Refinery Emissions from a Competitive Perspective

A.J. Plomp **(ECN)**
Ch. Barry **(Wood Mackenzie)**
P. Kroon **(ECN)**
I. McAlpine **(Wood Mackenzie)**
M. Mozaffarian **(ECN)**

January 2015
ECN-E--15-003

Acknowledgements

This study was conducted by the Energy research Centre of the Netherlands (ECN) in cooperation with Wood Mackenzie under assignment from the Netherlands Petroleum Industry Association (VNPI). The study is registered under ECN project number 5.2560. The ECN contact person for this project is Hamid Mozaffarian (mozaffarian@ecn.nl).

Abstract

The Netherlands Petroleum Industry Association (VNPI) engaged ECN and Wood Mackenzie to assess the effect of future emissions legislation on the economics and competitive position of the Dutch refining industry. Environmental measures may be implemented due to potential stringent policies. Scenario analysis has been used to assess the cost burden of potential stringent measures. The results have been put into the context of global and European developments, which are relevant for the refining sector. An extensive inventory of relevant legislation has been made as well, together with a comparison of relevant competing regions.

Although the Dutch refining sector is currently a front-runner with respect to environmental performance, stringent environmental measures have been identified that will lead to further emission reductions.

The cost burden associated with these stringent measures will have a marked impact on the competitiveness of the Dutch refining sector, resulting in lower aggregated refining gross and net margins, and a decrease in the industry's 'added value' for the Netherlands. This may ultimately reduce the attractiveness of operating or investing within the sector and may increase the risk of refinery closure.

Contents

Appendices

Summary

This study was performed by ECN and Wood Mackenzie at the request of the Netherlands Petroleum Industry Association (VNPI), to assess the effect of future emissions legislation on the economics and competitive position of the Dutch refining industry. Environmental measures may be implemented due to potential stringent policies.

General developments globally and in Europe have been seen to have a negative effect on the European refining sector. In Europe, the demand for oil products and hence refining capacity, is expected to remain subdued. At the same time, North American refineries are becoming increasingly competitive due to tight oil developments. New refining capacities in the Middle East will benefit from low-cost crude. Russian refineries are expected to upgrade due to changing regulations, which will improve their competitive position. The effects of these developments have been assessed under the Basic Plant Scenario.

Developments in emission regulations at the global, European and national levels have been assessed. Global and European legislation has an impact on the Dutch refining sector, but has a more or less similar effect as well on competing refining sectors abroad. On a national level, environmental regulations are variable and an analysis of national emission profiles demonstrated that the Netherlands is a front-runner in environmental performance. Belgium and the USA are other front-running countries with respect to national emission profiles. Emission profiles of Germany go towards a front running level, but are currently at a higher level as compared to the Netherlands. Emission profiles of France decline too, but are at a substantially higher level as compared to the Netherlands. Emission limit values for other relevant competing countries outside Europe and the USA were found to be generally more lenient than those in the Netherlands.

Based on existing and additional policies, a Stringent Plant Scenario was constructed in order to assess stringent environmental measures, along with measures to comply with major hazard regulations. As well as environmental emission reduction, these measures bring a cost burden. The total aggregated capital costs of these measures under the stringent plan scenario were estimated to be about EUR 1.33 billion per year, while the

additional aggregated operating costs associated of the investments were estimated to be about EUR 53 million per year.

The Netherlands is currently one of the stronger performers within North West Europe as a result of the scale, complexity and integration of the refining sector. Due to increasing supply from other regions, a stagnating domestic product demand and competition in key export markets, the outlook for the European sector, including the Dutch refining sector, is for a decline in the volume of crude processed over the next few years. The outlook for the Netherlands is analysed under the Basic Plant Scenario and the results showed an expected decrease of approximately 17 Mtons, or approximately 30% of the current volume of crude processed. This is reflected by a reduction in 'refinery utilisation', a measure of crude processed through existing facilities.

The longer term emission outlooks for NO_x, SO_2, NMVOC and dust, based on the measures under the Stringent Plant Scenario, demonstrate a decrease in emissions of 50%-75% up to 2025, as compared to 2012, for all relevant pollutants. Part of these reductions must however be attributed to reduced utilisation.

The impact of the additional cost burden arising from the implementation of stringent legislation, i.e. the Stringent Plant Scenario, has been recalculated to an equivalent reduction in aggregated refining gross and net margins of USD 0.86 per barrel. The added value of the Dutch refining sector could decrease by EUR 400 million per year compared to the current 2012 position, which is a reduction of approximately 20%.

In conclusion, it is expected that the Dutch sector will be threatened by emerging competitive refining regions under both the Basic Plant Scenario and the Stringent Plant Scenario. The challenge for the Dutch sector will be to remain competitive with its neighbours (Germany, Belgium and France). Decreasing margins are expected for the Stringent Plant Scenario, which will have a negative effect on the competitiveness of the Dutch refining sector. This may ultimately reduce the attractiveness of operating or investing within the Dutch sector and could potentially result in further loss of competitiveness and an increased risk of refinery closure.

1

Introduction

1.1 Background and project objective

Objective: to assess the impact of future emissions legislation on the competitiveness of the Dutch refining sector

The background for this study is the desire of the Netherlands Petroleum Industry Association (VNPI) for an integrated analysis of the impact of environmental legislative measures on the competitiveness of the Dutch refining sector. Though there are already numerous policies, from time to time discussions arise between the Dutch refining sector and the Dutch government with respect to additional policy measures. One of the latest developments with respect to the NEC Directive and the Industrial Emissions Directive resulted in the need for a study on the costs and impact of existing and additional emission reductions as well as an assessment of the economic and competitive position of the refining sector in the Netherlands.

The overall objective of this project is to assess the effect of future emissions legislation on the economics and competitive position of the Dutch refining industry.

As set forth in this report, ECN and Wood Mackenzie have received and/or developed information regarding individual refineries which may be viewed as competitively sensitive. This information is kept confidential. This report and all associated discussions are and will be based on aggregated figures only.

1.2 Methodology

This assessment was performed by answering the following research questions:

- How will Dutch refineries respond to and comply with future legislation?
- What is the current and expected future economic performance of Dutch refineries?
- What is the relative position of competing refineries and how will this evolve?

How will Dutch refineries respond to and comply with future legislation?
As a reference case, the current and future emissions profiles under the 'Basic Plant Scenario' were studied. Subsequently, the changes to emissions limits that new legislation will bring about in the future 'Stringent Plant Scenario' and the options available to refiners to meet future requirements, were analysed.

What is the current and expected future economic performance of Dutch refineries?
The current market environment for Dutch refineries was studied with respect to economic developments and the costs that would be incurred in complying with new legislation. Appropriate metrics were identified and used to assess the impact on the refineries' economic performance.

What is the relative position of competing refineries and how will this evolve?
The assets and geographies with which the Dutch refineries compete were investigated. Attention was also paid to the impact on other refiners of similar legislation, and the threats that might be expected from refiners not affected by the same environmental legislation.

A number of concepts are relevant to this study and are defined as follows:

Basic Plant Scenario (BPS)

Various scenario definitions

In this study, the BPS is used as the reference background scenario. Under this scenario it is assumed that the individual refineries have interpreted the regulations in order to achieve the highest set of emission limit values, and that implementation of the legislation applicable to all EU countries has been executed in the most lenient manner possible.

Stringent Plant Scenario (SPS)
This scenario is based on compliance with a stringent set of emission limit values prescribed on the basis of the interpretation and implementation of legislation by the Dutch authorities. Numerous environment-related measures are assumed to be implemented in this scenario.

Sustained Utilisation Scenario (SUS)
Although VNPI accepts the BPS, this scenario shows a very low aggregated utilisation rate for the Dutch sector. From both a technical and an economic perspective, this is not a sustainable scenario for any individual refinery in the long term. Each refinery will strive, under the given economic climate, for maximum utilisation.

To adequately represent the concept of uncertainty connected with outlooks based on economic optimisations, VNPI requested that the consultants address the actual 2012 situation as a sustained scenario for an alternative scenario outlook. This alternative scenario is presented as a 'what if' scenario in which utilisation is maintained at the current levels.

Net cash margin (NCM)

Definition of net cash margin

The net cash margin (NCM) is a key measure in analysing the competitiveness and profitability of an individual refinery, capturing the critical elements of a refinery's performance. In financial terms, the NCM is equivalent to earnings before interest, tax, depreciation and amortisation (EBITDA).

The NCM calculation is as follows:

Net Cash Margin (USD/bbl) = Gross Margin (USD/bbl) - Cash Operating Expenses (USD/bbl)

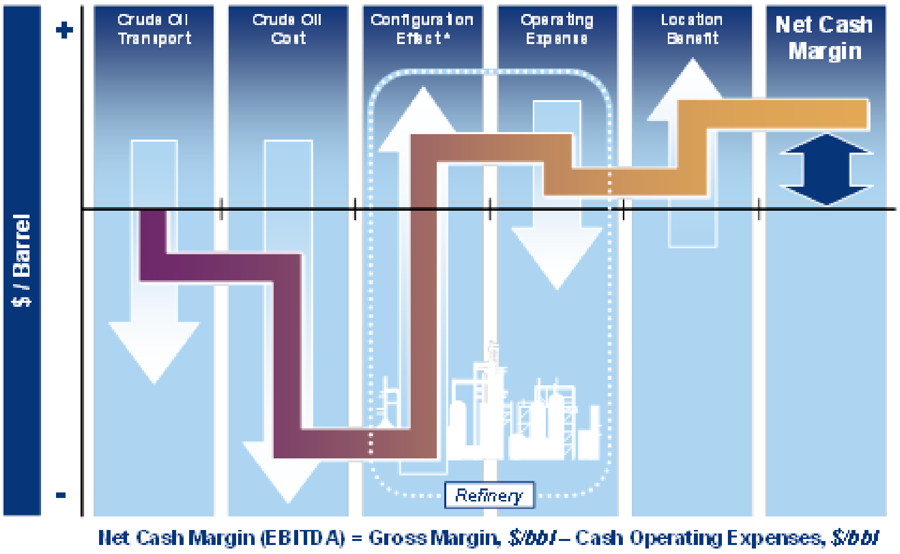
Where Gross Margin = Gross Product Worth + Location Benefit - Delivered Crude Cost

Wood Mackenzie analyses these key parameters for each refinery. It is important to note that the evaluation for each refinery is performed under a standard 90% assumed utilisation in an effort to allow for comparison of the sites on a similar basis. Furthermore, NCM and its constituent parts are calculated on a per barrel of crude basis. This is crucial since many refineries process intermediate feedstocks and some operators calculate NCM on a per barrel of throughput basis.

Additional costs on a per barrel basis are based on the full crude processing capacity of the refineries in order to best reflect the full impact of the fixed and variable operating cost elements.

Free market conditions are also assumed when calculating NCM, which means there is no government-controlled pricing or crude import tariffs as is the case in many Asia-Pacific and Middle East countries. By adopting this approach, the underlying strength of each refinery is measured on a level playing field.

Figure 1: Net cash margin (NCM) methodology



Assessing the NCM of refining clusters enables us to investigate global competitiveness as it indicates the profitability of processing an incremental barrel of product. In order to develop NCM results via modelling, a number of key elements are taken into account:

- Specific crude costs by crude grade.

- Delivery costs of crude to each refinery.
- The configuration effect of each refinery (its ability to convert crude oil into different products).
- The operating costs of each refinery (made up predominantly of utilities, energy, labour and fixed overhead costs). This also includes estimation of the impact of specific legislation such as EU-ETS costs for countries affected.
- Any specific product pricing advantages or disadvantages which could be achieved based on a refinery's location or proximity to market.

This analysis has used Wood Mackenzie's proprietary research and models to analyse the NCM of the Dutch and global competing refineries.

Added value

Definition of added value

The added value of the aggregated Dutch sector was also assessed as part of this study. Although this metric does not allow for a direct comparison with other global regions, it is a key indicator of the contribution the industry makes to the economy of the Netherlands. Added value is defined as:

Added Value = Value of Products Produced – Cost of Feedstocks – Operating Expenses + Employee Benefits

This is the 'value' the refining industry adds to the economy of the Netherlands in terms of both operating profits and benefits paid to the employees.

Our analysis forecasts the aggregated Dutch refining industry’s product yield and prices, throughput of crude and feedstock, operating expenses and employee benefits. By calibrating the models against the historical 'added value' as reported by the Dutch Central Bureau of Statistics (Centraal Bureau voor Statistiek (CBS)), an assessment of future added value impacts has been developed based on a number of different scenarios.

1.3 Refinery technology

Refining processes

Main refining processes:
- Distillation
- Processing: heavy to light
- Processing: quality and specs
- Blending

The purpose of oil refining is to produce useful oil products from crude oil. The four major processes relevant for oil refineries are:

- Distillation (atmospheric distillation, vacuum distillation).
- Processing of intermediary products into lighter products (coking, catalytic cracking, hydrocracking).
- Processing of intermediary products to increase quality and meet requirements (hydrotreating, hydrodesulphurisation).
- Blending to meet required specifications for delivery of final products.

First, crude oil is separated into various fractions, such as naphtha, gasoline, kerosene, gasoil and fuel oil, using distillation. Distillation is performed first at atmospheric conditions, and then the atmospheric residue is distilled again under vacuum conditions resulting in vacuum gasoil and vacuum residue. In the Netherlands, all refineries are equipped to carry out these processes.

Vacuum gasoil may be treated using processes such as catalytic cracking or hydrocracking to convert it into lighter products like gasoline and gasoil, and unavoidable by-products such as gases, LPG and heavy gasoil. Often, the cracking capacity is directly related to the capacity to produce vacuum gasoil.

The vacuum residue may be processed using coking technology to further increase the distilled fraction and decrease the amount of vacuum residue. Some Dutch refineries are equipped to process vacuum residue, while others often sell the vacuum residue as fuel oil. If necessary, the vacuum residue or atmospheric residue is blended with lighter products.

