach reserves of crude, trapped in hard rock formations, deep within oil wells. This technological advancement drastically increases the gains to be made from existing wells, most notably the Eagle Ford well in south Texas, which was estimated to produce around 200.000 b/d by the end of 2012; however measurements of 2013 levels showed a remarkable increase to 880.000 b/d. The method was first tested out in 2003 (Domm, 2013), and has since proven itself to be a game changer for the production of oil in the US. Fracking has been so successful that reports from renowned energy companies and energy market researchers, such as BP and Platts, suggest the US could become energy self-sufficient by 2020 and a net exporter of petroleum products by 2030, likely importing only a small fraction of the oil it does from Canada today. Translated into numbers, the US is estimated to produce around 11 million b/d by the end of 2020 (Platts, 2013), likely surpassing Saudi Arabia as the biggest producer of oil worldwide. Figure 5 contains data from BP's "Statistical Review of World Energy 2013" and illustrates the evolution of US oil production in comparison to the Russian Federation and Saudi Arabia.

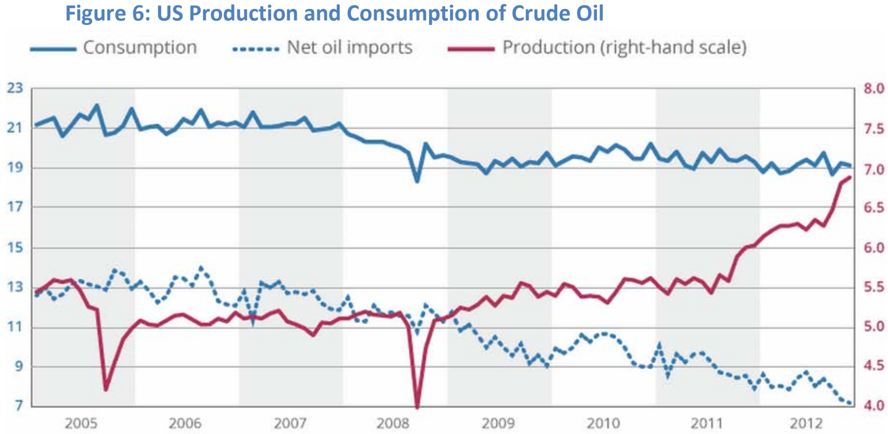
Figure 5: Oil production (thousands of barrels daily)



Source: (BP, 2013)

A clear trend of increasing production can be observed from 2008 to present day. The most notable changes however are when we take a look at the change in production from 2011 to 2012. The Russian Federation and Saudi Arabia have seen increases from 1.2% and 3.7% respectively, where the US has grown by a staggering 13.9%. (Note: Data for 2013 will be made available by BP's Statistical Review in June 2014, thus if it is timely enough I will replace the data given here with the new one). The increase in US production has narrowed the big discrepancy between its national consumption and production to the point where they are almost even at the end of 2012. This has led to a slowly declining domestic demand and an overall decrease of imports of crude oil (figure 6).

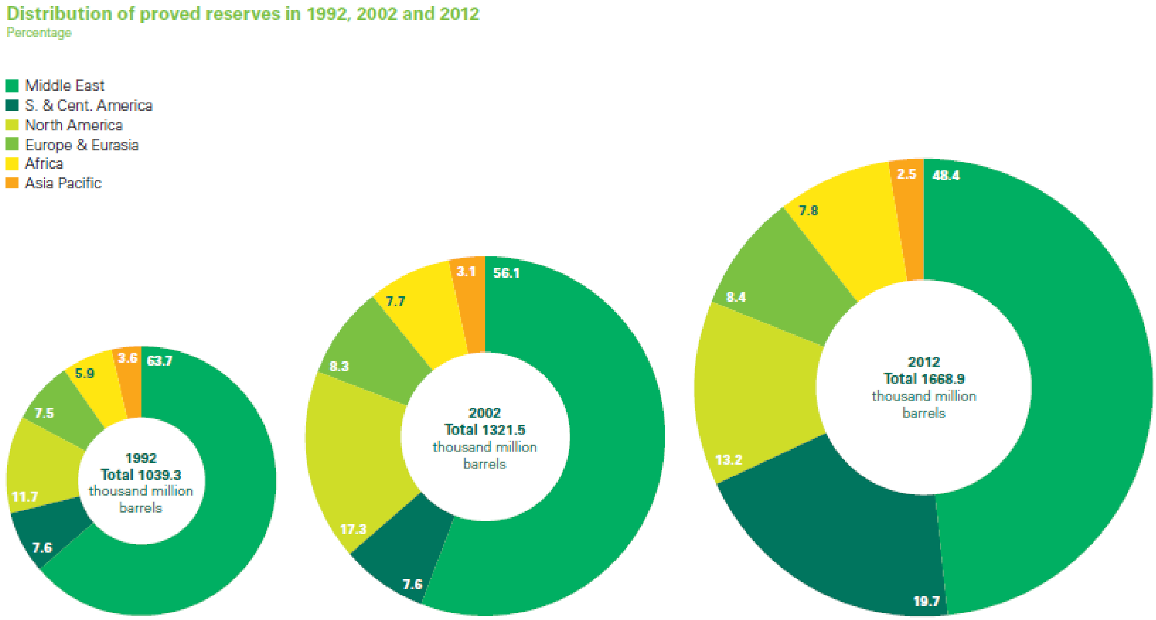
Figure 6: US Production and Consumption of Crude Oil



Source: U.S. Energy Information Administration/Citi Research

In light of this growth in production the estimates of oil reserves worldwide have changed, shifting the balance strongly in favor of the Americas. Evidence from the chart below (Figure 2), taken from the "Statistical Review of World Energy 2013" suggest that American reserves combined in 2012 sit at 32.9% of global produce, an increase of 8% over 2002 levels, which lowers Middle East reserves under the 50% mark of worldwide supply, to 48.4% and can be interpreted as a sign of the increasingly stronger competitive position of the US in the supply of crude oil in the future.

Figure 7



Source: (BP, 2013)

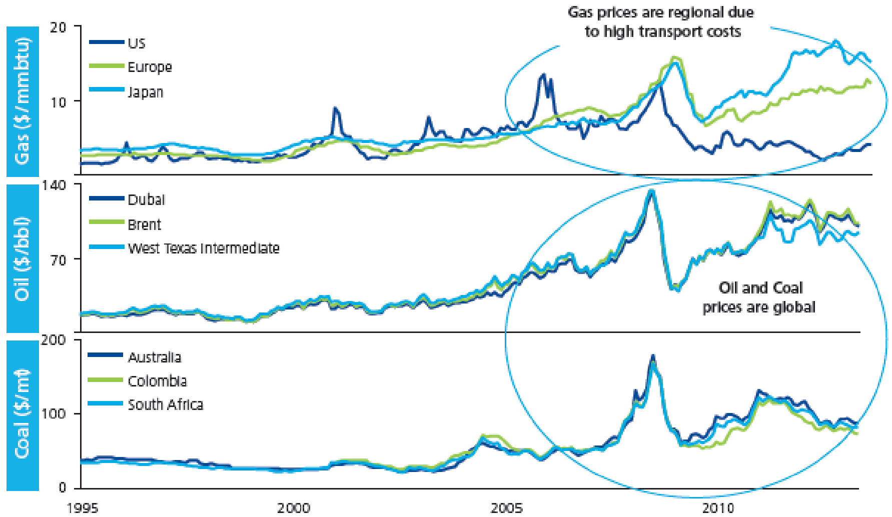
Further developments in the US are likely to have a significant impact on the international market of crude oil, shifting the roles of different actors and rearranging the balances of imports and exports for many. However evaluating these developments and substantiating their potential impact will be the focus of the next chapter.

Part 2: Evaluating and quantizing the potential impact of the present shifts in the market for petrochemicals on the European chemical industry.

In the process of evaluating the impact of the US shale plays on the European industry, a study called “The shale gas revolution and its impact on the chemical industry in the Netherlands”, conducted by the joint efforts of Deloitte and VNCI (“Vereniging van de Nederlandse Chemische Industrie”), presents a rather gloomy outlook for the future. According to this study, increased production in the US has led to a sharp drop in American gas prices. Contrary to that European gas prices have risen in the period, leading to a large discrepancy between the two, where in reality gas is not more expensive to produce in the Netherlands. The low gas prices in turn lead to an advantage in terms of feedstock and energy costs for the US, which spurs further investment into increasing production capacity.

This is bad news for Europe as fresh and strong competition starts to set root in the West. Specifically heavy is expected to be the impact on ethylene, ammonia, chlorine and caustic soda chains, which is estimated at a 29% blow to the Dutch chemical industry employment and a staggering 48% to total revenues. Ultimately if one takes into account possible ripple effects throughout the cluster, there is a chance that it might disintegrate, leading to an 8% loss of Dutch GDP, 20% loss to Dutch exports and endangering the jobs of up to 479.000 direct and indirect employees in the sector (Deloitte, 2013).

Figure 8: Prices of Gas, Oil and Coal for different carriers

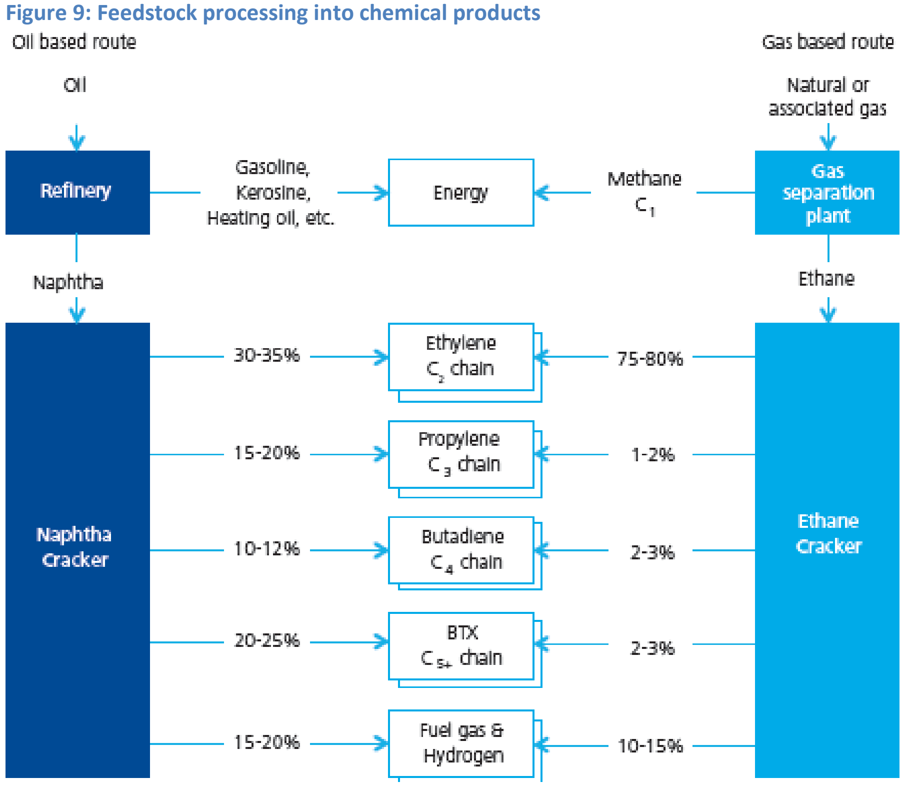


Source: IEA; World Bank

The figure above, taken from the International Energy Agency, clearly illustrates the price discrepancy phenomena between Europe and the US. The underlying reason for this sudden drop is failure of domestic demand to keep up with the steep increase in supply, as illustrated in Part 1, due to primarily high switching costs from oil to gas, and gas buyers being stuck with long term contracts (Deloitte, 2013). In numerical terms, US gas prices have dropped to $4 per MBTU, compared to European gas standing at around $12 for the same quantity.

Here is a good opportunity to delve into a few specifics regarding the processing differences between the naphtha and ethane crackers.

Figure 9: Feedstock processing into chemical products



Source: (Deloitte, 2013)

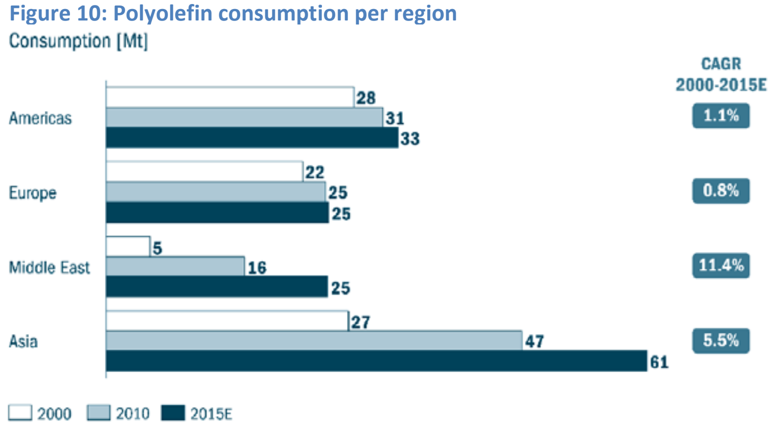
Figure 4 exhibits the route and gains to be made when using oil and gas correspondingly as feedstock. The variation between the two is very important, since it explains the discrepancy in prices between the industry in the US and the EU and can highlight which production tiers will be exposed at the highest risk. As mentioned earlier the US is mostly dependent on the use of gas as a raw input and thus relies heavily on the use of ethane crackers. In contrast, the chemical industry in the Netherlands is dependent on six naphtha crackers, which produce all of the building blocks represented in Figure 4 (ranging from ethylene (C_2) up to BTX (C_{5+})). Moreover the industry produces inorganic blocks like ammonia (NH_3), chlorine and caustic soda (Cl_2 and NaOH) (Deloitte, VNCI, 2013).

With this information at hand, it is estimated that a loss of about 29% to employment and 48% to revenues will be the result of the negative impact on ethylene, ammonia, chlorine and caustic soda chains, as mentioned earlier. US ethane crackers are likely to capitalize on their cost advantage and will have an edge in polyethylene and even ethylene oxide derivatives (21% of unemployment factor). Inorganic building blocks are also likely going to be affected, because they demand the use of gas as a raw input. Further loss on competitiveness is expected in propylene and BTX chains (8% of unemployment factor). On the positive side, Butadiene and some BTX products could allow for growth opportunities, as Dutch producers are able to utilize better yields and because some of the products come from bio-based sources, which are developed better in Europe. The rest of the activities will be impacted to a smaller extent (Deloitte, VNCI, 2013).

The effects of the unfolding US shale plays are to be felt in the short and long term and following through with immediate action will be required on the part of the Dutch producers, their partners and even government, in order for them to remain competitive in the years to come. It is expected that a high worldwide growth demand for energy or restricted expansion of production and investment in Asian markets, could potentially offset the negative impact on the European industry, however various studies suggest that at least the latter is likely not to be the case.

It is estimated that by 2015, expansion in Middle Eastern and Asian capacity will render 14 out of 43 crackers in Europe uneconomic (KPMG, 2010). Research by Keller and Kalkman (2012) suggests polyolefins as a suitable proxy for regional demand of chemical products, as they are used directly in the production process of various goods, such as automotive and plastics. Data from figure 10, below, taken from that research, suggests a total increase of 16.9% in combined demand for Asia and the Middle East, and shows a projected increase for Europe lower than 1%.

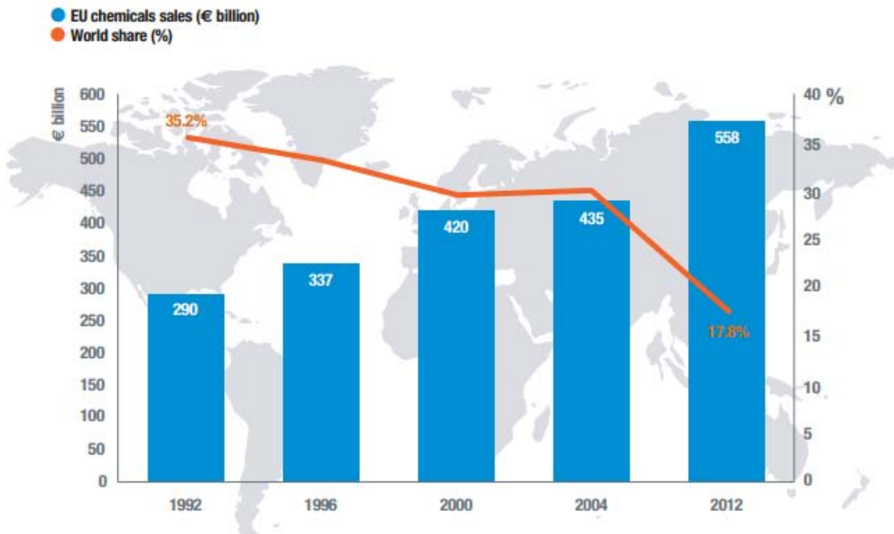
Figure 10: Polyolefin consumption per region



Source: (J. Kalkman, 2012)

One could assume with the above forecast that the sharp rise in demand in the East would create growth opportunities for European exports and that would not be entirely wrong. However data from CEFIC reveals a very important picture. Where the European chemical industry has seen growth for the past decade in absolute numbers, rising from €290 billion in sales back in 1992 to €558 billion in 2012, its share internationally has nearly halved in that period, falling from 35.2% to 17.8% (Figure 11). This is indicative of Europe's increasingly deteriorating competitive edge.

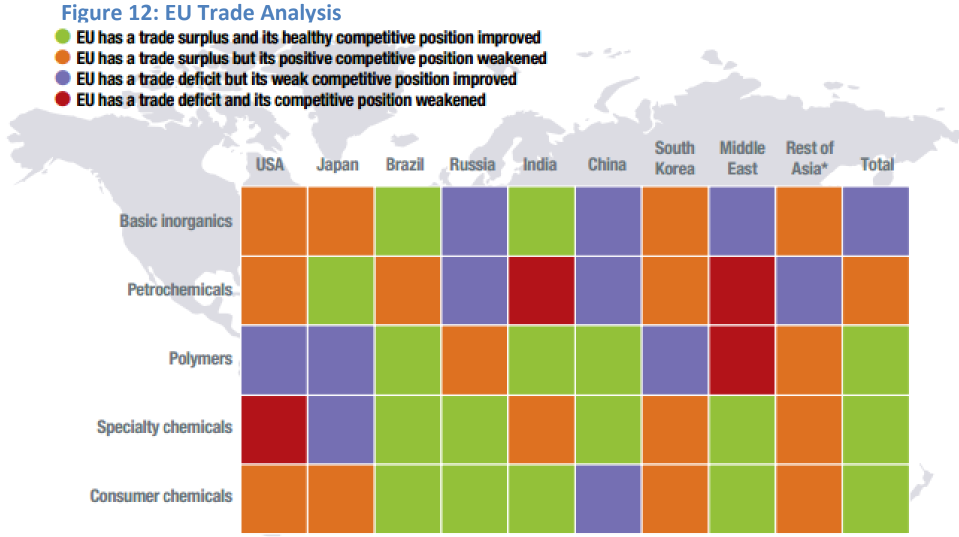
Figure 11: EU Chemical Sales against Share



Source: Cefic Chemdata International (2013)

A slightly more detailed picture of the industry's competitive position, with specifics regarding different production segments, is made available in Figure 12 below.