The intermediary products may need further treatment to increase their quality, for example to increase the octane number of gasoline. This is often carried out using a catalytic reformer. Sulphur requirements may dictate a reduction in the amount of sulphur in the oil products, for which hydrodesulphurisation processes are performed. Using a Claus plant, hydrogen sulphide from the hydrodesulphurisation process is separated and converted into pure sulphur.

Various fractions may be blended in order to meet requirements with respect to, for example, vapour pressure, ignition temperature or sulphur content.

Refining flexibility
A substantial portion of the refinery products is already present in the crude as received and is obtained via separation in the distillation units. In general, the crude type directly determines the product partitions. As described earlier, heavy intermediary products can be converted into lighter products, if appropriate conversion capacity is available. In general, these installations are designed and optimised for the major production of one product, for example diesel or gasoline, however the coproduction of by-products, such as gases or lighter and heavier oil streams, is inevitable.

The vacuum distillation capacity and the capacity for further processing therefore dictates the crude mix that a refinery can handle. In general, there is little flexibility within these specifications. For example, if the product demand were to change from gasoline to diesel, the existing refining capacity would barely be capable of adapting to such a development. Therefore, investment in additional secondary conversion capacity would be needed.

1.4 Refinery economics

Oil refining can be defined as a 'conversion' industry; the conversion of crude oil into functional finished oil products such as gasoline, jet fuel and diesel. Its profitability is less driven by the overall price of these commodities (such as the price of Brent crude oil), but by the difference in value between the finished products and the feedstocks required to produce them. The fixed and variable operating costs associated with

Main economical driver for oil refining: price difference between oil products and feedstocks processing must also be taken into account (including utilities, energy, labour, equipment and overheads). The type (and quality) of the crude oil purchased, combined with the configuration of the refinery, will ultimately determine the relative yield of different products. Highly 'complex' refineries are able to upgrade significantly lower quality crude into more valuable lighter products and can therefore reap the benefits of purchasing lower quality, often discounted crude oils. As such, a refinery's complexity is often a key indicator of its potential performance. The location of a refinery can also be critical, as those situated near crude production regions can benefit from reduced crude delivery costs, and those situated near major deficit product markets can achieve stronger local pricing for products.

Profitability is also influenced by configuration, efficiency and costs of operation

Ultimately the profitability or performance of a refinery is driven by the difference in price between oil products and feedstocks (referred to as product cracks), a refinery's ability to convert feedstocks into the various products, and the efficiency and cost of operating the refining process.

The net cash margin (NCM) of a refinery, the net margin made per barrel of crude processed, is a key industry standard measure of performance. It is defined as the value of the products produced, minus feedstock and operating costs. The NCM is the driver of refinery economics as it indicates the value that a refinery adds to a crude oil through its conversion to finished products, and forms the basis for refinery benchmarking and competitiveness assessment. The ultimate value generated by a refinery, earnings before interest, tax, depreciation and amortisation (EBITDA) is therefore determined by multiplying the NCM of the refinery by the total number of barrels of crude processed. As such, a refinery's throughput or 'utilisation' must also be taken into account. Typically refineries will operate at around 90% of their installed processing capacity (taking into account planned and unplanned shutdowns or outages).

1.5 Contents of the report

- **Chapter 2** presents a detailed introduction to current and relevant future developments within the refining industry, together with an extensive description of the Dutch refining sector.
- **Chapter 3** assesses the relevant global, European and national legislation, which may have substantial financial effects on the mineral oil refining sector, and makes a comparison of international legislation.
- **Chapter 4** describes the relevance of and methodology for the scenario analysis in this study. The modelling results for all scenarios are described, together with the associated current and future utilisation and emissions outlook for the Dutch refining sector.
- **Chapter 5** analyses the impact of stringent measures on competitiveness, and describes the metrics used to assess competitiveness. Based on the modelling results, an outlook for the Dutch refining sector is outlined and the main competitors for this sector are identified.
- Finally, **Chapter** 6 presents the conclusions.

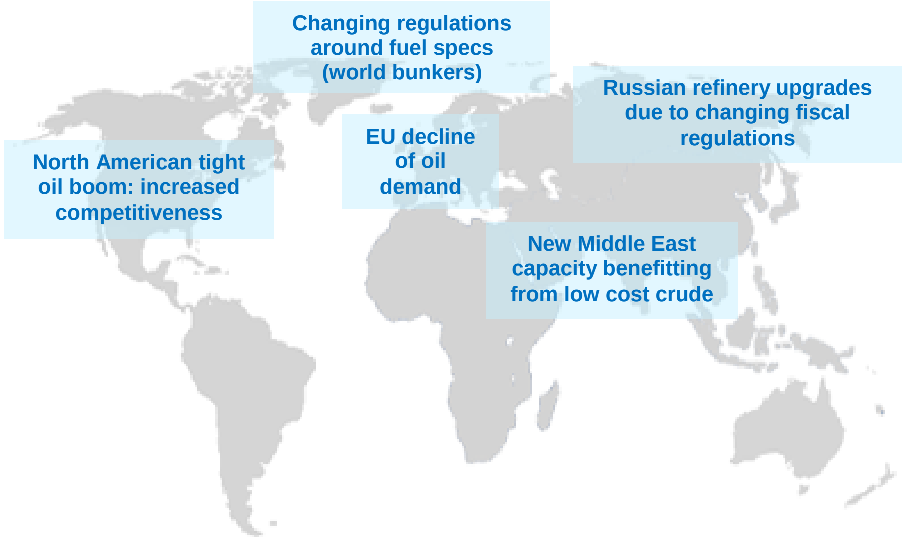
2

General overview of refining sector

2.1 World-wide and European developments

Due to its openness to cross border trade and competition, the oil refining industry must be considered in its global context. Global developments in crude supply, product demand, refinery investments, regional pricing and margins, trade and legislation all have an impact on the Dutch sector. The figure below indicates a number of key emerging themes within the industry which will have a significant impact on the Dutch refining sector as the industry continues to evolve. The drivers of these changes and their impact on the Dutch sector are considered further in this report.

Figure 2: Global refining developments

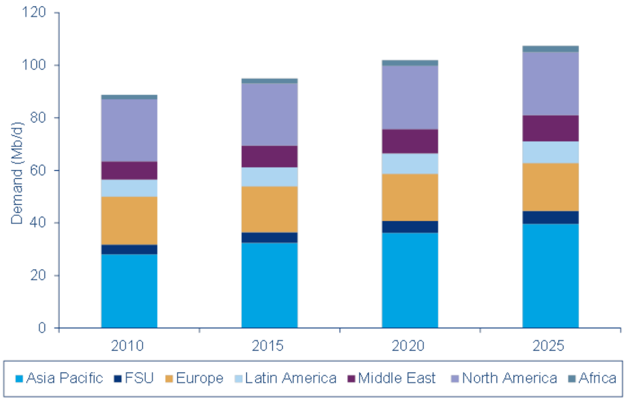


2.1.1 Demand expectations for mature economies

Demand for oil products, and hence refining capacity, is expected to remain subdued in mature economies like those in Europe

Global oil demand is expected to grow by 0.8% per annum between 2010 and 2025, most of which is driven by growth from the Asia Pacific region. Oil product demand in other emerging regions such as Africa, the Middle East and Latin America are also expected to continue to grow. In stark contrast, demand from regions with more mature markets, such as Europe and North America, is forecast to stay relatively flat.

Figure 3: Global demand for oil products by region



Source: Wood Mackenzie.

In Europe, oil product demand has declined significantly from its pre-recession peak in 2007 of 19.2 million barrels per day (Mb/d) to 17.2 Mb/d in 2012. Demand is expected to return to growth (albeit at a reduced rate), mainly due to growth in Central and Eastern Europe and the non-OECD Mediterranean region. Focusing on North West Europe, oil product demand is expected to drop from 8.5 Mb/d in 2012 to 8.3 Mb/d in 2025. In this region, low population growth, low GDP growth, compliance with environmental legislation and competition from other fuels and technologies are all key factors contributing to the expected decrease in overall oil demand.

In North America, weakening demand in the USA and minimal growth in Mexico will result in an overall demand growth of 0.2% between 2012 and 2025. A better economic outlook across the region and resurgence in the US petrochemical industry should stabilise oil demand over the medium term, but improvements in vehicle fuel efficiency as well as inter-fuel substitution will ultimately cause North American oil demand to decrease over the long term.

In the Asia Pacific region, strong macroeconomic and demographic fundamentals such as an average GDP growth of 4.4% per annum will translate to an oil demand growth of 2.2% per annum between 2012 and 2025. Asia Pacific will account for nearly 58% of the growth in global oil demand of 16.7 Mb/d during this time. This strong growth will likely fuel new investment in refining capacity.

In the Middle East, oil demand is expected to grow at 2.2% per annum to reach 10 Mb/d by 2025 (an increase of 2.5 Mb/d). Growth will mainly be driven by the transportation sector and industrial demand as much of the region looks to further develop and monetise its advantageous natural resource position.

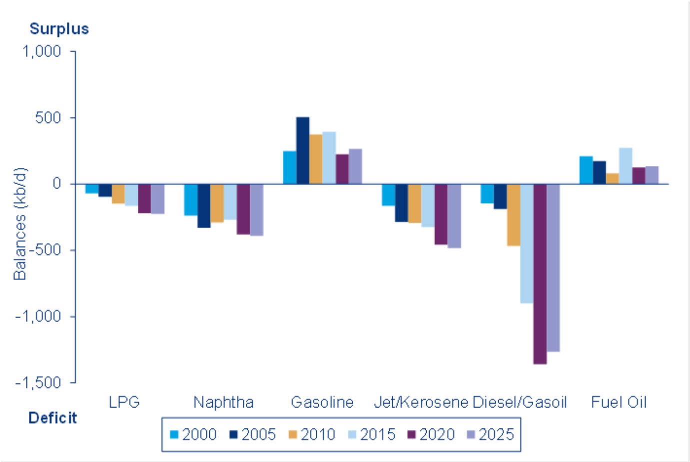
In Latin America, rising car ownership and an increase in road freight movement will drive transportation fuel demand. Despite being a swing fuel in the power generation sector, oil demand in this sector has also risen over the years. Oil demand is expected to grow at 1.4% per annum to reach 8.2 Mb/d in 2025 from 6.8 Mb/d in 2012.

In Africa, oil demand is mainly driven by the growing energy intensive transport and industrial sectors. Its share of oil demand in the transportation sector is expected to grow by over 70% between 2012 and 2025, during which regional oil demand will grow by 2.4% to reach 2.5 Mb/d by 2025.

In FSU (Former Soviet Union) countries, oil product demand is expected to grow by 1.7% between 2012 and 2025. Despite a decreasing oil intensity, increases in personal mobility and rising commercial transport will be the main drivers of the growth in oil demand. Gasoline growth in the FSU will be lower than diesel growth, as the move from gasoline fuelled to diesel fuelled vehicles is expected to continue.

2.1.2 Refineries in North West Europe

Figure 4: North West European oil products balance



Source: Wood Mackenzie.

Refinery production in North West Europe is mismatched to market needs

Product demand trends within Europe have seen dramatic changes over the past two decades, with large volumes of road fuel demand switching from gasoline to diesel, a general move towards low sulphur fuels, and a growing demand for jet aviation fuel. These changes in demand have resulted in a growing structural misalignment with the region's refining configuration and product output, resulting in an increased need for imports of middle distillates, and exports of gasoline and high sulphur fuel oil.

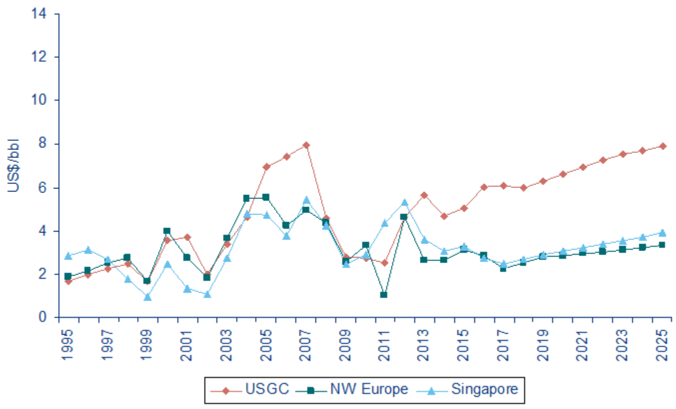
Despite decreasing overall product demand in North West Europe, the recent lack of investment, low refinery throughput utilisation and refinery closures will result in a growing overall deficit in oil products. The total oil product deficit is expected to reach

1.8 Mb/d by 2017 as compared to the 2012 deficit of only 0.1 Mb/d. Per type of oil product, the major expectations are as follows:

- The already large deficit in middle distillates is forecast to continue growing as strong demand growth outpaces the flattening regional supply.
- The gasoline surplus is expected to remain at present levels until after 2015, after which reduced refinery throughputs and limited export opportunities will contribute to considerable surplus reduction. Further decreases in demand will lead to this surplus again gradually widening into the longer term.
- The fuel oil surplus should increase in the short term before widening sharply in 2015, as bunker fuel regulations restricting higher-sulphur residual fuel use come into force. Reduced refinery throughputs will cause this to contract again in the medium term.

2.1.3 European margins

Figure 5: Regional composite benchmark gross refining margins



Source: Wood Mackenzie.

European margins have been volatile in recent years, and are forecast to remain at low levels in the future

Refining earnings rose to unprecedented levels in all regions in the mid-2000s. This was driven by rapid demand growth for liquid fuels in the East (primarily China and India), which resulted in a relative lack of suitable refining capacity to meet demand. The demand for refined products stimulated refiners to operate at a previously uneconomic capacity, often distributing their products long-haul to meet demand in distant lands. However, with the onset of the global financial crisis in 2008/9, demand for fuels fell rapidly and dramatically, resulting in a surplus of global refining capacity.