Figure 12: EU Trade Analysis



Sources: Eurostat and Cefic Chemdata International (2013)
* Asia excluding China and Japan

The orange and the red squares are representative of a weakening competitive position respectively in trade surplus and deficit. The green and blue squares correspondingly represent an improved competitive edge. At a glance it can be seen that the heaviest impact comes from the USA, Middle East and Asia. However due to close relations and strong business, we can see that the EU is mostly benefitting from trade with Russia and China.

Overall a very slow growth, coupled with ageing facilities and lack of significant investment in the EU, presents a gloomy outlook and a difficult future for the chemical industry.

Part 3: Petrochemical clusters, their advantages and disadvantages in the modern age.

Before we discuss the specifics of petrochemical clusters, it is good to begin with a short overview of cluster theory.

In the past decades fundamental innovations in communications and transport have fostered never before seen levels of growth in global industry and trade. In the modern age it is possible to complete transactions across the globe, with varying degrees of logistical complexity, with just the press of a button on a keyboard. This is one of the underlying drivers of change in the competitive business environment.

Historically industrial clusters have relied on persistent geographical and/or natural advantages in order to remain competitive, such as the proximity to a harbor, or the availability of natural resources as raw inputs. Michael Porter (1998) argues however, that such advantages are to a certain extent mitigated by global sourcing of materials and the availability of cheaper alternatives internationally, as transport costs have been drastically reducing, enabling goods to reach new markets. Because of this, industrial clusters have to rely on a different set of advantages, in order to remain competitive. These are innovation and productivity.

Porter (1998) defines clusters as “geographical concentrations of interconnected companies and institutions in a particular field”. Such concentrations of mutually benefitting businesses, demonstrate how important the economic environment and what is outside of a company is, next to the importance of its inside processes. In this regard, the defining properties of such clusters are the linkages and complementarities, between the different actors engaged in competition as well as cooperation. Clusters have the feature of harboring cooperation and competition under the same roof, where these concepts can coexist and create a healthy environment for economic development. The lack of any of the two ingredients means the cluster is going to fail or will not have been formed in the first place.

Cooperation in industrial clusters usually takes on a form, similar to vertical integration, where companies specialize in serving individual needs along the value chain, from supplies to manufacturing, to transport and everything else included in the process. In this way a cluster allows bigger and smaller companies to coexist and provide the best possible alternatives for each other, without the need for the big companies to vertically integrate processes themselves, because more efficient and cheaper opportunities already are part of their informal network. This is also inherently beneficial to all the players in a cluster, as it allows for far greater flexibility than vertical integration.

Through fierce competition for customers and retaining those customers, only the most efficient and productive of players will survive. This to a certain extent ensures that prices will be adequately lowered to the best possible outcome. In order to remain competitive it is important for firms to invest in innovation. Employing advanced technologies and more sophisticated processes is what gives them the competitive edge and spurs better productivity and efficiency. Firms among all branches of industries are able to employ new tech, however they are very dependent on a number of outside factors, related to the quality of their local business environment. Things like a well-educated work force, an adequate and well-developed infrastructure, a favorable political and tax climate, all are prerequisites for a healthy environment, which can in turn stimulate innovation and productivity.

Thus clusters fundamentally change the perception of the roles of different institutions and their interactions with the industry. It is vitally important for the successful operation of a cluster, to have strong linkages with universities. This would allow access to a pool of well-educated potential labor force to pick from and would guarantee that innovation will not be far behind on the agenda. Furthermore governmental support is of imperial importance as clusters are some of the biggest contributors to a country's GDP. In the case of the petrochemical cluster at the port of Rotterdam, we have seen that it accounts for as much as 20% of Dutch GDP and for up to 80.000 direct and indirect jobs in the sector, which numbers signify a huge importance, not only to the local but also international economies, as its output is directly linked with external economies through significant imports and exports.

It is well known and visible how large scale chemical companies tend to form clusters, in order to reap the benefits of the geographical concentrations of related industry. Research by Dijkema, van Zanten and Grivenik (2005) provides insight into the specifics of chemical clusters. They postulate that the main characteristic of chemical clusters is that the industry is involved in the production of "undifferentiated products, which are traded under standard specifications in large volume, global markets". There are two most widely used types of feedstock, and those are gas and petroleum. Because of that, costs are at the heart of petrochemical economics.

In order for operating companies to remain competitive, it is of significant importance for them to excel both in specialization and generalization. What is meant to be understood under specialization is a company focus on its own business, in ways of increasing efficiency and productivity of its operations, introducing technological innovation, etc. Generalization on the other hand refers to outside factors, such as networks, labor, various investments, which are not core company businesses, but create and increase value, by serving the business. Generalizations can usually lead to better cost efficiency, especially if there is collaboration with external regional development parties, such as the Port of Rotterdam Authority, in the case of the ARRRA cluster. Such relationships usually create physical, business, knowledge and information linkages, which can be very beneficial to all parties involved. Furthermore it is possible to create advanced costs savings, not only by introducing new technologies or creating linkages with outside parties, but also by creating links amongst adjacent chemical plants. Such action leads to a greater reduction in logistics costs, impact and risk. In light of that, the physical proximity of companies is a prerequisite for cost savings and efficacy of operations, as the costs of shipments through different alternatives, such as road, rail or sea, becomes prohibitive with increasing distance. Many of the clusters however are situated already on or near ports, which allows for their production to reach global markets, through a simple plant-vessel exchange, and vice versa, imports of feedstock can be shipped to the plant from any point of the world, as long as this is an economically viable transaction. However being located on port surface, presents a disadvantage in the scope of limited surface area, which leads to constraints in physical development and expansion. It does on the other hand increase competition for land and location, which can be seen as beneficial to the overall business environment (Dijkema, 2005).

In their study on "Public Roles and Private Interests in Chemical Clusters", the authors view chemical cluster dynamics to be characterized as "discrete event driven" and "slow". Chemical plants of various size and purposes, are usually an expensive one-off investment, which takes anywhere between 2 to 5 years to build and has a lifespan of 20 to 30 years. Depending on the availability of new technologies or demand shifts, plants can be modified and improved in the process, with the requirement of additional investment. Scrapping uneconomic operations and processes is also viable in order to retain profits and competitiveness. In general the final closure of a plant affects all of the companies in a cluster directly or indirectly.

For an operating company there are generally two reasons to decide whether to invest in or build a new plant. The first reason is that a plant is becoming technologically or economically obsolete and the second reason lies in the emergence of demand for new products, which create lucrative market opportunities. Combinations of the two, usually lead to a decisive incentive for existing plant closure and construction of cutting edge modern facilities, which can capture the new demand and market share, whereby correcting the supply/demand imbalance and profiting in the process. Generally we observe two approaches to modification, which operating companies carry out. Those are either scrapping, where a whole plant is demolished and replaced with brand new facilities and technology (as mentioned above), or rejuvenating or investing in economically beneficial additions to the already existing infrastructure. However it is mostly the replacement of existing facilities with brand new ones, which is of highest interest to investors. The number of such projects is however limited around the world. This can be partly explained by the fact that brand new investments take between 4 to 5 years to be completed and in full operation, and if we take into account a brand new plant working at an average of 85% capacity, which is standard with most plants, it takes up to 7 years of operation, in order for investors to realize any return on their investments. Taking that into account with the current changes and balance shifts in the chemical industry, it is easy to see why investors can be reluctant in spending their money on projects, which have high risk and uncertainty attached to them.

With this information in mind it is interesting to turn our attention to the petrochemical cluster at the port of Rotterdam.

Part 4: The Rotterdam petrochemical cluster

The petrochemical cluster is the result of Rotterdam's historical geographical advantage and a series of vital infrastructural investments, which rendered the port largest in the world between the 1960's and 70s. One of these was the construction of the Europort, which expanded the port area by 3600 hectares and connected it to the North Sea. With this extra capacity many large chemical companies, such as Esso Chemical, Kemira and Mobile Oil, found it lucrative to expand their businesses there. In the early seventies, the Rotterdam-Antwerp pipeline was finished, effectively connecting the two separate chemical clusters and allowing for a more efficient, faster and greater distribution of liquid bulk among the two clusters. At the time of the construction of that pipeline, Rotterdam's port had also the advantage of having developed the Euro-channel. This manmade channel, with its superior depth, allows even the world's largest tankers and container ships to enter the port. Because of it, the port of Rotterdam to this day offers unrivalled accessibility in comparison to any other European ports. The port also has the invaluable advantage of its natural connection to the river Rhine and its access to the river's waterways towards its European hinterland. The multimodal nature of the logistical infrastructure, offered at the port, is of significant competitive advantage to operating companies in the area.

From the 1970's to the present day a couple of large scale developments increased the synergies in the chemical cluster. The construction of the Maasvlakte Oil terminal allowed companies to create large storage facilities at the entrance of the port and allow for greater management of input to local refineries, by storing excess capacity and supplying when needed. In addition to that Vopak Logistic Service was involved in the development of a large internal net of pipelines, which would facilitate seamless resource utilization by competing companies. At the time major chemical companies such as BASF, Air Liquide and Dupont would become part of the cluster.