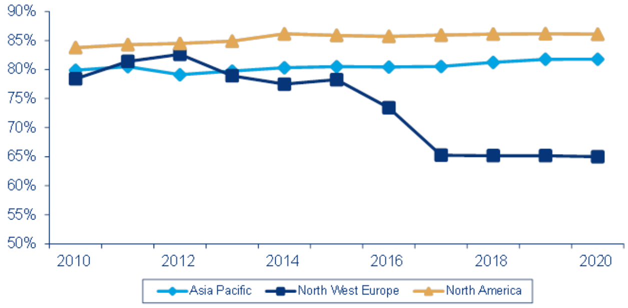
In 2012, global refining margins were supported by refinery closures in the Atlantic basin and strong demand growth in Asia. However, in 2013 overall refining margins have fallen with new capacity additions. On a regional level, the outlook for margins are as follows:

- Recent European margins have been affected by weak product demand and tight crude supply with disruptions to output from several key suppliers. There was a brief respite in 2013, however, when some of the short-term effects were reversed, and refinery outages and rationalisations supported the strengthening of margins. However the long-term outlook is for a sustained lower margin environment (2-3 USD/bbl) resulting from the range of factors covered in this section of the report.

- US Gulf Coast margins have strengthened and are forecast to remain strong, primarily driven by the boom in tight oil developments in the US giving access to significantly lower cost crude and gas supply.
- In Singapore, margins have been hit by a reduction in demand growth rate, particularly in China. Average refinery complexity and scale in the region is also on average below those in the US, which reduces overall margin potential. Margins are projected to remain at low levels as government-backed oil companies invest in capacity to avoid the shortages witnessed in the mid-2000s.
- The poor outlook for refining margins in addition to plateauing demand puts the European sector at a structural disadvantage to the US Gulf Coast refining hub. This could also cause a secondary knock-on effect on European refinery investments, with greater returns achievable for other regions.

2.1.4 European refinery utilisation expectations

Figure 6: Average regional refinery utilisation rates



Source: Wood Mackenzie.

Low demand growth and increasing competition for both local and export markets will depress European refinery utilisation rates

Refinery utilisation is defined as the volume of crude or feedstock processed in aggregate by the refineries within a region. A reduction in refinery utilisation within a region is typically driven by a reduction in demand for products and/or increasing competition from external markets. A significant reduction in utilisation below minimum sustainable levels is a signal for the need for additional refining capacity rationalisation within a region.

The utilisation rates required for long-term sustainable refining are expected to be around 80-85%. In the past five years, utilisation rates in Europe were typically lower than this, resulting in a number of refinery closures. Therefore, the high utilisation rate in 2012 was mainly due to the reduction in capacity due to refinery closures, rather than increased throughputs. Europe's refining assets are relatively old and smaller in scale, which translates to higher operation costs. Domestic crude supply is also expected to fall, forcing the refineries to import crudes, increasing feedstock costs. All of these challenges, coupled with an overall weak product market, will result in a decline in the overall NWE utilisation rate. Utilisation rates are expected to drop from

83% in 2012 to 65% in 2020. This low level of utilisation is not sustainable for refinery operation; as such it is very likely that much of this reduction in capacity will be met by further refinery rationalisation. Although it is not possible to forecast the closure of a specific refinery, an outlook for reduced utilisation within a region is a strong indicator of an increased risk of closure.

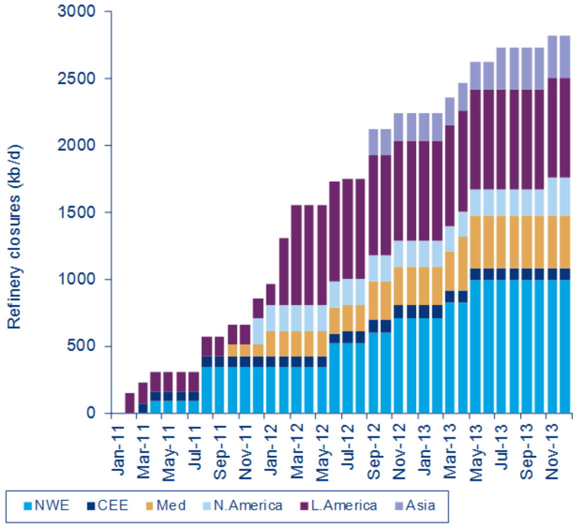
2.1.5 Refinery closure expectations

The depressed earnings environment means that refineries are closing around the world, but especially in Europe

Low refining utilisation rates typically result in lower margins as fixed costs remain the same for a lower product throughput. In the long run, such a situation is unsustainable and refiners will look to rationalise to reduce cost per barrel and maximise refining margins. Refineries in Europe are facing closures, with 13 refineries already having ceased operations between 2010 and 2013.

Other global regions have also lost refining capacity for a range of reasons, but no regions have experienced such a structural response to the need for refinery closures as Europe has seen during the past three years.

Figure 7: Refinery closures by region 2011-2013



Source: Wood Mackenzie.

Table 1: List of announced refinery closures

Refinery	Region	Country	Owner	CDU (kb/d)*	Closed
Yorktown	North America	USA	Western Refining	71	Sep-10
Mardyck	Europe	France	Total	137	Oct-10
Montreal Shell	North America	Canada	Shell	130	Oct-10
St. Croix	Latin America	Virgin Islands	PDVSA, Hess Corporation	150	Feb-11
Arpechim	Europe	Romania	OMV	72	Mar-11
Reichsett-Vendenheim	Europe	France	Petroplus	85	Apr-11
Wilhelmshaven	Europe	Germany	Hestya	260	Aug-11
Cremona	Europe	Italy	Tamoil	90	Oct-11
Marcus Hook	North America	USA	Sunoco Inc.	194	Dec-11
Berre l'Etang	Europe	France South	LyondellBasell	105	Jan-12
St. Croix	Latin America	Virgin Islands	PDVSA, Hess Corporation	350	Feb-12
Aruba	Latin America	Aruba	Valero Energy Corporation	247	Mar-12
Coryton	Europe	UK	Petroplus	175	Jun-12
Paramo	Europe	Czech Republic	Unipetrol	20	Jul-12
Fawley	Europe	UK	ExxonMobil	80	Sep-12
Rome	Europe	Italy	ERG, Total	92	Sep-12
Clyde	Asia Pacific	Australia	Shell	82	Sep-12
Ogimachi	Asia Pacific	Japan	Toa/Showa Shell	120	Sep-12
Gonfreville l'Orcher	Europe	France	Total	110	Nov-12
Kubiki	Asia Pacific	Japan	Teikoku Oil	5	Dec-12
Harburg	Europe	Germany	Shell	114	Mar-13
Porto Marghera	Europe	Italy	Eni	106	Apr-13
Petit Couronne	Europe	France	Petroplus	162	May-13
Sakaide	Asia Pacific	Japan	Cosmo Oil	110	Jul-13
Dartmouth	North America	Canada	ExxonMobil	87	Nov-13
Tokuyama	Asia Pacific	Japan	Idemitsu	120	Mar-14
Muroran	Asia Pacific	Japan	JX Nippon Oil & Energy Corp.	180	Mar-14
Wakayama	Asia Pacific	Japan	TonenGeneral Sekiyu	37	Mar-14
Kawasaki	Asia Pacific	Japan	TonenGeneral Sekiyu	68	Mar-14
Kumell (Caltex)	Asia Pacific	Australia	Chevron	136	Aug-14

* crude distillation unit (capacity in x 1000 barrels/day). Source: Wood Mackenzie.

2.1.6 Development of new refineries by strategic investors

Companies in the Asia Pacific and Middle East are investing heavily in refining capacity, accounting for 80% of the global capacity increase expected between 2013 and 2018. The FSU, Latin America and North America are also seeing some investment activity. Most refinery investments are aimed at supplying domestic markets but several refineries are well placed to supply volumes to Europe, threatening European refiners.

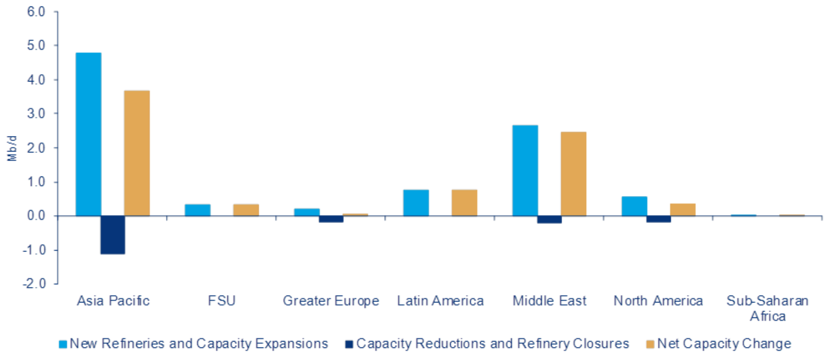
A wave of new, world-class refineries are being developed by strategic investors, despite the depressed earnings environment

In the Asia Pacific region, there will be an increase in investment of 2.7 Mb/d in refining capacity by 2018, accounting for 75% of the incremental capacity during that period. China's refineries are aimed primarily at supplying to the domestic market, but a surplus in diesel is forecast up until 2018, and this could be exported to satisfy demand in other Asian countries. India is expected to increase its refining capacity by 0.6 Mb/d by 2018, further increasing its product surplus and hence its export-oriented position. As a result, exports from India to Europe are expected to grow, especially of middle distillates.

Similarly, new refineries in the Middle East are expected to affect European oil refiners as these refineries have a number of structural advantages that result in a lower cost of supply. Middle distillate exports will target the European market.

In addition to selling more product directly into Europe, many of these new export refineries will also compete to supply product into other regions where many European refineries typically export surplus product volumes (such as gasoline into Africa and North America, or fuel oil into the Asia Pacific region)

Figure 8: Capacity change by region 2013-2018



Source: Wood Mackenzie.

2.1.7 Impact of refining investments

Refining investments in the Middle East will have a significant impact on the European products market

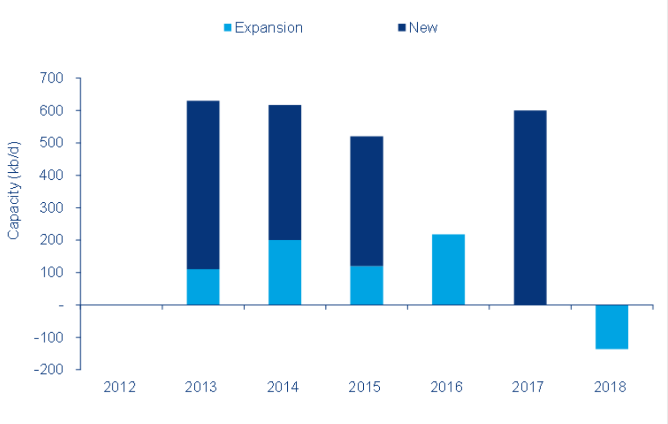
Developments among Middle Eastern refineries are expected to have the greatest impact on European refineries. Saudi Arabia is developing three new refineries, each with a capacity of 400 kb/d. Saudi Aramco has deployed the strategy of upgrading their heavy crudes into high value products to capture more value for the country's vast natural resources.

The current investments in Saudi Arabia alone will add 1.2 Mb/d of refining capacity, which is similar to the total current crude capacity in the Netherlands. Saudi Arabia's new refineries have improved economies of scale, lower labour costs and greater complexity than the Dutch assets and will also process lower cost domestic heavy crudes from onshore oil fields.

Saudi Arabia's new refineries are therefore likely to have a much lower cost of supply compared to the Netherlands and will be able to price their products competitively in the European market.

In addition to Saudi Arabia, the United Arab Emirates are also investing in two refineries, at Ruwais and Fujairah IPIC, with a CDU capacity of 417 kb/d and 200 kb/d respectively. These are two other export refineries which could send more products into the European market, providing more options for European importers.

Figure 9: Middle East capacity change 2012-2018



Source: Wood Mackenzie.

Table 2: Middle Eastern refinery new builds (Source: Wood Mackenzie)

Location	Refinery	Sponsor	Capacity (1000 barrels/day)	Expected completion date
Iran	Persian Gulf Refinery, Bandar Abbas	100% Persian Gulf Star Oil Company	120	2013
Saudi Arabia	Jazan	100% Saudi Aramco	400	2017
Saudi Arabia	Yanbu (YASREF)	62.5% Saudi Aramco, 37.5% Sinopec Group	400	2015
Saudi Arabia	Jubail Refining and Petrochemical Company	62.5% Saudi Aramco, 37.5% Total	400	2013
United Arab Emirates	Ruwais	100% ADNOC	417	2014
United Arab Emirates	Fujairah IPIC	100% IPIC	200	2017

2.1.8 US tight oil developments

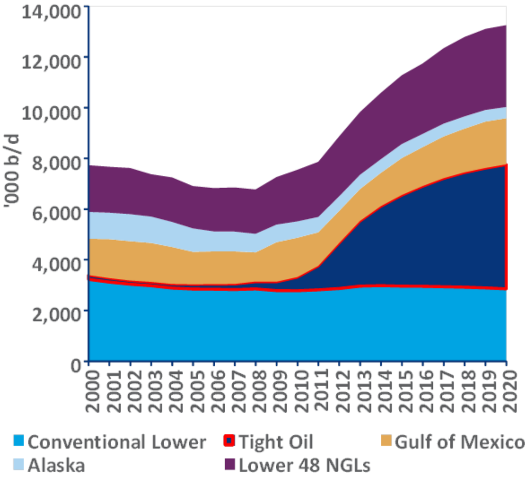
Tight oil development provide US refiners with cheap domestic crude and gas, increasing their ability to compete in Europe

The emergence of US tight oil supply is expected to have a significant impact on the global energy market. US tight oil supply is expected to increase from approximately 2 Mb/d in 2012 to 5 Mb/d in 2020. This new supply of crude oil will account for nearly 1/3 of total US liquids production by 2020. With current US legislation and constrained overland infrastructure inhibiting crude oil exports, domestically produced crude oils have to be consumed domestically.

In the absence of such constraints, the US crude marker, WTI, and the similar quality European crude marker, Brent, should be closely priced as both products are broadly substitutable with one another. However, crude transportation bottlenecks and US crude oil export bans have resulted in an increase in US domestic oil supply causing a price drop in WTI, widening the price difference between WTI and Brent. The recently widened WTI–Brent crude price differential is expected to persist in the long term, and therefore WTI will remain at a significant discount to internationally traded benchmark crudes (see **Figure 11**). This underpins a key US refining sector advantage, which is a major driver of their competitiveness with the Dutch sector. A lower priced WTI market results in US refiners being able to buy crude at a significant discount to international (and hence European) prices, providing the US industry with a significant structural advantage over European refiners which process crudes based on Brent indexation. The growing supply of shale gas has also reduced gas prices in the US relative to most other global regions, giving an additional advantage to US refiners as a result of lower operating costs (gas heating, steam and power generation).

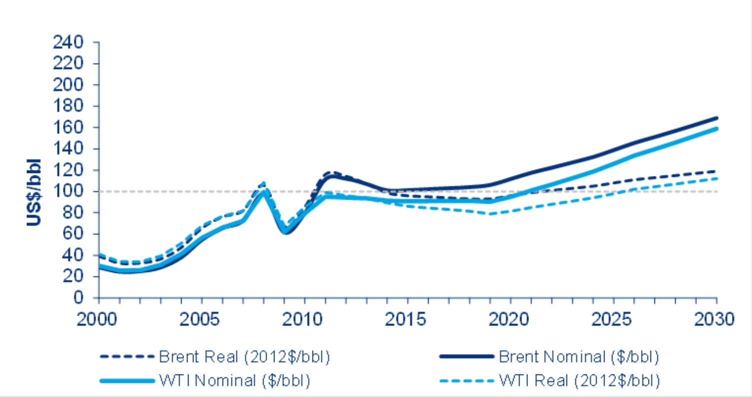
Due to the improved competitiveness of the sector, certain US refiners on the Atlantic and Gulf coasts are able to export products into the European market at increasingly competitive prices. The high utilisation of US refiners is also decreasing the region's gasoline deficit, which has historically been a major outlet for excess European gasoline. This will force European refiners to find a new export market for the excess gasoline, reducing their ability to economically produce it and lowering their utilisation rates.

Figure 10: US domestic liquids production 2000-2020



Source: Wood Mackenzie.

Figure 11: WTI and Brent price forecast



Source: Wood Mackenzie.

As a result of these developments in crude production and pricing, refineries within the US are now amongst the most competitive in the world. This has resulted in USGC benchmark refining margins exceeding 5-6 USD/bbl, significantly higher than current EU or Asian margins. Specific refineries able to fully utilise the developments in tight oil crude and energy supplies are expected to have even greater margins (as described in section 6). As such, even the top performing assets within the EU and Netherlands will struggle to compete against US refineries in supplying competitive export markets, and may face the risk of competition in supplying EU or domestic markets.

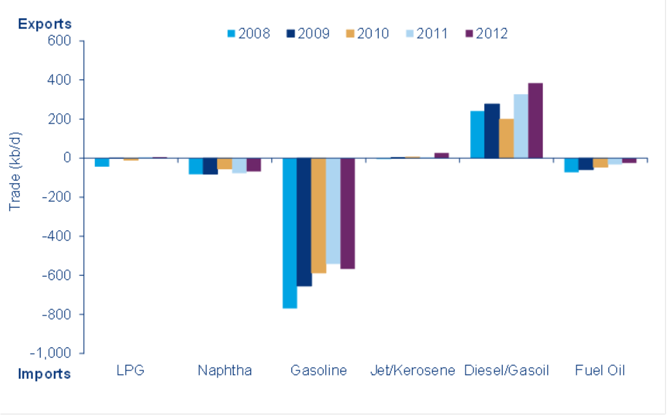
2.1.9 US exports to Europe

Increasing diesel/gasoil exports from the US further threaten European refiners

Due to the favourable refining economics of US refiners with the development of tight and shale oil, US refineries have been increasing their utilisation rates to maximise production and revenue. The relatively low feedstock cost enables US refiners to price their diesel/gasoil products competitively and supply volumes to Europe. The refining boom in the US is already having an effect on the European markets, evidenced by the increase in diesel exports to Europe over the past three years.

With the expected increases in supply of US tight oil, US refiners are expected to continue enjoying a crude advantage over European refiners. As a result, exports to Europe could potentially increase in the future.

Figure 12: North America net trade by product



Source: Net Trade Balance: IEA, Wood Mackenzie analysis.

2.1.10 Developments in Russia

The threat to European refiners from Russia is increasing in response to the '60.66' Tax Legislation

During 2010, the tax structure in Russia supported the production and export of dark products (atmospheric residue and fuel oil) as the export duty on these products was much lower than that on light products (diesel, gasoil and other middle distillates). At the time, this regime suited the domestic refining infrastructure, with a number of assets having low complexity and limited upgrading capacity, thus receiving good returns on dark product yields. This trend accelerated for most of 2011, with dark products continuing to receive a lower tax rate than light products. Refiners increased their processing rates and achieved record product exports during 2011.

However, a new tax regime, dubbed '60.66' was put in place from October 2011. Under the new tax regime, duty on exported crude oil was reduced by 5% from 65% to 60% as a means of increasing revenue for companies with upstream production capacity, thereby stimulating the continued development of brownfield upstream assets. Gasoline and naphtha duty was increased to 90% of the crude export duty as a means of addressing a domestic gasoline shortage.

Light product duty, excluding the emergency rate imposed on gasoline and naphtha was reduced by 1% to 66%. However the biggest change is the export duty on dark products, which was raised from 47% to 66%. This change will reduce netbacks for companies that export fuel oil. Refiners with simple configurations, and thus limited capacity for upgrading, will feel increasing pressure as a result of this change. The ability to upgrade to lighter and more valuable products is key. Things are only going to get worse by 2015 as the dark product duty is expected to move to parity with the crude export duty, further incentivising upgrading.

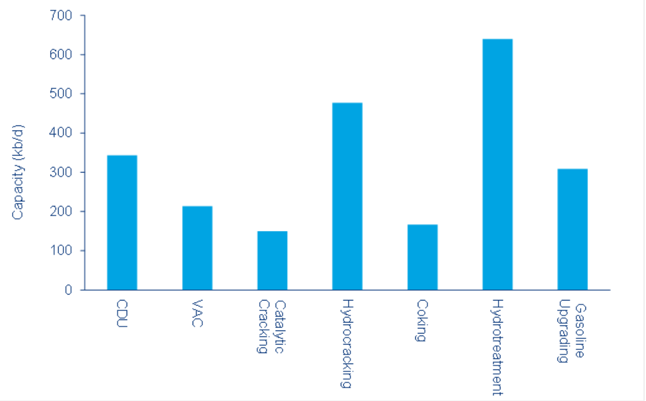
Table 3: Changes to Russian export duty (Source: Wood Mackenzie). The Urals price is assumed to be above 25 USD/bbl to illustrate oil tax evolution over the years.

Rate of export duty (%)	2010	2011	2012+ (60.66)	2015+
Crude export duty (% of Urals price)	65	65	60	60
Gasoline duty (% of crude duty)	72	67	90	90*
Light product duty (% of crude duty)	72	67	66	66
Dark product duty (% of crude duty)	39	47	66	100

*The gasoline export duty is assumed to remain at the emergency rate imposed earlier this year

The change in legislation has already affected the Russian refining industry, with a wave of investment in upgrading units being seen. The completion of upgrades to refineries capable of producing Euro-grade diesel means that additional supply will be available for European importers, increasing the competition for European refiners.

Figure 13: Russia's refinery investments 2013-2018



Source: Wood Mackenzie.

2.2 The Dutch situation

2.2.1 Dutch refining industry

Netherland's refining industry is a key component of the Rotterdam energy hub

The Netherlands is a major transit and product trading centre based on the large oil storage terminals in the ports of Rotterdam and Amsterdam, and is the pricing centre for oil products in Europe. Dutch refiners are able to leverage this and fetch hub prices for their products, saving on inland transportation costs. The large volume of oil products stored and traded within the region is supported by the local refinery cluster. A number of other industries have also developed within the region that utilise and benefit from the existence of feedstocks and products from the refining industry, such as trading, petrochemical producers and shipping bunker suppliers. The sector also supports a large number of associated high paying jobs, both directly and indirectly. **Table 4** provides an overview of the current five primary fuel refineries within the Netherlands and their technical characteristics.

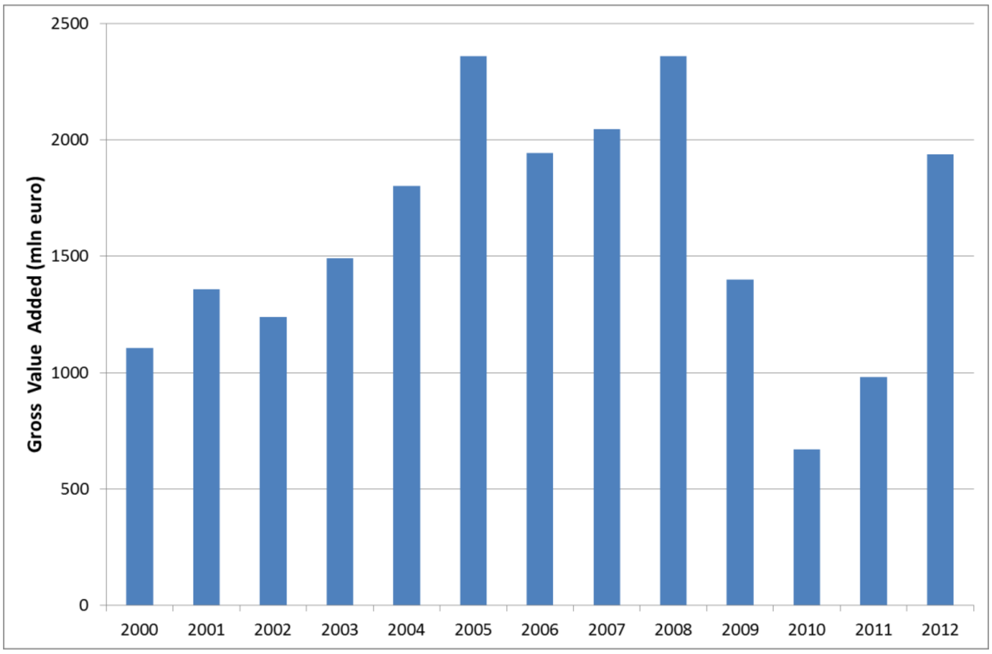
Table 4: Overview of Dutch refineries and their technical characteristics. Data based upon and calculated from Worldwide Refining Survey (2014)

Refinery, location	Crude capacity (barrels per calendar day)	Nelson Complexity	Equivalent distillation capacity (x 1000 barrels per calendar day)	Bottom of the barrel index
BP Refinery, Rotterdam	358,492	5.4	1,939	15%
ExxonMobil Refining, Rotterdam	190,500	9.3	1,773	49%
Kuwait Petroleum Europoort, Rotterdam	83,600	9.5	796	0%
Shell Nederland Raffinaderij, Pernis	404,000	7.7	3,109	32%
Zeeland Refinery, Vlissingen	147,581	11.5	1,700	43%

The crude capacity represents the atmospheric distillation capacity of a refinery. The other parameters are calculated based on the refining capacity per unit type. The Nelson complexity index (NCI) is a pure cost-based index. It provides a relative measure of refinery construction costs based upon a refinery's distillation and upgrading capacity. The index was developed by Wilbur L. Nelson in the 1960s to quantify the relative cost of the components that make up a refinery. The NCI compares the cost of upgrading various units such as a catalytic cracker or a reformer, to the cost of a crude distillation unit. The equivalent distillation capacity (EDC) is calculated by multiplying the crude capacity with the NCI. NCI and EDC statistics have become widely used in industry literature to provide insight into various aspects of refinery value or operations. The bottom of barrel index (BoB index) provides a means of quantifying and characterising a refinery's ability to process heavy crudes and produce premium refined products. It represents the combined capacity of a refinery's coking, catalytic cracking and hydrocracking units relative to the distillation capacity (expressed as a percentage). The US average BoB Index is 55% (1 January 2011), while the 'rest of the world' average is 21% (excluding the US). The total world average is 28% (PennEnergy, 2014). The data presented in **Table 4** may show some deviation from the data available online through the PennEnergy (2014) database, which is partly due to data round offs and to an error in the Worldwide Refining Survey (2014).

The refining sector contributes significantly to the economy of the Netherlands with 'added value', equating to around EUR 2 billion in 2012. The chart below shows the level of added value in past years, which has fluctuated significantly as a result of the recent volatility in refining throughput and profitability.

Figure 14: Gross value added for the refining sector (Source: Dutch statistics of CBS)



2.2.2 Recent developments in oil product demand

The port of Rotterdam is one of the world's largest shipping centres. The Netherlands has high value-added industries such as iron and steel, transport and machinery manufacturing, agriculture and petrochemicals. The industrial sector is undergoing structural change as heavy industries consolidate and become more efficient, while sectors such as financial and business services grow. Investments in the port of Rotterdam's rail, road and pipeline infrastructure will underpin economic growth for key industrial sectors.

The country's large petrochemical sector has been hit by the global economic slowdown, with a decrease in demand for LPG and naphtha. Bunker fuel oil demand has also been hit by the downturn in world trade. Although oil demand recovered somewhat in 2010, it shrank again in 2011 and 2012.

2.2.3 The Netherlands as net exporter of oil products

With surplus gasoline, jet/kerosene and diesel/gasoil, the Dutch refining industry is reliant on exports to neighbouring countries and other regions to place all of its products. As such, the domestic and regional markets are both critical to the Dutch refining sector. It is predominantly in the export markets of the Netherlands that the risk of external competition is observed to pose the greatest threat.