At the present day the petrochemical cluster consists of 5 refineries, 6 refinery terminals, 11 tank terminals for oil products, 45 chemical manufacturers and producers, 4 biofuel manufacturers, 5 edible oils refineries and 17 tank terminals for biofuels and edible oils. Additionally there are 4 gas power plants, 3 coal and biomass power plants, 2 LNG terminals and 4 coal and biomass terminals (Port of Rotterdam, 2010). The cluster amounts up to 33 km2 in size, which constitutes up to 60% of the port area. When crude oil arrives at the port of Rotterdam, it will be unloaded and stored in the refinery terminals.

Figure 13: Chemical industry capacities at the port of Rotterdam

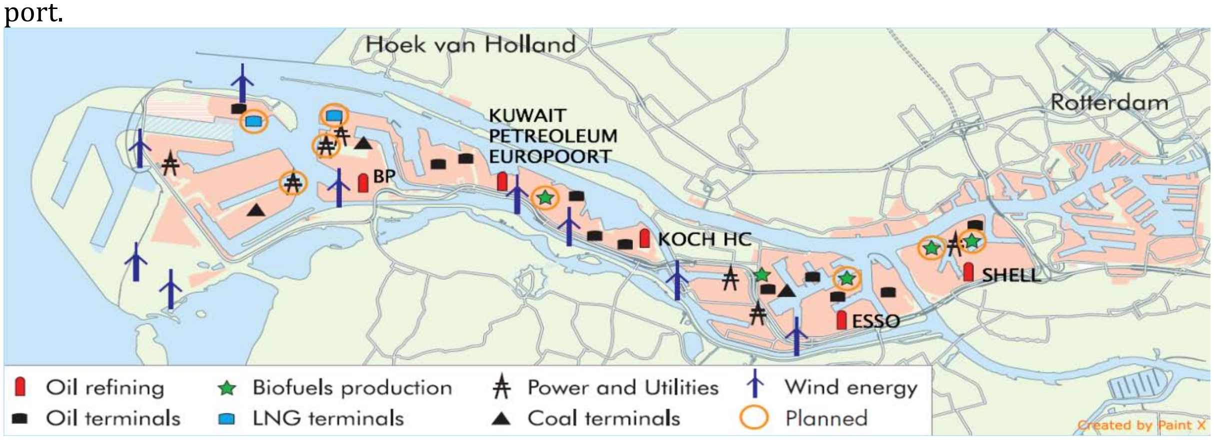
COMPANY	SITE (X 1,000 M²)	NUMBER OF EMPLOYEES	DRAFT (M)	CRUDE CAP. (X 1,000	NUMBER OF TANKS	CAP. PER (X 1,000 M³)	NUMBER OF BERTHS
Kuwait Petroleum Europoort	1)	55	21	285	5	40 - 90	1
Maasvlakte Oil Terminal (MOT)2)	1,220	43	23	4,500	39	112	2
MET	670	19	21	1,400	19	60 - 100	2
BP	640	18	15 - 21	1,300	15	50 - 100	3
Shell Europoort Terminal	1,080	33	13 - 20	2,150	32	20 - 100	4
TEAM Terminal	710	40	21 - 23	2,800	33	40 - 120	3
Total	4,320	208	-	12,435	143	-	15

1) *Included under Kuwait Petroleum Europoort Refinery* 2) *Capacity per 2012*

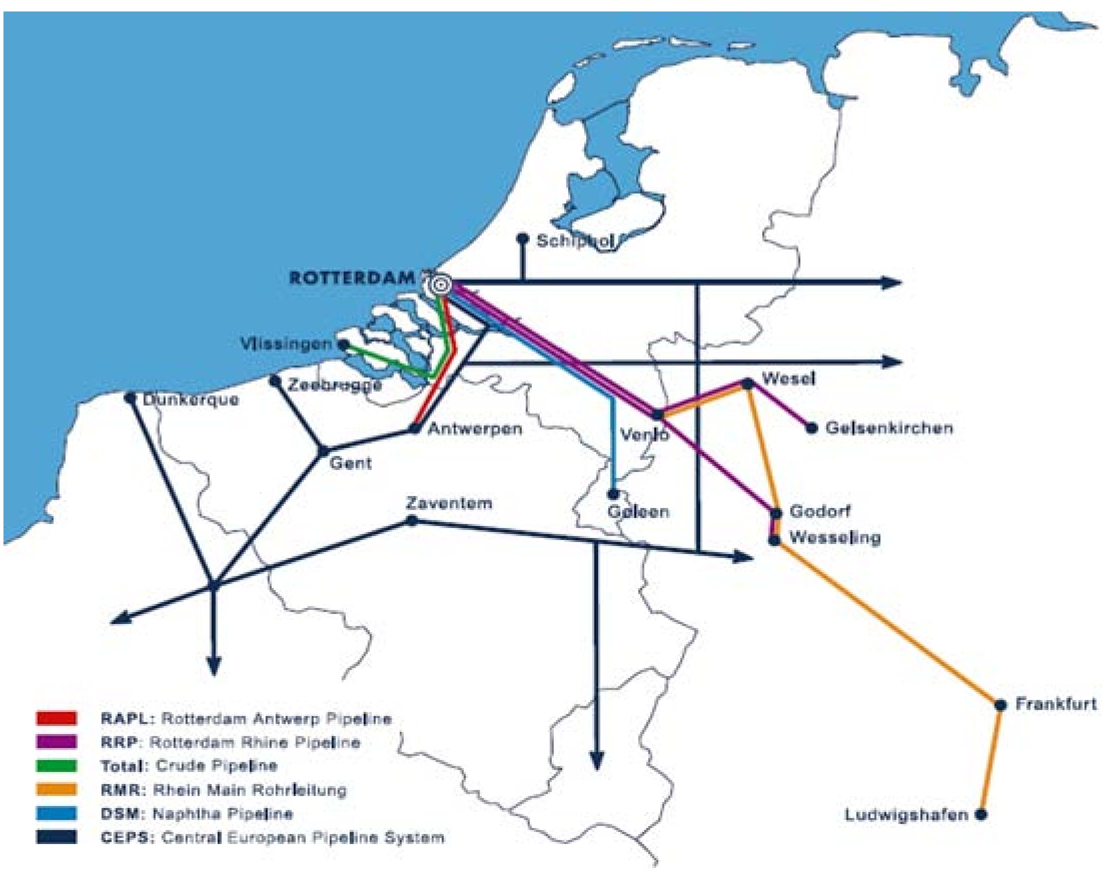
Source: (Port of Rotterdam, 2010)

The figure above lists the various owners of the terminals and their respective capacities, number of employees stationed, water draft accessibility in meters and so on. The total storage capacity of all of these terminals together sums up to 12.435 million cubic meters.

Once unloaded, the crude is transported via the established pipelines towards the five refineries. It will be then segregated into different oil products like LPG, gasoline, diesel, jet fuel among others during the refinery process. The owners of the five refineries are Shell, BP, Esso Nederland (Dutch branch of Exxon Mobile), Kuwait Petroleum and Koch HC Partnership. This is respectively also the order of these refineries from largest to smallest. The map below illustrates their location on the port.

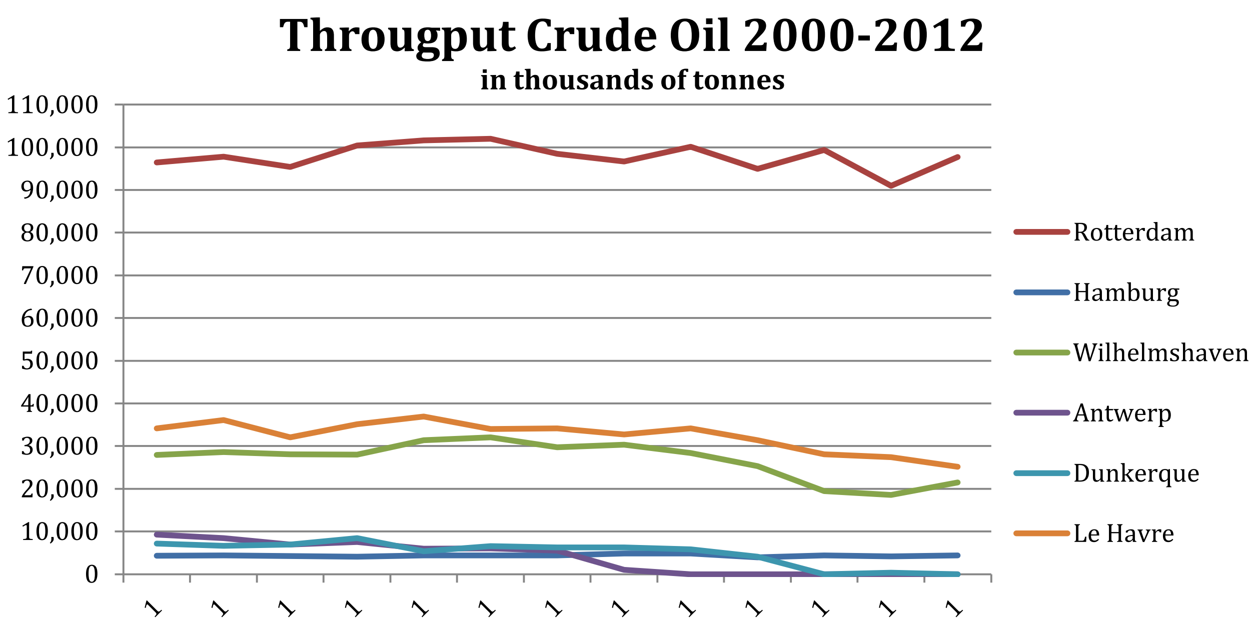


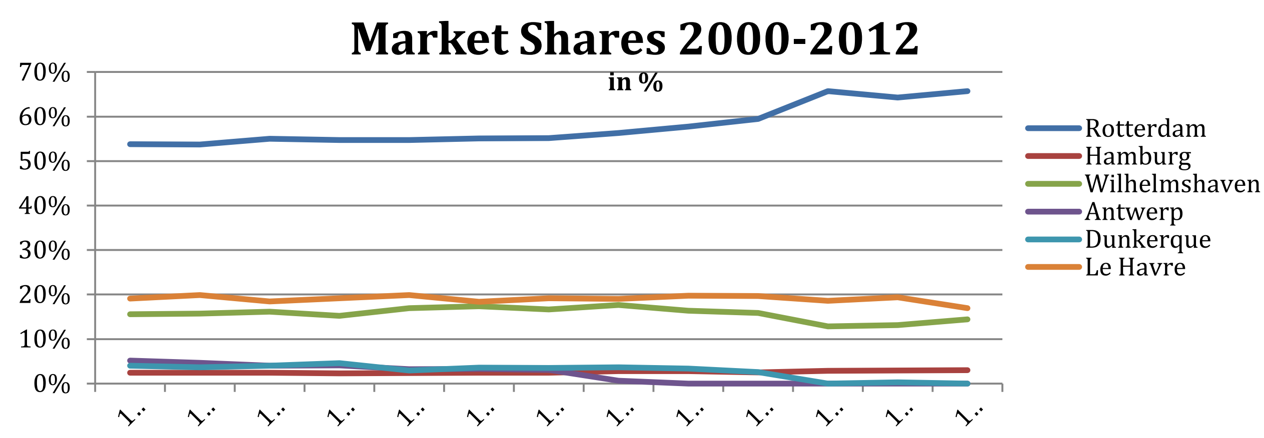
Half of the crude oil, which arrives at the port, is refined on location, where the other half goes to refineries outside Rotterdam. Around 7% goes to a refinery in the Dutch city of Vlissingen. The French company Total owns the refinery there, as well as the pipeline, connecting the port of Rotterdam with it (Spitzen, 2014). The map below illustrates the current pipeline connections, which are available from the port.



In total there are 3 pipelines. The green line indicates the location of the Rotterdam-Vlissingen pipeline, owned by Total, which we mentioned above. Furthermore we can see the red line, indicative of the Rotterdam-Antwerp pipeline, whose construction we also mentioned earlier. Around 28% of the crude oil, which arrives at the port, will be transported through this pipeline. The pipeline, like the Rotterdam-Vlissingen pipeline is owned by Total (RAPL, 2010). The main stakeholders of the Rotterdam-Antwerp pipeline are Shell and British Petroleum. The third and last crude oil pipeline is the purple line on the map and it is connected to two refineries in Germany. One of them is located in Gelsenkirchen and is owned by BP, and the other refinery is located in Wesseling and owned by Shell. Shell owns 55.6% of the stcoks of the pipeline from Rotterdam to Rhone, Ruhr OEL and BP both own 22.2% of the stocks (RRP, 2014).

Inarguably these natural advantages and significant infrastructural investments have been the reasons behind the ports success and the strength of its petrochemical cluster. As indicated below, Rotterdam has the highest market share and throughput of crude oil in the Hamburg – Le Havre range, statistics taken from Eurostat, the statistical office of the European Union.





Source: (Eurostat, 2014)

Albeit having the extensive pipeline connections to the hinterland, deep sea access and well developed internal pipeline network, the cluster at the port of Rotterdam enjoys a competitive edge in a number of other aspects too.

As the port has evolved during the decades, scarcity for land has been an increasingly important issue that had to be addressed and is still present to this day. In order to tackle this problem a highly innovative land reclamation project has been developed with the construction of the Maasvlakte 1 and 2, which extend the port surface area further into the sea. This massive operation required significant funding, which the port was unable to provide by itself and this is where the Dutch government stepped in. Currently the City of Rotterdam owns 75% of the port and the government owns the remaining 25%, however both are not directly involved in the activities of the port. The synergy between government and port is of immediate benefit to the growth and success of the cluster located there as well.

Furthermore the port is closely cooperating with the Erasmus University and Delft University, which provide access to a well-educated labor pool. Despite the strong connections with these universities however, there are no training programs or specific research being carried out to facilitate innovative solutions in the petrochemical sector. This can turn out to be costly in the long term, as any cluster which strives for competitiveness is bound to employ the latest technologies and put in as much innovation as can be accumulated, and by not embracing the full potential of these prominent universities, the industry might forgo unexplored possibilities.

The facilities at the cluster are also ageing and slowly becoming obsolete or uneconomic. As we have seen earlier, investments in refinery infrastructure usually have a lifespan of around 30-40 years, depending on the technology developed, and most of the facilities at the port of Rotterdam are already at least 30 years old. The lack of innovation and the underinvestment, paired with the unproductive relations with universities severely blunt the competitive edge of the Rotterdam cluster.

The chemical industry at the port of Rotterdam, albeit forming a cluster in its own right, is so well interconnected with the clusters of Antwerp and Rhine/Ruhr region, that together they can all be viewed as one mega-cluster, which we refer to as the ARRR. A study by the European Petrochemical Association reveals each cluster’s unique characteristics and history, which we summarize in the following part.

Part 5: Comparing the Rotterdam cluster with other competitor clusters in Europe.

The European Petrochemical Association (EPCA) views the separate clusters in Rotterdam, Antwerp and the Rhine/Ruhr as sub-cluster parts of one mega-cluster, referred to as the ARRR. Because of their strong integration, production flows and interconnectivity, it is a justified view, despite the fact that this mega-cluster spreads over 3 European member states.

In terms of production output the ARRR cluster is arguably the largest in the world. It is also the best integrated and interconnected chemical production region in the world. The primary clusters, as mentioned above, include the ones on the ports of Rotterdam in the Netherlands and Antwerp in Belgium, as well as two major inland regions: the Rhine/Ruhr in North Rhine-Westphalia (NRW) and the Ludwigshafen-Mannheim-Karlsruhe region. A number of smaller or "satellite" clusters are further integrated with the primary clusters. Among these are Terneuzen, Geleen/Sittard, Feluy and Frankfurt. These smaller clusters are highly dependent on the primary clusters for their production and successful operation as they lack the manufacturing depth to operate autonomously. The clusters are connected through four modes of highly developed transport infrastructure, such as pipelines, waterways, road and rail, enabling a moderately efficient supply chain management. The clusters in Antwerp and Rotterdam are connected to the ones in Rhine/Ruhr via ethylene pipelines, which pass through the SABIC cluster in Geleen.

With this information, the EPCA study evaluates individually the different parts of the ARRR cluster and compares it to another large chemical park in Western Europe, namely the Tarragona cluster in Spain. The following are the summaries of the profiles of each sub-cluster and the Tarragona cluster.

The Antwerp Sub-Cluster

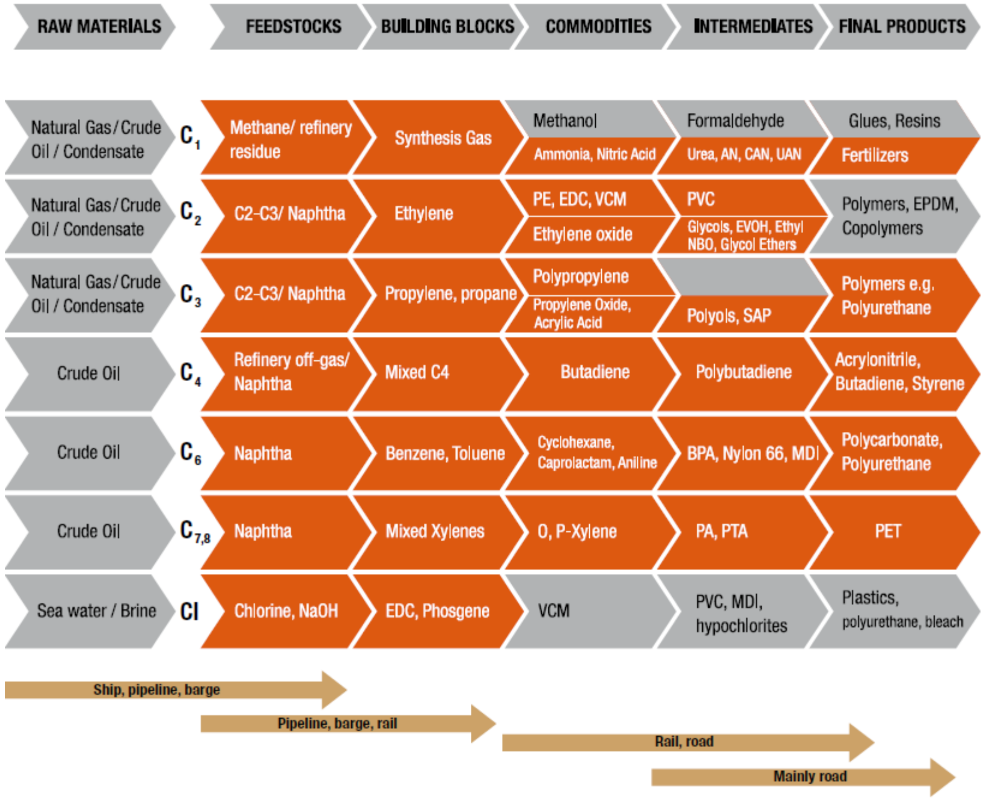
The chemical cluster of Antwerp is situated alongside the banks of the Schelde River and it covers 3650 hectares. It was only during the 1930s that its petrochemical industry was established with the creation of two refineries. Real progress was observed post the Second World War when an additional two refineries and an ethylene oxide production facility were built.