The Netherlands has a large refining industry compared to its domestic demand, and therefore is a net exporter of oil products

The Netherlands operates as a production and export hub with large volumes of gross trade. This is shown in **Figure 15**, where the Netherlands is highest among various European competitors if the net export volume is compared to the refinery output. The

Netherlands typically imports diesel from other regions such as the US and FSU and exports to neighbouring EU countries such as Belgium and Germany. Jet/kerosene is exported within Europe to Germany and Belgium, supplemented by imports from South Korea and India. Gasoline is exported to Germany as well as other regions such as the US and Mexico. Netherlands is short on fuel oil and imports for the bunkering market mainly come from the FSU.

Figure 15: Net export volume of oil products divided by total refinery output (Source: IEA, Oil Information, 2014).

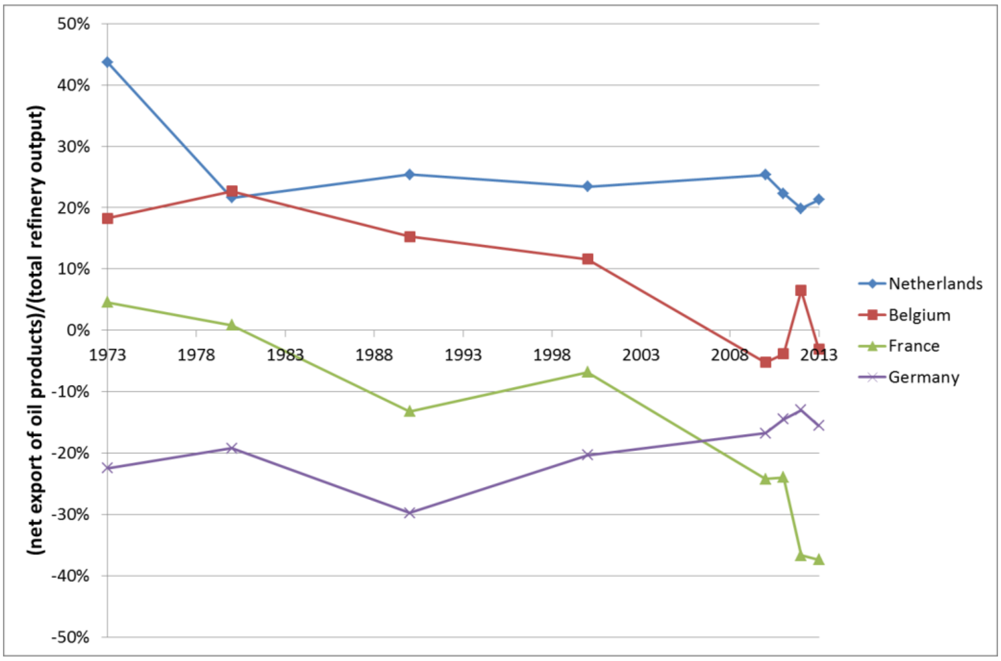
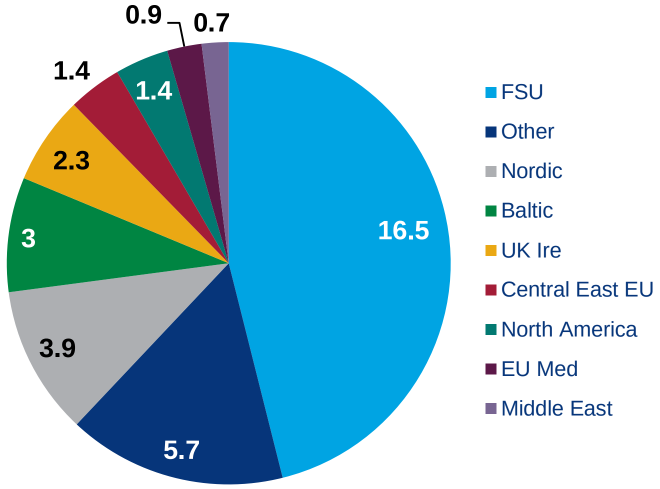
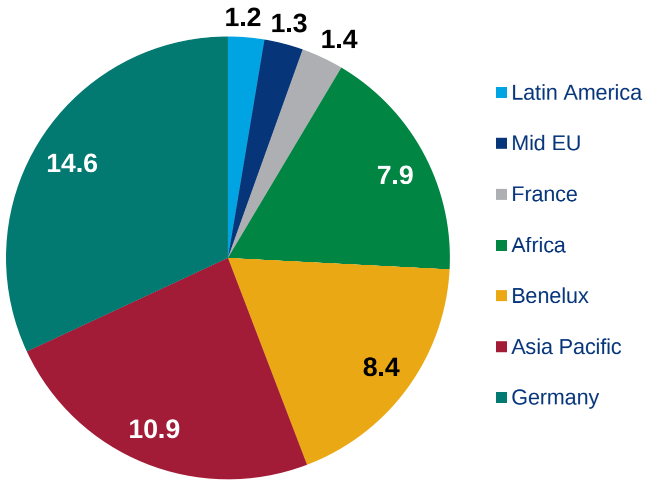


Figure 16: Net oil product imports for the Netherlands, 2012 (mtpa)



Source: Wood Mackenzie

Figure 17: Net oil product exports for the Netherlands, 2012 (mtpa)



Source: Wood Mackenzie

3

Environmental regulations

3.1 Introduction

This chapter creates a theoretical basis for determining the Stringent Plant Scenario. Potentially relevant regulations are assessed for the Dutch refining sector, and an analysis is performed to situate the Dutch refining sector in the international context. Finally, a historical cost burden is determined for the Dutch refining sector.

3.2 Current and future legislation relevant for the Netherlands

Relevant legislation with a potentially substantial financial effect on the refining sector was assessed. There is legislation relevant for oil refineries at the global, European and national levels. An extensive description of the various types of relevant legislation can be found in Appendix A. A summary of this assessment is provided in **Table 5**, including a reference to the pertinent legislation, its impact and the way it was addressed for the scenario analysis.

IMO Marpol: bunker fuel standards. Potential unit expansions included in BPS

IMO Marpol sets global standards for the sulphur content in bunker fuels, as described in Paragraph A.1.1. Since various technical developments may be implemented both for ships as well as refining technologies, no assumption has been made with respect to potential investment in the refining sector. As stated elsewhere in this report, the information has only been used for the scenario analysis if the individual refineries provided such information on potential investments.

Table 5: Legislation and the manner in which it is addressed for the scenario analysis

Legislation	Appendix reference	Route of impact on emissions, costs, competitiveness	Addressed in scenario analysis
IMO Marpol	A.1.1	Investments must lead to product upgrade, change in demand product slate.	Not included, except for potential projects in BPS to the extent submitted by refineries.
IED	A.2.1	Framework legislation, actual impact limited in NL refineries because units have pre-2003 status. Exceptions relevant.	Included in BPS as stated in its definition.
BREF	A.2.1	New BREF currently under revision. BREF is the main driver for permit requirements, also for process units. Ranges lead to potentially different implementations in the EU and differences in cost.	Differences in interpretation: lean interpretation is included in BPS. Measures as a result of strict interpretation are included in SPS.
NEC	A.2.2	Main driver for authorities to impose more stringent implementation of EU regulations.	Incorporated in SPS.
RED	A.2.3	Various indirect influences. Only minor effect expected on cost and competitiveness till 2025.	Included in market demand models.
FQD	A.2.4	Legislation still under development. Substantial impact possible on refinery operation via article 7a.	Not included.
EED	A.2.5	Refinery sector not included in setting Dutch target. Refinery energy savings possibly included in meeting the target. Only measures will be considered with five year payback or less for the EED. No net cost burden.	Not included.
ETS	A.2.6	Systems for set aside/back loading are under discussion in order to increase the CO_2 market price. Volume allowances that need to be bought are known. Financial impact still uncertain.	Additional cost burden to the sector, included under BPS due to influence on Europe versus rest of the world.
Oil Stocks	A.2.7	The Netherlands recently increased the portion of oil stocks held by industry, resulting in a loss of income. Among the main EU competitors there is also a division of stocks between public and industry, which is comparable with the Netherlands to a certain level.	Not included.

The Industrial Emissions Directive (IED) sets emission standards for various combustion installations and is described in Paragraph A.2.1, together with a description of the BREF (Reference document on Best Available Technologies). As a result of the current design of the IED, the potential consequences for Dutch refining installations remain rather limited. This directive is regarded as being implemented under the BPS scenario.

IED: regulation of combustion installations. Incorporated in BPS.

The BREF sets ranges with which units must comply. The ranges have a strict and a lenient side for compliance. The strict side of BAT ranges may be considered relevant for SPS, while the lenient side is relevant for BPS. The current refinery BREF dates back to 2003. A new version is currently in the final stages of completion.

BREF: regulation of all refining units. Strict side of ranges included in SPS

The National Emission Ceiling (NEC) sets fixed ceilings for NO_x, SO_2, NMVOC and PM with which Member States need to comply. This is described in Paragraph A.2.2. These ceilings are currently being revised. A strict ceiling may result in the implementation of stringent measures. Meeting strict ceilings is anticipated under SPS.

NEC: national ceiling for various emissions. Tighter room for emissions under SPS

RED: standards for the amount of biofuels. Via market effects included in BPS

The Renewable Energy Directive (RED) sets standards for the amount of biofuels blended into the commercially available stocks (see Paragraph A.2.3). When refining sectors in different countries are supplying the same market, it is concluded that their economic positions are equally affected, thereby ensuring a level playing field. The RED does decrease the demand for the fossil-based portion of diesel and gasoline. This decrease is incorporated into the BPS.

The Fuels Quality Directive (FQD)(see Paragraph A.2.4) is still to be implemented. Although there are potential consequences for the refining sector, there is good argument not to incorporate this directive into the scenario analysis.

Various key factors are relevant for the Energy Efficiency Directive (EED)(see Paragraph A.2.5). The Dutch refining sector has not been included in the methodology for calculating the target. In addition, the policy consequences of this directive are currently seen as rather weak. Next to this, energy efficiency measures also gain money, since a pay-back period needs to be considered. For these reasons, the EED is not incorporated into the SPS.

The Emissions Trading Scheme (ETS) brings a cost disadvantage compared to global competitors outside Europe (see Paragraph A.2.6). These costs are therefore already present for analysis of BPS.

ETS: market price for CO_2 emission allowances. Costs included in BPS at current market price

The compulsory oil stock regulation has been changed quite recently for the Netherlands, see Paragraph A.2.7. The portion of oil stocks held by industry has recently been increased, resulting in a loss of income. For the main EU competitors there is also a division of stocks between public and industry in place. These divisions are generally comparable with the Netherlands, thus setting a level playing field. It is therefore not incorporated into the SPS analysis.

3.3 Comparison of international legislation

The aim of the analysis described here is to assess the effect of future emissions legislation on the economics and competitive position of the Dutch refining industry. It is therefore relevant to compare requirements, or the results of those requirements, for various competing countries or regions. Environmental regulations may be compared in two ways: on the basis of emission limit values and required measures, or on the basis of sector emissions in relevant competing countries in a normalised unit.

The comparison of emission limit values and required measures requires substantial knowledge of the actual text of the legislation. Complications may arise as soon as distinctions are made between regulations for existing and new installations. Furthermore, legislation may be enforced at various levels of stringency, resulting in exceptions which are hard to define.

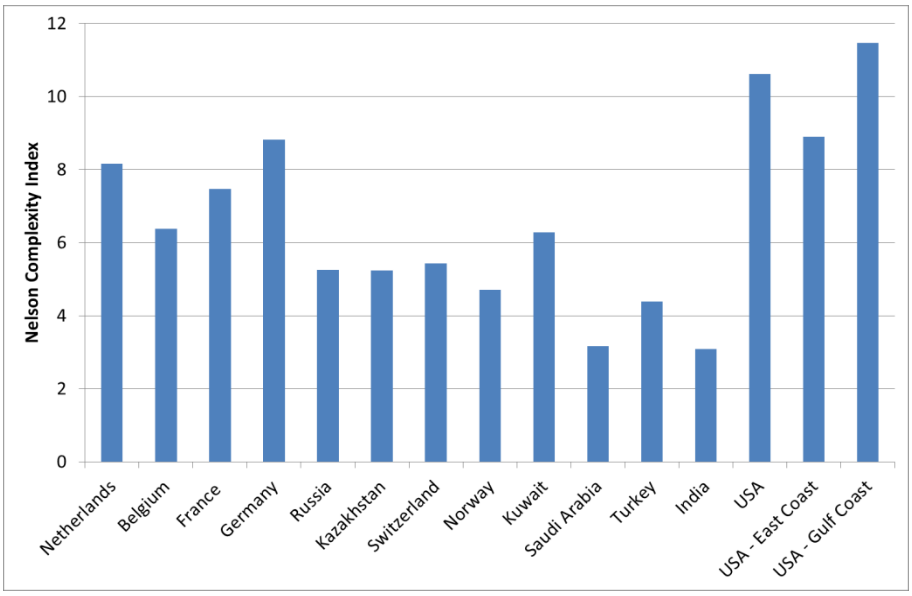
Some emission regulations have been described for France (Appendix B.1), Belgium (Appendix B.2) and Germany (Appendix B.3). This inventory shows the complexity of the regulations and the number of exception rules. For example, in Belgium the regulations covering the sulphur recovery efficiency of Claus plants are surpassed by the current installations (see Appendix B.2).

Comparison of emissions based on crude throughput makes sense

The second option is to compare the sector emissions of the entire oil refining sector in a country and use these as the basis for comparison. A simple and straightforward way to compare emissions is to divide these by the nationally reported amount of crude throughput. The question may arise as to whether this approach might over-simplify, since there are differences in crudes, feedstocks, product mixes and refinery complexity between countries. According to paragraph 3.1 of the Draft BREF (2013), these parameters have a minor influence on environmental emission profiles. This means that emissions per crude throughput provide a proper indication of the actual status of environmental performance for various countries.

Indeed, analysis with respect to refinery complexity confirms this conclusion: if the Nelson Complexity Index (see also Paragraph 2.2.1) of refining capacities in various countries (see **Figure 18**) is related to the refining sector emission profiles of those same countries (**Figure 19** and Appendices B.4 to B.7), the emission profiles are not linearly related to the complexity index.

Figure 18: Nelson complexity index



NO$_x$, SO$_2$ and dust outside Western Europe and USA often at higher levels.
NMVOC inventories are calculated, which probably results in differences.

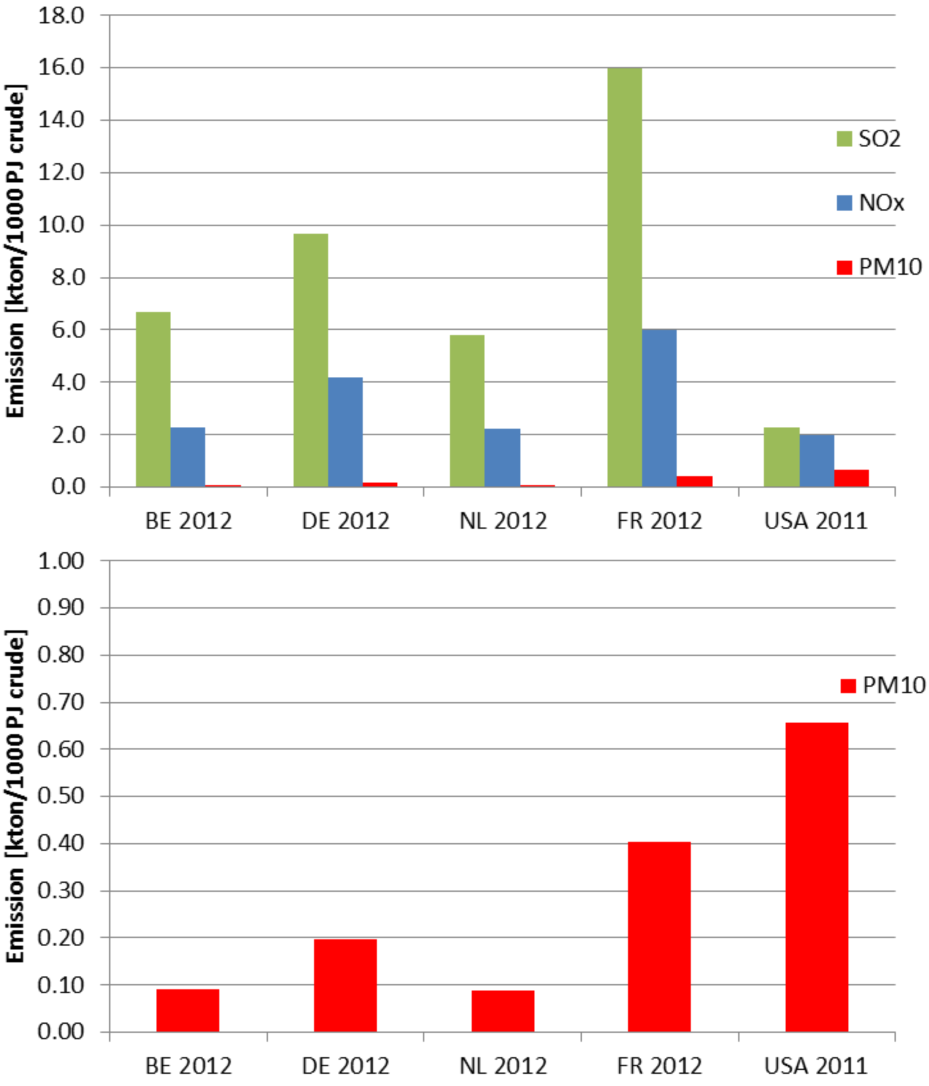
Emission profiles are provided in **Figure 19** for the countries most relevant to the analysis here, but extensive analysis has been performed for many more countries (see Appendices B.1 to B.7). References to current sources may be found there. Since most of the NMVOC data are calculated, and the calculation factors and methods probably differ between countries, it is difficult to draw robust conclusions based on this comparison. Studies show substantial differences between measured and calculated data.

Several countries outside Western Europe and the USA show emission profiles for NO$_x$, SO$_2$ and dust at substantially higher levels than those in the Netherlands. **Figure 19** shows that, within the limits of this analysis method, emission levels in the Netherlands are in the same range as those in Belgium. Emission levels in Germany are declining, but are still higher than in Belgium and the Netherlands. Emission levels in France are declining too, but are much higher than in the Netherlands and Belgium. All four countries should adhere to the same BREF-based emission levels.

According to the USA data, SO$_2$-emission profiles are relatively lower compared to the Netherlands, while emissions of particulate matter is lower in the Netherlands. NO$_x$ emissions are in the same range.

An inventory has been made of emission limit values for countries outside Europe, namely the Middle East region (Appendix B.7 and B.8), India (Appendix B.9), the FSU region (Appendix B.10, B.11 and B.12) and Turkey (Appendix B.13), as well as the limits established by the World Bank (Appendix B.14). In general, the emission limit values are found to be more lenient than those in the Netherlands.

Figure 19: Most recent emission profiles for Belgium, Germany, the Netherlands, France and the USA



3.4 Historical cost burden

In the period 2005-2013, the largest investments made to comply with environmental regulation were:
- Investment in hydrotreating capacity.
- Investment in hydrogen production.
- Switching from oil firing to 100% gas firing and other SO_2 reduction measures.
- Other environmental measures.

The first two investment items are related to the more stringent low sulphur quality requirements for products. The last two items can be seen as additional costs, because other refineries, especially outside the EU, do not have to take comparable environmental measures.

Investment in hydrotreating capacity
Between 2005 and 2013 there was an increase in hydrotreatment capacity in the Netherlands of 63,000 barrels per day, according to the Worldwide Refining Surveys of the Oil and Gas Journal. Part of this capacity increase was realised via debottlenecking and/or rejuvenation of existing installations. New capacity was also constructed.

Investment costs for ULSD are 3000-3500 USD/(barrels per day) (US Gulf Coast 2010), according to the Handbook of Refining Processes (2011), for a unit of 40,000-45,000 barrels per day. For 63,000 barrels per day, this means an investment of USD 220 million. Since these installations have to be implemented within existing installations, a retrofit factor of 2 is assumed. At a dollar-euro conversion of 0.755 (CBS Statline, 2010), the total estimated investment costs are approximately EUR 333 million.

Investments in hydrogen production capacity
According to the Worldwide Refining Surveys of Oil & Gas Journal, an increase in the Dutch hydrogen production capacity of 136 MMcf/day was observed between 2005 and 2013. This capacity increase includes hydrogen recovery via pressure swing adsorption and hydrogen production via steam methane reforming or partial oxidation.

Assuming costs of USD 30 million (US Gulf Coast, 2005) for hydrogen production via steam methane reforming for a unit capacity of 20 MMcf/day (Gary et al, 2007), the total costs are estimated to be about USD 200 million. At a dollar-euro conversion of about 0.8 (Eurostat, 2005), investment costs are estimated to be EUR 160 million. Retrofit aspects are less relevant for hydrogen production, since there is only a connection to hydrogen networks required.

The costs of hydrotreatment and hydrogen production capacity were largely made to fulfil fuel requirements, such as for ultra-low sulphur diesel. The associated environmental benefits fall outside of the refinery, however. Competing regions are also expected to fulfil the fuel specifications before putting their products on the same market. It is therefore difficult to allocate these costs to on-site emission reductions.

Switch from oil firing to gas firing and other SO_2 reduction measures

SO_2 emissions in the Netherlands have declined substantially due to the implementation of several measures. A reduction of 65% (from 32.2 kton in 2005 to 11.3 kton in 2012) was primarily the result of the switch from the remaining oil firing to gas firing. The switch also led to lower NO_x and dust emissions. The cost of this fuel switch is difficult to determine. The price difference between refinery oil and natural gas is not known upfront and varies over time, which means that the switch also entailed financial risks. The current situation with low natural gas prices and high oil prices is profitable for a fuel switch. An alternative option that could have been chosen is a wet gas scrubber which removes SO_2 from flue gas. The cost price figure is more stable here.

If refinery fuel oil is used for fuel at the refinery site, it needs to be sold or converted to more valuable products. The latter option may need additional investments, which may be compensated for by higher prices.

Besides the fuel switch, other measures were also implemented with respect to Claus plants, FCC units and the sulphur content of the refinery gas.

Based on the cost figures for different SO_2 mitigation options, from CONCAWE (2011) and other sources, a mean cost effective figure of 2 EUR/kg SO_2 reduction is assumed. The expected costs ranges from 1.5 to 3.5 EUR/kg SO_2 reduction. The reduction of 20.9 kton SO_2 multiplied with 2 EUR/kg results in a cost burden of EUR 42 million per year in 2012.

Other environment-related measures

Rough estimates historical cost burden:
SO_2: EUR 42 million/year
NO_x: EUR 5 million/year
Dust: EUR 14 million/year

In 2004, RIVM published a report on the cost of reaching the 2010 emission targets (Smeets, 2004). This report gave indications of the specific costs for the industry, refineries and power plants sector to take additional measures. This report can be used to give an indication of the costs related to environmental measures in the sector between 2005 and 2012. Looking at the different environmental reports, it can be concluded that the reduction in SO_2 and PM10 emissions is almost entirely attributable to the switch from oil firing to gas firing, as discussed earlier in this section.

Therefore, the only costs remaining are those for the reduction between 2005 and 2012 of NO_x emissions by 3.8 kton and NMVOC emissions by 4.8 kton. The NO_x emission reduction was also somewhat affected by the substitution of oil with gas (estimated at 1.3 kton), resulting in a reduction of 2.5 kton by other measures. Using the RIVM's cost efficiency figures of 2 EUR/kg NO_x reduction and 3 EUR/kg NMVOC reduction, the refinery sector sustained additional costs in 2012 (compared to 2005) of EUR 5 million per year for NO_x reduction and EUR 14 million per year for NMVOC reduction.

3.5 Conclusions

The inventory of international legislation relevant to the Dutch refining sector shows that mainly the BREF and the NEC directive should be considered for the SPS, while the

IED, the RED, the EU ETS and potential consequences of IMO Marpol should be considered for the BPS.

Emission levels in Belgium and USA at the same level as the Netherlands, Germany and France show higher emission levels.

A comparison of international emission levels shows that Belgium has an environmental performance in the same range as the Netherlands. Data for the USA shows that SO_2 emission profiles are relatively lower there than in the Netherlands, while particulate emissions are lower in the Netherlands. It also shows that the NO_x emissions for both countries are in the same range. The emission profiles for the Netherlands, Belgium and the USA show that these countries are among the front runners.

Emission levels in Germany are declining, but are still higher than the emission levels of Belgium and the Netherlands. Emission levels in France are declining too, but are substantially higher than in other countries. The same BREF is applicable for all of these EU countries, setting the same set of emission levels.

An inventory was made of emission limit values for countries outside Europe, namely the Middle East region, India, the FSU region and Turkey, as well as the limits laid down by the World Bank. The vast majority of the emission limit values were found to be more lenient than those in the Netherlands.

Finally, the historical cost burden for the Netherlands is quantified at a level of EUR 42 million/year for SO_2 measures, EUR 5 million/year for NO_x measures and EUR 14 million/year for NMVOC measures. This adds up to a cost estimate of EUR 61 million/year for the Dutch refining sector to achieve the emission reductions observed during the period of 2005 to 2012.

4

Scenarios and emission outlooks

4.1 Introduction

The impact on the Dutch refining sector's competitiveness of the costs resulting from stringent measures was analysed under various scenarios. These scenarios were also developed to assess the aggregated future emission profiles.

The Basic Plant Scenario (BPS) was developed first, to be used as the reference background scenario. It was assumed that the highest set of emission limit values would be achieved under this scenario, according to the regulations and legislation as interpreted by the five individual refineries. The future utilisation of Dutch refining capacity was also calculated based on the market expectations for the Dutch refining sector. The combination of the 'highest set of emission limit values' and the utilisation of capacity determines the emission outlooks.

The Stringent Plant Scenario (SPS) was calculated next, based on BPS. This scenario assumes a stringent set of emission limit values required by potential legislation set by the Dutch authorities. Combined with the utilisation of capacity as determined under BPS, emission outlooks were calculated for this scenario.

Capacity utilisation was mainly determined using the economic optimisation models of Wood Mackenzie. Since economic outlooks are subject to uncertainty, a Sustained Utilisation Scenario (SUS) was calculated as well. As well as being a 'what if' scenario, this scenario may be used as the upper range of the presented outlooks.

4.2 Methodology

4.2.1 Basic Plant Scenario(BPS)

The emissions of the Dutch refining sector are determined by the operations at the sites. The emissions profile is mainly established by the utilisation of the refining and storage installations. As a consequence, the emissions outlooks are mainly determined by the expected utilisation, together with potential expansion of refining capacity, potential shut down of installations, and deployment of new techniques affecting environmental emissions.

The expected refinery crude throughput and product output was modelled in order to develop the aggregated outlook for the Dutch refining sector's competitiveness and emissions.

Actual refinery throughput data for historical years (2005 and 2010) was used where supplied by the individual refineries, in order to provide the closest match possible to actual operations and emissions. Where this data was unavailable, proprietary Wood Mackenzie PetroPlan modelling software was used to determine the expected product yields based on refinery configuration and estimated crude slates. In those circumstances where Wood Mackenzie modelling data was used, the relevant refineries were supplied with the results in order for them to provide comments or feedback. This feedback was incorporated into the scenario.

Refinery output data for the forecast years (2015-2025) was audited by the individual refineries. Where additional projects or major changes to operation were identified by the individual refineries, this input was incorporated into the forecast output. It was also agreed that no additional major investments would be included in the outlook view unless specifically endorsed in the discussions with individual refineries.