From 1951 to 1963 a series of investments led to the extension of its historical docks towards the Zandvliet lock and also to the opening of the Boudewijn lock. In 1963 a joint investment in two steam crackers and their respective ethylene processing capacities (which at the time were around 500.000 tons) increased the port of Antwerp's chemical orientation and focus. Companies such as Union Carbide Belgium and Amoco Fina had opened facilities to take advantage of the by-products of these investments. In the same year Bayer Rubber set up operations in the left bank of the port. Until 1970 five more multinational chemical companies set up facilities there, among these 3M and Exxon Mobil.

On the right bank of the port growth continued from 1966 through 1971 with large scale investments from BASF, Monsanto, Bayer, Solvay and Degussa. BASF and Air Liquide signed the first co-siting agreements in the port during 1971.

In the period 1979 through 1987 the cluster enjoyed growth without any significant investments. In the following years up until 2006, it benefited from the inception of new chemical producers, such as North Sea Petrochemicals (Shell/Borealis), INEOS Phenol as well as a few Japanese companies, such as Kuraray, Nippon Shokubai and Tokyo Kasei Europe. The port of Antwerp currently serves a variety of products along the value chain, which are summarized in the exhibit below.

Figure 14: Antwerp chemical cluster processing chain

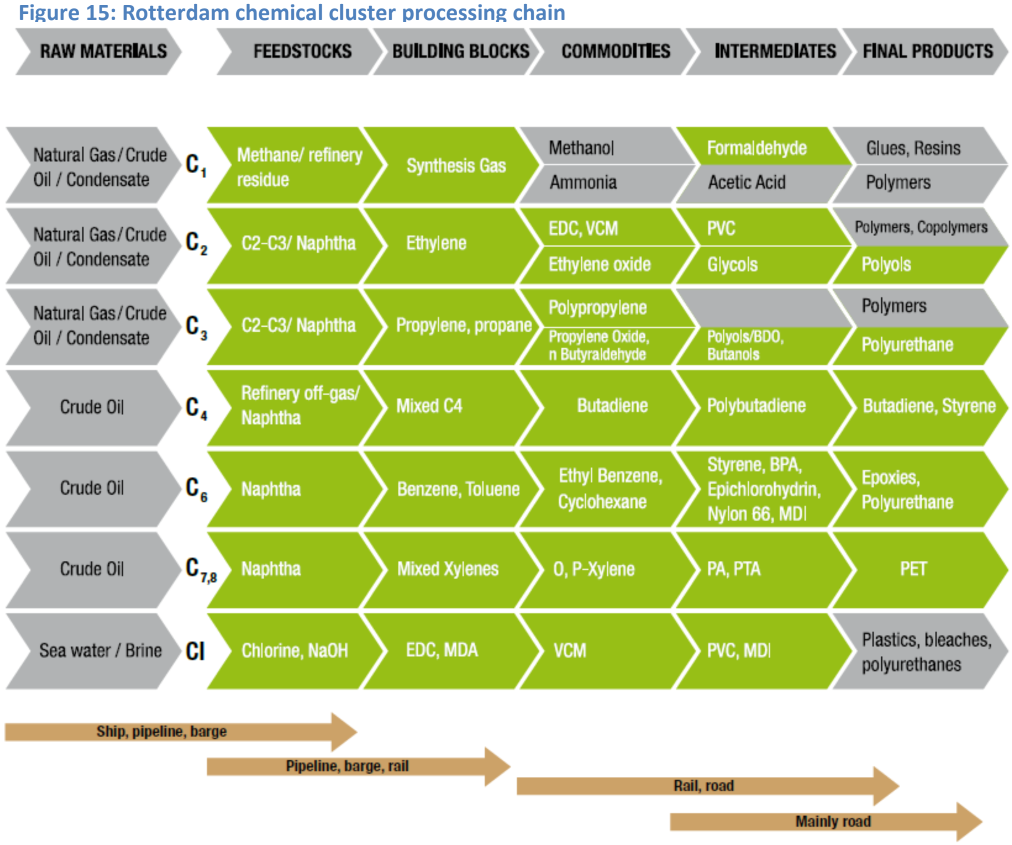


Source: (EPCA, 2007)

The Rotterdam Sub-Cluster

The Rotterdam petrochemical cluster covers 2865 hectares of land and is primarily based off manufacturing of base chemicals and processing of raw materials. We have covered its characteristics extensively earlier in part 4 and we will not go into further detail in this section. What is of interest here is the cluster's value chain, which is presented below:

Figure 15: Rotterdam chemical cluster processing chain



Source: (EPCA, 2007)

The Rhine/Ruhr Sub-Cluster

There are two clusters situated at the German state of North Rhine-Westphalia. One is the "ChemSite" cluster in the Ruhr region and the "ChemCologne" cluster in the Rhine area. Together they form the Rhine/Ruhr cluster. The two are well connected via all applicable modalities (such as pipeline, road, rail and waterways) with the largest inland port in Europe: Duisburg. Because of the well-established transport infrastructure, these clusters are well connected with the raw material import centers and feedstock production facilities, such as Rotterdam, Antwerp and Wilhelmshaven, and also with the German and Eastern European hinterlands.

The Rhine/Ruhr region emerged with the exploitation of local coal reserves. Similar to Rotterdam and Antwerp however significant investments began to take place after the Second World War, with the breakdown of the former chemical group IG Farben, which lead to the establishment of several refineries and steam crackers in the cluster. This was a turning point for the long term competitive advantage of the cluster as the raw inputs were replaced from the declining reserves of coal to oil.

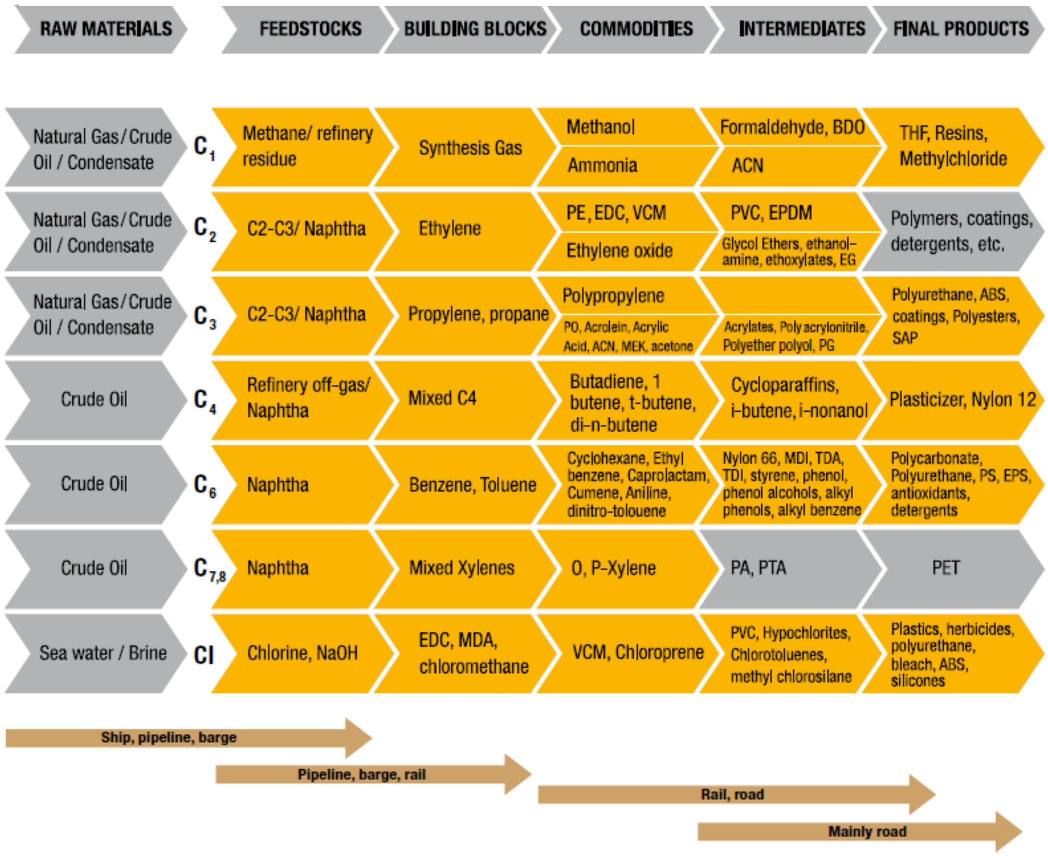
Until the 1990s most of the chemical facilities were run by a single user. Since then the trend has been a diversification of those operator's portfolios by co-siting additional chemical manufacturers. In the process the sites were transformed into interconnected, strongly integrated chemical parks, which offered their infrastructural benefits to a multitude of users, who in turn would benefit from the gains in efficiency, productivity and knowledge spill-overs. The site management and utilities are mostly still under the control of the founding member of the site, however with the arrival of new opportunities through co-siting, there is an ever stronger focus on the attraction of complementary partners to increase synergies in the clusters.

By the end of the millennium a growing number of operating companies in the cluster started combining their efforts to attract new players. This was a result of their vision for an "opened chemical cluster". As a consequence, the ChemSite initiative found its ground in 1997. It was a public-private partnership between the state of North-Rhine-Westphalia and the chemical manufacturers from the Northern Ruhr region. Among the founding chemical manufacturers are companies like Degussa, BP Refining & Petrochemicals, Rutgers Chemicals and SABIC. The initiative has since then successfully encompassed the Ruhr region. The region spans across 1400 hectares and out of these 240 are eligible for the relocation of new companies.

The Cologne/Leverkusen/Bonn region sites the counterpart to the ChemSite cluster in the face of ChemCologne. Some of the largest producers there are Bayer and Degussa, among 150 other members, ranging from logistics companies, authorities and universities to manufacturers. ChemCologne follows the same vision of ChemSite, which is promoting further investment in the region.