BPS is based on refinery utilisation resulting from economic optimisation modelling

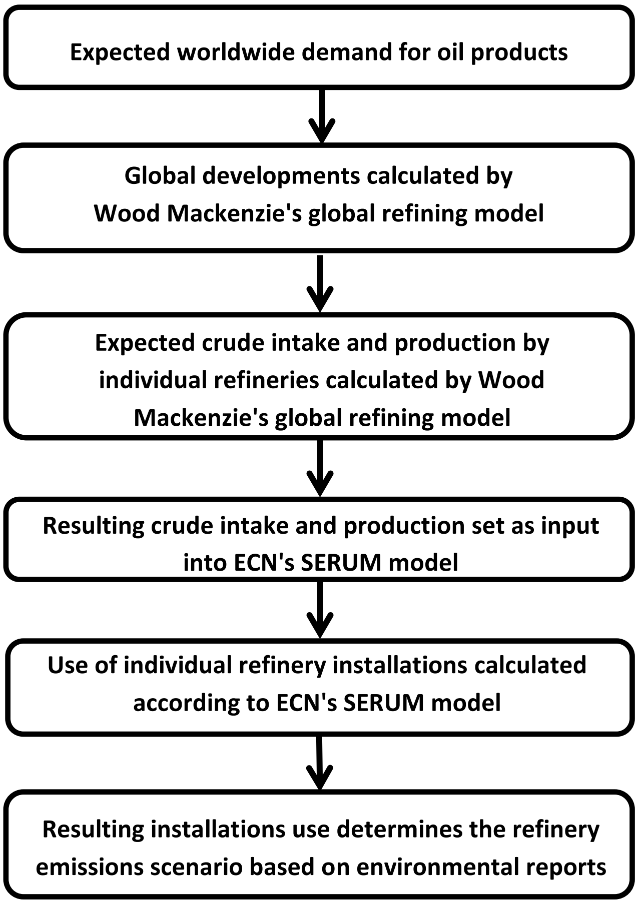
Globally, total oil product demand must be in balance in the long term with total product supply, since there is also limited capacity to store products. The Wood Mackenzie models provided a view on crude utilisation globally and a large number of key factors were considered. These are of major importance and need to match with the utilisation outlook for each region and country during a modelling exercise. The following key factors were mainly relevant:

- Country supply and demand barrel alignment.
- Refinery configuration and complexity.
- Integration – feedstocks, petrochemicals.
- Ownership structure.
- Strategic importance.
- Calculated net cash margin.
- Global and regional competition.
- Investments and infrastructure.
- Global themes and legislation.

Utilisation outlook determines the BPS emissions outlook

The expected utilisation for the Netherlands, together with the potential expansion of refining capacity, potential shut down of installations and deployment of new techniques affecting environmental emissions, were the input to model each individual refinery, using the Dutch refining model SERUM. A short description of the SERUM model is attached in Appendix C. The emission outlooks under the Basic Plant Scenario were calculated based on the refining operations calculated by the SERUM model and the environmental reports from statistical years. The sequence of calculation activities is illustrated in Figure 20.

Figure 20: Calculation flow to determine the future outlook for environmental emissions



4.2.2 Stringent Plant Scenario(SPS)

To develop the Stringent Plant Scenario (SPS), both the refineries and several government bodies were required to answer the general question: which legislation and/or required measures could become relevant in the future up to 2025? In general, the measures considered were those which are mainly regarded as an additional Dutch burden on top of European-based legislation. Measures which had been studied in the past and rejected or postponed then, were also discussed again with the responsible authorities. Such measures are often relevant for current permitting procedures, for example.

The government bodies interviewed were:

- Ministry of Infrastructure and Environment. Topic: environmental regulation and fuel standards.
- DCMR Milieudienst Rijnmond (competent authority). Topic: all issues relevant to new permits, in particular environmental regulation and major hazard regulation.
- RUD Zeeland (competent authority). Topic: all issues relevant to new permits, in particular environmental regulation and major hazard regulation.
- Ministry of Economic Affairs. Topic: energy efficiency requirements and regulation for compulsory oil stockpiling.
- RVO (responsible body for the MEE-covenant). Topic: energy efficiency requirements.

Furthermore, the individual refineries were requested to submit a list of measures, including costs and potential results (for example, emission reduction). This list of measures was compared to the information provided by the authorities to guarantee alignment with potential future stringent regulations and potentially lacking information due to non-declared measures. Costs and potential results, such as emission reductions, were also validated.

The major themes of the declared measures are:

- Measures to abate environmental emissions to air, in particular NO_x, SO_2, and NMVOC, including benzene.
- Measures to comply with major hazard regulation, in particular with respect to tank storage.
- Some measurement techniques which may be required in the future.

Various measures were incorporated under the SPS. Measures comprise environmental emissions to air and major hazard regulations

The measures include, amongst many others:

- NO_x: low-NO_x burners, $DeNO_x$ installations.
- SO_2: desulphurisation of flue gases and fuel gases and increase of SRU efficiencies up to 99.8%.
- NMVOC: installation of better seals for tanks, fixed roofs on external floating roof tanks, vapour recovery units for the major loading and unloading streams.
- Measures with few NMVOC effects due to the current NMVOC calculation methodologies: tanks with heavy oil will be equipped with internal floating roofs, or loading and unloading of heavy oil is facilitated with a VRU. These measures are assumed, since heavy oil may become a substance with a minimisation requirement (In Dutch: minimalisatie verplichte stoffen (MVP)).
- Major hazard regulation: tank overfill protection and various measures for the bund and bund wall, such as increase of bund containment or impermeable floors. Measures are largely based on requirements laid down in the current version of the Hazardous Substances Publication Series number 29 (in Dutch: PGS 29).
- Measurement techniques: additional continuous measurements of particular pollutants.

Several measures were defined as being part of the Stringent Plant Scenario since these will be the result of (additional) policies. Some measures will be directly implemented due to existing policies, while the vast majority will be implemented as a result of additional policies. Future additional policies may not enforce some of the measures due to high cost-effectiveness factors, for example. The Stringent Plant Scenario includes these measures though, since these are considered by several policy-makers to have a great potential to meet stringent targets, for example.

Costs of measures have been validated

Validation of the various measures was performed based on Draft BREF (2013) and Handbook of Refining Processes (2011) and recent environmental reports from individual companies. The majority of the information about the measures was confirmed to be valid. For some measures, validation remained relatively difficult due to specific processes, and validation of some NMVOC emission reductions due to complicated emission declarations. For some measures, costs and/or emission reductions were amended, rejected or added. With respect to major hazard regulation in particular, costs are based on estimations from the individual refineries, while the cost validation is mainly based on surface estimates of the tank terminals and number of tanks combined with the cost information from Chapter 4.21 of the Draft BREF 2013, where, for example, the concrete paving of bunds is declared at a cost level of EUR 70-140/m^2.

Reasons not to incorporate particular measures in SPS

Some measures have not been included in this list, since these are part of the international regulations (such as the EU ETS scheme, see also Paragraph A.2.6) and have already been used as an input parameter under BPS in the Wood Mackenzie models. Other regulations which were considered but rejected include:

- Compulsory oil stockpiling: like the Netherlands, various IEA countries do have a more or less comparable number of stockpiling days as a base policy. Additional policies, which may increase costs, were not indicated by any of the parties of interest.
- Emissions to water and soil: by project definition, measures within this category were not incorporated into this study nor included in the impact analysis. The raw information provided has not been validated. It can be found in aggregated form in Appendix D.
- Compared to the BPS, no different crude and/or product portfolios were indicated by the refineries. No assumptions were made for different product portfolios under the SPS compared to the BPS as a result of IMO/Marpol requirements.
- Energy efficiency measures were not incorporated for various reasons. Based on the information provided, it is currently difficult to foresee substantially heavier policies on this subject for the Dutch refining sector. Furthermore, the current policy enforces measures based on a pay-back period, which means that financial savings as well as costs are made.

4.2.3 Sustained Utilisation Scenario (SUS)

SUS was developed as an alternative view of refinery utilisation in the future

The BPS was determined using economic optimisation models (see Paragraph 4.2.1). The aggregated utilisation rate determined for the BPS is not sustainable for any individual refinery in the long term, either from a technical or an economic perspective. Each refinery will strive for maximum utilisation under the given economic climate.

To adequately represent the concept of uncertainty connected with outlooks based on economic optimisations, the actual 2012 situation was used to present an alternative scenario outlook. This 'what if' scenario was constructed assuming a sustained product yield and crude throughput utilisation scenario. This Sustained Utilisation Scenario (SUS) describes the situation should Dutch refineries manage to avoid the developments anticipated under the BPS and the Dutch refining sector continues to operate in the same manner as it does at present.

Although this scenario does not reflect Wood Mackenzie's base view of the Dutch sector as described in Paragraphs 4.2.1 and 4.3.1, it does provide a useful reference point for product and emissions output. This is an important scenario for the purpose of the emissions modelling as it removes the impact on total emissions in future years which may result from any decline in refinery utilisation and throughput. Therefore, this scenario provides emission outlooks that are comparable to those of the current refinery operations.

4.3 Scenario results

4.3.1 Basic Plant Scenario (BPS)

Globally, total oil product demand must balance with total product supply in the long term, also since there is limited product storage capacity. A significant excess of refining capacity already exists over and above that which is required to meet global demand. Going forward, it is anticipated that additions to global refinery capacity will significantly outpace growth for product demand. Furthermore, a growing volume of non-conventional refinery-sourced products will displace the need for some crude refined products (such as biofuels and NGLs).

As described in Chapter 2, the European refining sector is expected to see a decline in volume of crude processed over the next few years as a result of increasing supply from other regions, a stagnating domestic product demand and competition in key export markets. The low level of crude throughput utilisation is unlikely to be sustainable in the long term, and therefore this decline in throughput is seen as a signal for refinery capacity closure.

The Dutch refining sectors crude utilisation expected to decline going forwards

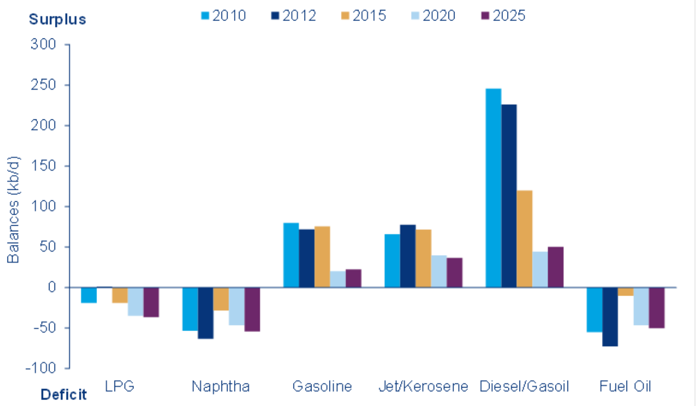
The Dutch sector is expected to experience a decline in crude throughput as a result of the same effects that are driving a reduction in crude utilisation throughout Europe. Despite the Dutch sector's position as a key refining hub, a significant risk of refinery closure is foreseen as a result of external threats. This reduces refinery profitability in the region and increases the competition to maintain profitability between assets within Europe and the Netherlands. The two major threats observed are:

- Surplus and deficit combinations for particular oil products.
- Increasing competition from refineries outside the EU, in particular the Middle East, Russia and the USA.

Surplus in gasoline and middle distillate are expected to shrink whereas deficits for petrochemical feedstock and fuel oil is expected to grow

Due to the lack of product demand growth and global competitive pressures, refinery utilisation in the Netherlands is expected to drop drastically from 77% in 2012 to 58% in 2025. Even with the reduced utilisation rates, the Netherlands is expected to remain in surplus for gasoline, jet/kerosene and diesel/gasoil. Deficits for naphtha and LPG will remain as the Dutch petrochemical industry is expected to grow slightly. Bunkering demand in one of the world's shipping hubs is expected to remain robust, resulting in an increase in fuel oil deficits. The Netherlands is relatively unique in Europe in that it runs a middle distillate surplus (due to its large throughput) and a fuel oil deficit (due to the large bunker market).

Figure 21: Oil product balances in the Netherlands



Source: Wood Mackenzie

Dutch refinery exports are expected to face increasing competition from the Middle East, Russia and the USA

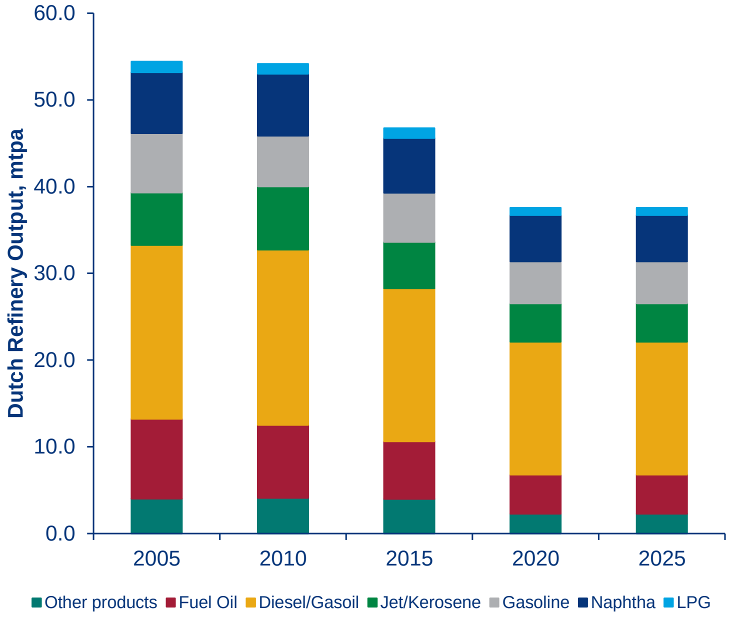
As shown under Paragraph 2.1, the increase in product supply from investments in the Middle East and Russia is expected to increase competition to supply diesel to Europe. In addition, US refiners are also seeking to export to Europe, benefiting from their low cost of supply. This increases the competition for Dutch refiners who are targeting the same market. Considering the scale, complexity and crude costs of the new refineries, these new suppliers could potentially provide volumes to Europe more competitively than the Dutch refiners.