ChemCologne and ChemSite produce along the whole chemical value chain, emphasizing on base and specialty chemicals. The exhibit below provides a detailed illustration of the chemicals, which are produced.

Figure 16: Rhine/Ruhr chemical cluster processing chain



Source: (EPCA, 2007)

The Rhine/Main Sub-Cluster

The building blocks of the Rhine/Main sub-cluster are the Miro Refinery and petrochemical complex, the BASF Verbund site and several other chemical sites, among which Raschig's specialty chemicals site, all situated in Ludwigshafen.

The cluster is supplied with raw materials via pipeline and relies on the Miro refinery and other European refineries for naphtha, which is used as primary feedstock. The BASF Verbund site receives its naphtha from Antwerp and Cologne through the available Rhine waterway.

Rhine/Main processes yearly over 20 million tons of raw input and just as much sales products. It is the most integrated cluster in Europe in terms of petrochemicals, polymers, intermediates and performance materials. It has more than 200 production units, which are capable of creating more than 8000 products. In addition a highly developed and well integrated infrastructure of services, utilities, logistics and waste management ensure that efficiency and productivity, alongside environmental impact are minimized.

When we examine the Antwerp, Rotterdam and Rhine/Ruhr clusters in detail, it is easy to see why the EPCA decides to view them as parts of one mega-cluster. The ARRR mega-cluster is so well integrated and interconnected, through an advanced network of pipelines, waterways, railways and road, that each sub-cluster part is able to focus its area of expertise and attract its own niche of investors and manufacturers. This can be seen from the individual value chains, which illustrate how each sub-cluster covers the full range of products along the value chain from C_1 to Cl, however they diverge further down each chain. Where final products, such as polymers out of ethylene are not produced, as is the case with the sub-clusters in Antwerp and Rhine/Ruhr, they are instead produced in Rotterdam for instance. This allows the sub-clusters to fit together almost like pieces of a puzzle, where each sub-cluster fulfills demands for a specific product, which is not as developed among the other clusters. However this comparison, although close to reality, is not accurate in its entirety, as the clusters do not have fully defined strengths and weaknesses, which they complement in cooperating, but some have a clearly stronger position than others in terms of production capabilities. Better developed clusters, such as the Rhine/Ruhr, however are exposed to dependencies on other clusters, such as Antwerp and Rotterdam for the delivery of raw inputs and feedstock.

Besides cooperating together, there is also an ever present strong competition between the manufacturers in each individual cluster, for the slightly decreasing European chemical demand. Some more capable clusters, such as the Rhine/Ruhr and Rhine/Main, are likely to force their counterparts in Rotterdam and Antwerp to fulfill a supporting role, rather than allowing them to develop larger scale and scope of their individual industry. The primary drivers behind such a turn of events would be the very strong promotion and attraction of innovation in the region, coupled with well-established linkages to local universities and research facilities. Such focus on innovation and research is far from what we observe and could potentially be achieved at the Rotterdam cluster.

The Tarragona Cluster

Tarragona, located 100 km west of Barcelona, is the most important chemical production location in southern Europe and the Mediterranean. The production of the cluster amounts to 18 million tons yearly, 25% of which are exports. Tarragona takes 3rd place in Europe, among the largest producers of ethylene.

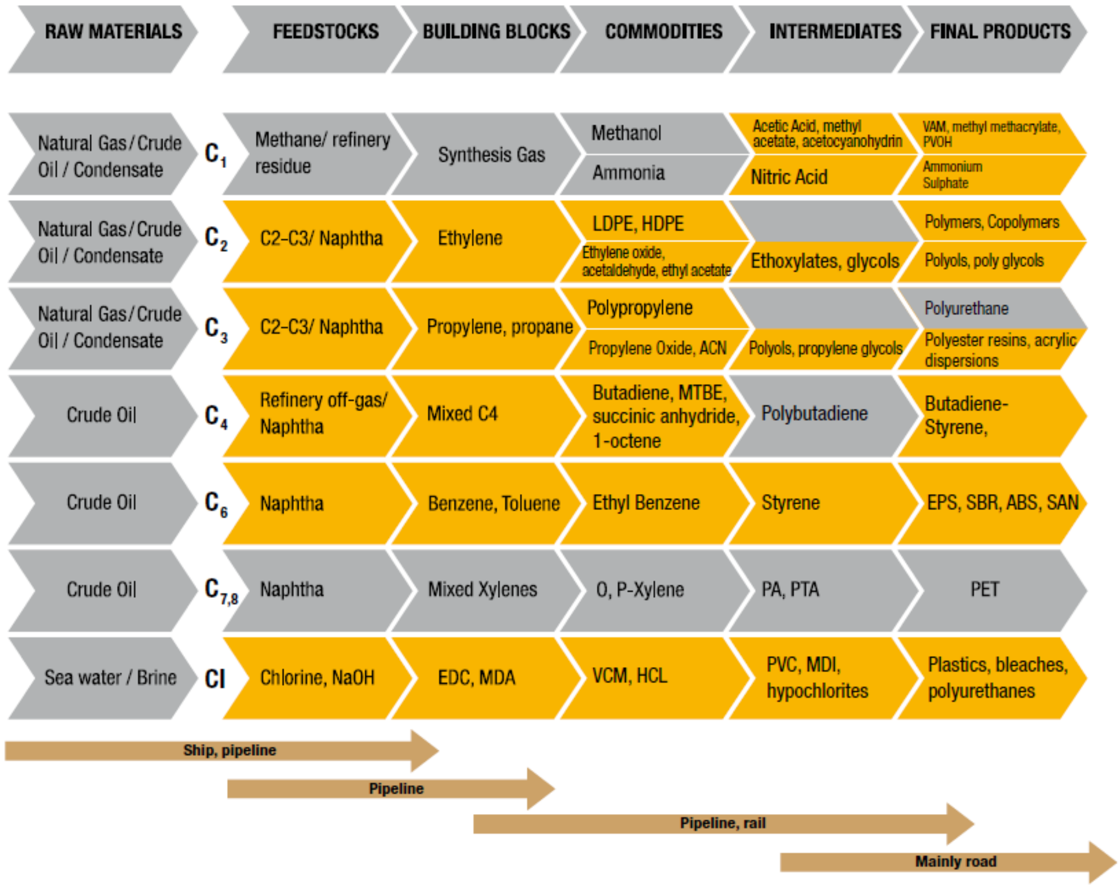
Typical, as is the case with the sub-clusters of the ARRR mega-cluster, is the establishment of major international chemical companies after the end of the Second World War. In total 34 companies operate, among which Bayer, BASF, Dow, Solvay and Repsol.

Tarragona's value chain is similar to other European petrochemical clusters, however a difference in its product slate results in no production among the C1 and xylenes chains.

The cluster facilitates high integration among the operating companies, with a third of their produce being used before leaving its boundaries, as input for other manufacturing. Most of the companies are also under the flagship of the AEQT (Chemical Business Association), which is also a part of the national FEIQUE (Chemical Trade Association). The AEQT's primary goal is to lobby local and national government in order to defend the interests of the chemical industry.

The exhibit below represents the Tarragona value chain.

Figure 17: Tarragona chemical cluster processing chain



Source: (EPCA, 2007)

What we observe by comparing the profiles of the ARRR mega-cluster with the profile of Tarragona is that ARRR finds itself in a much stronger competitive position, with respect to accessibility to diverse feedstock, alignment of government policy, infrastructure and interconnectedness, and last but not least, the emphasis on R&D and innovation. Government involvement is an integral part of each sub-cluster of the ARRR and active promotion to international investors is coordinated on cluster level, whereas this is not the case with Tarragona, where landowners are individually responsible for government lobbying and attraction of investment (EPCA, 2007). As a part of the ARRR mega-cluster, the petrochemical cluster at the port of Rotterdam benefits from its collaboration with the other sub-clusters, such as ChemSite and Antwerp. It is also uniquely positioned at the largest port in Europe, giving it unmatched flexibility for international maritime trade. While positioned in a favorable geopolitical environment, the port of Rotterdam cluster will be subjected to competitive pressure from both international shifts in energy trade and from the rest of the sub-clusters of the ARRR. Whether Rotterdam will be able to maintain its competitive edge will depend on how adequate and prompt the response from authorities and operating companies will be to changing market conditions, and also will be subject to the type of scenario the future holds for the global energy market. An array of four likely scenarios is further discussed in the following part.

Part 6: Four scenarios for the future of the Rotterdam petrochemical cluster.

As a preface to the following scenario discussion, it is worth reiterating the concept of 'long run' and paying specific attention to the most important assumption that is conveyed within it. In the economic understanding of 'long run' all factors are subject to change and nothing is held constant. This holds true not only to our understanding of costs and prices, but also to everything else in the natural world we live in. Everything around us can be viewed as a dependent variable, which is influenced by a set of independent variables. These independent variables however are chosen by the researcher, who is investigating the given event, and as close as they may get to define the phenomena, there is always a chance that an omitted variable could change the whole interpretation of things, had it been considered. With that being laid out, it is important to note that the proposed scenarios are only simplified versions of the expected future. What we observe in reality could in fact be approximate one of these scenarios, it could be a mix of a few of these scenarios or it may be completely different view altogether, therefore the following should be taken with a grain of salt.

The Association of the Dutch Chemical Industry (VNCI) in collaboration with Deloitte discusses four different scenarios for the future of the chemical industry and its impact on the Rotterdam chemical cluster. The four scenarios are labeled 'fragmentation', 'green transition', 'abundant energy' and 'high-tech world' and all of them present a possible future outcome according to a set of assumptions. A brief summary of each follows.

Scenario 1: Fragmentation

The fragmentation scenario presents the least positive outlook of the future. It assumes that few technological breakthroughs in the upcoming decades force nations to seek self-sufficiency and to endorse protectionism as global supplies become scarcer. The scramble for resources leads to the imposition of trade barriers and military conflicts between the world's superpowers are not out of the question. In turn a rise in energy and commodity prices is observed. Innovation and R&D are channeled into solutions of local or regional nature. Europe sees limited market growth, as its domestic demand remains low, due to weak economic growth, and its exports are limited by global protectionist measures. As global competition becomes less intense, Europe looks for diversification of its feedstock, because of its dependence on imports. Innovations such as smart packaging to reduce perishability of goods and improved desalination techniques for water take priority. The chemical industry focuses on providing products which increase the efficiency in various sectors, such as construction and the automotive industry among others.

According to the assumptions of this scenario, China and India will have a small impact on the European market, because of trade restrictions. Therefore European companies are expected to focus on optimizing their processes and making their production more efficient in order to serve their local markets. Companies both upstream and downstream are expected to survive and continue to provide their services.

Because the ARRR cluster is in a much stronger competitive position than other clusters in Europe, it is expected that it will take market share away from other domestic clusters.

The Rotterdam cluster will be negatively impacted by trade barriers as it heavily relies on imported feedstock for its production. Necessary closures of uneconomic facilities, improving the efficiency of its operations and promptly catering to emerging customer needs will be the most important factors of its success (VNCI, 2012).

Scenario 2: Green Transition

In this scenario, global climate change and the environment have become the primary issue of concern to society. Awareness of these problems creates growing demand for sustainability, which in turn drives innovation towards cleaner, more eco-friendly produce, production processes and services. Companies adopt the vision for sustainability and create consumer demand for green products. Innovation in bio-based feedstock leads to the use of second generation biomass, which is different than current biomass, because it no longer competes with food. Second generation biomass comes from materials like wood, straw and non-edible plants. Third generation biomass may be obtained from algae and may offer the same uses as naphtha-based products. This scenario suggests that 15 to 20 percent of feedstock globally will be bio-based by 2050. Recycling and reuse of waste materials also contributes to sustainability. Furthermore recycled chemicals and metals can be used as feedstock, thus the food and waste sectors enter the chemical sector's value chain.

The green transition leads to low economic growth, as strict environmental rules and regulations need to be complied with in order to achieve sustainability. Under this scenario the industry sees little change as bio-based plants are similar to naphtha based plants. Integration and conversion to bio-based feedstock is prioritized by operating companies. The market fragments and emerging players in biomass, such as Brazil can coexist with oil-producing regions. Competition remains high among Chinese, India, US and European markets. If Europe is to be successful in this scenario, it is completely dependent on its capacity to meet demand for green products and its ability to integrate the new bio-based feedstock into its production lines.

The Rotterdam cluster is uniquely positioned in this scenario as it sits at a major world port and if new feedstock were to flow through it, it is well positioned to process it at the ARRR cluster. Furthermore the Netherlands and Germany are world leaders in recycling and waste management. Demand for sustainability is also growing faster in the Netherlands than in the US or Asia (VNCI, 2012).

Scenario 3: Abundant Energy

Abundant energy assumes new sources of energy and technical breakthroughs that limit the negative impacts of the current hazardous energy production. Inventions such as high performance, low cost photovoltaic panels, inexpensive and powerful solar energy allow companies and households to satisfy their own energy needs. With this technology chemical plants will also be able to operate with energy created on their own. In response to that oil, natural gas, biomass and other sources of energy observe a dramatic drop in price. Chemical products become cheaper and innovation spurs. A drop in transport costs encourages international trade and leads to strong economic growth. High-tech environmental solutions become available as a consequence of strong growth and large profits.

This scenario assumes that as a consequence of the abundance of solar power and alternative sources of energy, hydrocarbons become widely available and oil and gas based chemicals remain dominant on the market. Western Europe stays cost competitive, since lowered transport costs render competition at feedstock distribution level irrelevant. Process efficiency becomes the dominant competitive aspect. Operating companies use their advantages to grow even further and form an 'oligopoly of mega chemical companies' which lead the industry. They are based in America, India, China and Europe. The largest of these companies are mergers between Eastern and Western firms. Smaller players are forced to position themselves in niche markets in order to compete.

The abundant energy scenario is one of the most favorable scenarios for the ARRR cluster and the port of Rotterdam cluster as well, since both the mega-cluster and its sub-part are in an excellent position to take advantage of the unfolding events (VNCI, 2012).

Scenario 4: High-Tech World

High-tech world assumes multiple scientific breakthroughs. Technological revolution allows bio-engineers to model molecules in ways never before seen as possible, creating new applications and giving rise to larger revenues for the chemical industry worldwide. Molecular design builds on top of low cost, efficient processes. Energy efficiency improves significantly and safety standards rise as plants become more decentralized and smaller plants form alongside larger ones. New systems, such as nanocatalysis, allow for the conversion of CO_2 into CH_4, rendering CO_2 as a possible feedstock.

The high-tech scenario is based on the assumption of constant growth in successful scientific output. This is a likely assumption, because scientific output has grown at a stable rate of around 4 percent yearly since 1883. It is expected that if this pace keeps up, by 2050 there will be 5 times the number of inventions we see today.

A boom in the number of engineers is expected, as China and India become wealthier and able to provide higher education to the masses. Decreases in the cost of computing power and innovations in the fields of bandwidth transmission and storage capacity allow for real time information sharing between scientists. Intellectual property no longer is developed by individual companies, but is rather transformed into crowd sourced ideation, similar to today's "open source" software.

New technologies will inevitably evolve current chemical products and bring about new production processes as well as products. As the scale of chemical plants becomes less important for efficient production the industry is likely to fragment and introduce new dynamics to the current structure of clustering, or even change it completely.

The high-tech scenario predicts strong economic growth, facilitated by free international trade. The positive economic conditions create a favorable and stable policy environment for investment. As revenues increase in response to innovation, the chemical industry transforms into a high tech, highly innovative industry, much like the contemporary IT sector. It consists of a small number of very large players alongside which, many start-ups ready to focus on a specific niche.

In order to be successful in this scenario, the ARRR will have to build on its current potential and attract adjacent industries, such as health and personal care, agriculture and life sciences. Nevertheless it is very important that the industry attracts more scientists and chemical engineers, who would collaborate with leading researchers, and also actively promote itself in order to attract investment (VNCI, 2012).

Conclusion

This study has covered an array of available data, scientific literature in the field of clustering and reports from leading experts in the chemical industry with the purpose to evaluate the competitive position of the petrochemical cluster at the port of Rotterdam. We began by exploring the current mega-trends in the international chemical trade. Among the key findings are an industry shift towards Asia and the Middle East, as favorable conditions for healthy profits there attract larger investment, and a boom in shale oil production in the United States, which has effectively flooded local markets and satisfied local demand. Because of these two events, international competition has intensified and the European chemical industry is facing increasing pressure to stay profitable. In part 2 we quantized the effects of these changes and saw that the European chemical industry, albeit enjoying an absolute increase in revenues, has in fact being drastically dropping down in international market share. As new markets and players emerge, the lost market share is a further sign of the intensification of competition, rather than one of a failing industry. We have also estimated that the most immediate effect of the shale revolution in the US will be a hit on the ammonia and chlorine chains of production in Europe. In part 3, an overview of Porter's cluster theory revealed that clusters uniquely benefit from the symbiosis of competition and collaboration between the different parties involved, however that the driving factors of a cluster's success ultimately lay upon alignment of political and private interests and the presence of innovation. In the following part, an outline of the port of Rotterdam's cluster structure revealed well aligned interests and a healthy collaboration with other clusters under the ARRR label. Troubling however is and absence of significant investment and innovation. The ageing facilities at the Rotterdam cluster are at a point of time, where a fresh vision of the future and structural change is required in order to keep up with emerging needs and shifting demand. In part 5 we compared the different sub-clusters of the ARRR and the Tarragona cluster in the South of Spain in order to see how the cluster in Rotterdam fares against them. With the unique focus on innovation and collaboration in the German clusters and the complementarity in production between the Antwerp and Rotterdam clusters, we observe that Rotterdam is uniquely positioned as the entry port for the largest imports and thus cements its place as the most important relay point in Western Europe. The last part of this research presented a set of plausible future scenarios, which all contained a unique set of challenges and opportunities for the petrochemical cluster in question.

With this information at hand, the answer to the research question this paper seeks to find out is relatively rhetoric: the competitive position of the petrochemical cluster is stable and strong in the short to medium turn. However the cluster has all of the necessary prerequisites to transform and become a successful chemical hub in the long run as well, creating jobs and contributing significantly to the Dutch economy. In order to achieve this it is necessary that collaboration between port authorities and the operating companies leads to an identification of the most valuable future markets and opportunities and a common goal is set to transform the cluster in the best way possible, in order to take advantage of the current market changes. The solutions will not come from one side, but from a good cooperation between private and public entities. Encouraging further integration of the communication between local and international universities, and the chemical industry is going to stimulate innovation and this should be strongly adopted for an optimal outcome.

It should be recognized at this point that the conclusions taken by this paper are approximations of reality. Furthermore the studies which have been reviewed present a current picture of reality, which in the rapidly growing world today may be outdated tomorrow, by the emergence of a new invention or a sudden change in policy in response to a military conflict. Such factors are however impossible to estimate and thus are presented as the scenario discussion in part 6. As further research it would be interesting to evaluate the most likely progression path for alternative energies (like biomass) and which one will be the most beneficial for the port of Rotterdam to turn to.

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