Based on the methodology described earlier, the product output of the Dutch refining sector has been forecast and the results are displayed in **Figure 22**. This output is a key factor in the development of the impacts on the sector's emissions and competitiveness.

Under the BPS view, the Dutch sector is expected to see a significant decline in output. This is primarily driven by the Wood Mackenzie view of the reduction in overall Dutch sector crude throughput utilisation. It is reflected as an overall reduction in throughput from each individual asset and **Figure 22** presents the aggregated result of this modelling process.

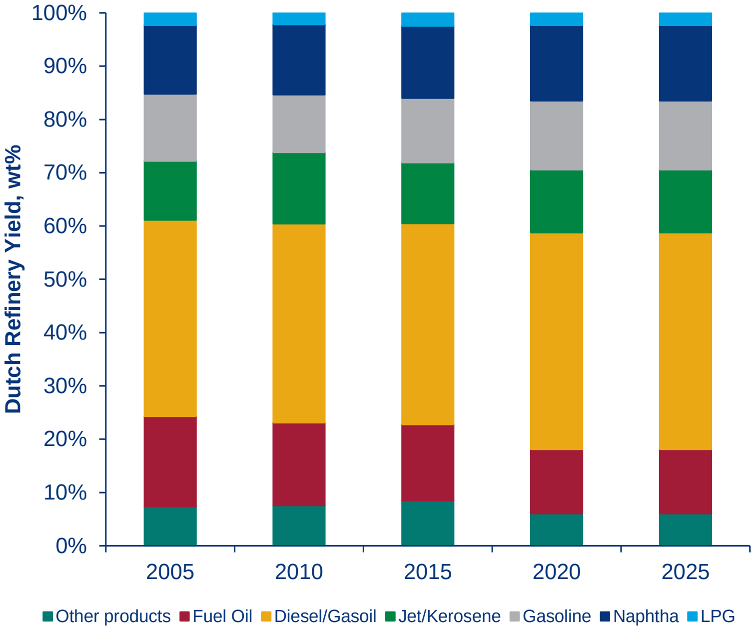
The results of the modelling process indicate that the total expected refinery output will decrease from 54.2 million tons per year in 2010 to around 37.6 million tons per year by 2020. This reduction in product output is driven by reduced feedstock processing based on the Wood Mackenzie view of Dutch sector refinery output. Changes in individual product output also occur as a result of other factors such as the introduction of additional upgrading projects. The effects of refinery optimisation and refinery investment projects can be better understood by investigating the effects on refinery product yields. **Figure 23** illustrates the impact of these yields under the Basic Plant Scenario.

Figure 22: Dutch sector aggregated production (mtpa)



Source: Wood Mackenzie

Figure 23: Dutch sector aggregated yield (wt%)



Source: Wood Mackenzie

The modelling results indicate that there will be a significant shift in the product yield percentage of the Dutch refining sector. The primary driver behind the change in yields are identified upgrading projects, which are predominantly geared towards reducing the production of lower value heavy products such as fuel oil and residue, and increasing the production of more valuable lighter products such as diesel and gasoil. As a result of this outlook a number of changes to the product output are expected:

- **LPG** yield will remain reactively constant over time.
- **Naphtha** production on a yield basis will experience a small increase.
- **Gasoline** and **jet/kerosene** will also see a small increase in relative wt% yield.
- **Diesel/gasoil** will see the greatest % increase in yield (as most projects identified are geared towards production of diesel).
- **Fuel oil** production will see a sharp % decline beyond 2015.
- **Other products** will see a small decline in the long term as crude rates are cut and upgrading projects reduce the production of lower value products.

Low utilisation rates and increasing competition might force refinery closures in the Netherlands. Security of domestic supply may become an issue

The expected decline in the Netherlands' overall refinery utilisation rate will force reductions. As previously illustrated, low utilisation rates are unsustainable in the long run and could potentially result in refinery closures in the Netherlands. In the case of large refinery closures, the Netherlands might end up in a position where it is reliant on imports from other regions, so that domestic security of supply becomes an issue.

4.3.2 Stringent Plant Scenario (SPS)

The emission outlook for the Stringent Plant Scenario (SPS) was obtained by calculating the total emission reductions of the relevant measures under the SPS (see also 4.2.2 for the methodology). The total emission reduction potential is summarised in aggregated format in Appendix E.

The emission reduction potential is based on recent emission statistics from the period 2010-2012. Since there is an emission decrease under the Basic Plant Scenario due to lower utilisation of the capacity, the entire reduction potential decreases as well. This effect was taken into account when calculating the emission profiles under the SPS.

The investment costs required for compliance with legislation under the SPS total EUR 1.3 billion

The aggregated costs for the entire sector as a result of the SPS are summarised in **Table 6**. The aggregated investment costs and annual operating and maintenance (O&M) costs are split into the themes of the two major measures: environmental measures and major hazard measures. The environmental measures comprise the largest investment, although the major hazard measures still represent 42% of the total investment costs.

Table 6: Aggregated cost burden of the measures under the Stringent Plant Scenario, split into the two major themes: environmental measures and major hazard measures. The lump sum investment costs are a non-recurring expense, while the O&M costs recur yearly. Summations may deviate from the declared total budgets due to rounding off to the nearest million euros.

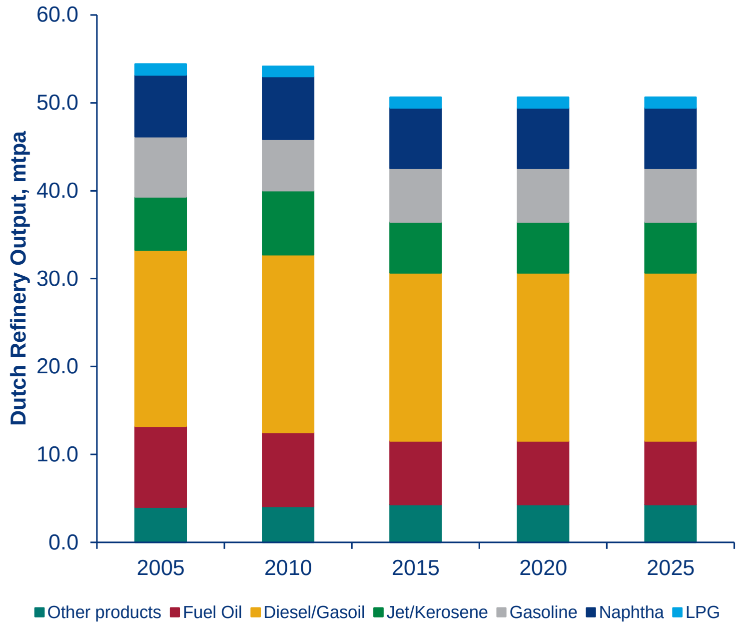
Type of measures	Lump sum investment costs (EUR mln$_{2010}$)	O&M costs (EUR mln$_{2010}$/year)
Environmental measures	766	44
Major hazard measures	562	9
TOTAL	**1328**	**52**

4.3.3 Sustained Utilisation Scenario (SUS)

As described in Paragraph 4.2.3, economic optimisation modelling is subject to uncertainty. The underutilisation of capacity as determined under the BPS (see Paragraph 4.3.1) is too low to sustain operations without refinery capacity reductions. Since the current refining capacity in the Netherlands has already been in existence for several decades and forms one of the most competitive refining hubs in North West Europe, the key factors may turn out to be less negative than analysed using Wood Mackenzie's models. Therefore, this 'what if' scenario was constructed to investigate the Dutch refinery sector's output, assuming that Dutch refineries manage to survive and continue operations in the same manner as they do at present.

In this scenario, the product yield outputs remain constant in forecast years in line with actual data for historical years, and refinery utilisation is assumed to remain constant at a current crude throughput of ~80% (see also **Figure 24**). No investments were assumed which would impact product volumes or yield by any of the refineries. Under this sustained scenario the modelling process indicates that the expected total refinery output would remain at 50.7 million tons per year in line with historical production under Wood Mackenzie's 2012 data.

Figure 24: Dutch sector aggregated production (mtpa) for the SUS



Source: Wood Mackenzie

4.4 Emission outlook scenarios

The current emissions for the Dutch refining sector are shown as actual emissions in **Table 7** and **Figure 25**. Since five refineries represent almost the entire Dutch sector, the total for these refineries will also be used as the aggregated sector total in this report. The data is based on statistics and environmental reports and is corrected with recent information from the refineries. SO_2 emissions were adjusted downward due to the provision of updated information on 2012 emissions. Due to several changes in the monitoring and calculation of NMVOC emissions, older pre-2005 data are not comparable with recent data. For the emission calculations for the various scenarios, emission data was used which was in line with the environmental reports used.

Since the total NMVOC emissions are mainly determined by the calculation method in the Netherlands, Dutch data often differs from the data for other countries using a different approach. The sources of NMVOC emission in 2012 can be categorized as: 5% energy use, 9% flaring, 15% piping and installations (diffuse emission sources), 7% specific locations (point sources), 48% storage tanks and 16% loading. Emissions from diffuse sources and loading decreased substantially between 2005 and 2012.

It was observed that it has only been in recent years that environmental reports have made a distinction between total dust emissions and PM10 dust. In many reports, these numbers are equal or almost equal. It is therefore concluded that the term 'dust', also in the earlier years, refers almost entirely to PM10. The term 'dust' is used in this report to ensure alignment with the environmental reports used.

Based on Wood Mackenzie's refinery projections for the BPS (see Paragraph 4.3.1), the utilisation and production for each individual refinery were calculated using ECN's refining model SERUM. The emission scenarios for the BPS were calculated based on environmental reports and the performance of the main groups of installations. The emissions from flaring were mainly provided by the individual refineries and will remain steady for the future. NMVOC emissions were calculated based on the production of lighter products, namely LPG to kerosene.

For the SPS, various measures were identified and the subsequent impact on the emission outlook for the BPS was determined.

The scenarios show decreasing emission outlooks:
- SUS: background measures
- BPS: lower utilisation
- SPS: stringent measures

The results for all of the scenarios are summarised in **Table 7**. The outlooks are displayed in **Figure 26** for SO_2 emissions, **Figure 27** for NO_x emissions, **Figure 28** for dust emissions and **Figure 29** for NMVOC emissions.

Differentials were calculated In **Table 7** as well. These differentials are defined as follows:

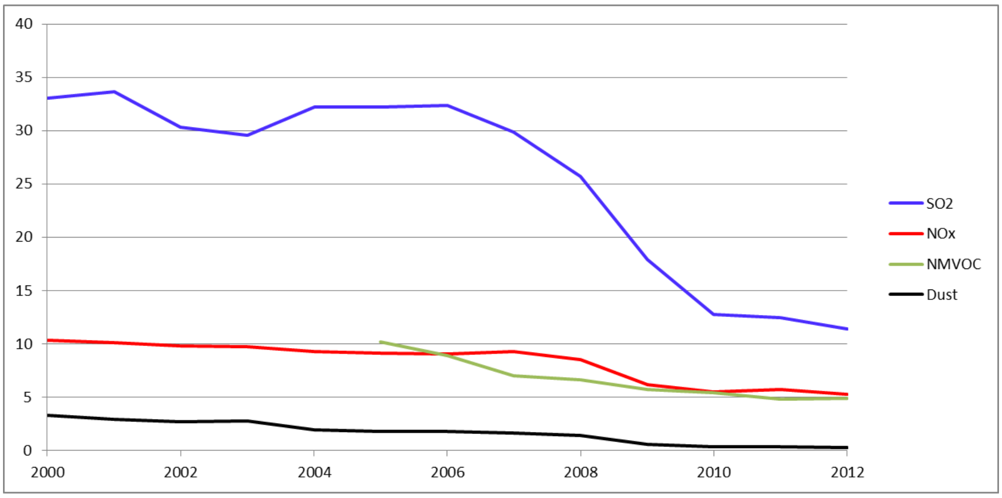
- Background measures: the difference between the SUS outlook and the actual emissions in 2012. The difference is determined by a combination of expected measures which will be implemented anyway and expectations with respect to the failure of refining units.
- Underutilisation: the difference between the BPS and SUS for the relevant outlook year. The difference is determined by a lower utilisation of capacity.
- Stringent measures: the difference between the SPS and BPS for the relevant outlook year. The difference is mainly determined by the implementation of measures as identified under the SPS.

Table 7: Emissions of the Dutch refinery sector

	Actual emissions				Emission outlook				Differentials			
Kton per year	2000	2005	2010	2012		2015	2020	2025	Emission reduction due to:	2015	2020	2025
SO$_2$	33.0	32.2	12.7	11.4	SUS	10.1	10.0	9.9	background measures	-1.3	-1.4	-1.6
					BPS	9.1	7.6	7.4	underutilisation	-1.1	-2.4	-2.5
					SPS	7.3	4.7	3.0	stringent measures	-1.8	-2.9	-4.4
NO$_x$	10.3	9.1	5.5	5.3	SUS	5.4	5.4	5.4	background measures	0.1	0.1	0.1
					BPS	4.3	3.6	3.5	underutilisation	-1.0	-1.7	-1.8
					SPS	3.7	2.6	2.0	stringent measures	-0.6	-1.0	-1.5
Dust	3.3	1.8	0.4	0.3	SUS	0.3	0.3	0.3	background measures	-0.02	-0.02	-0.02
					BPS	0.2	0.2	0.2	underutilisation	-0.03	-0.05	-0.05
					SPS	0.2	0.2	0.2	stringent measures	-0.03	-0.05	-0.07
NMVOC		10.2	5.4	4.9	SUS	4.7	4.6	4.5	background measures	-0.2	-0.3	-0.4
					BPS	4.3	3.6	3.5	underutilisation	-0.4	-1.0	-1.0
					SPS	3.7	2.6	2.0	stringent measures	-0.6	-1.0	-1.5

Figure 25 presents the emission developments for all relevant pollutants for the actual years. As described earlier, the emission calculation method for NMVOC changed in 2005 and the data from before this year is therefore not comparable to the most recent data. There is a decrease in emissions for all pollutants.

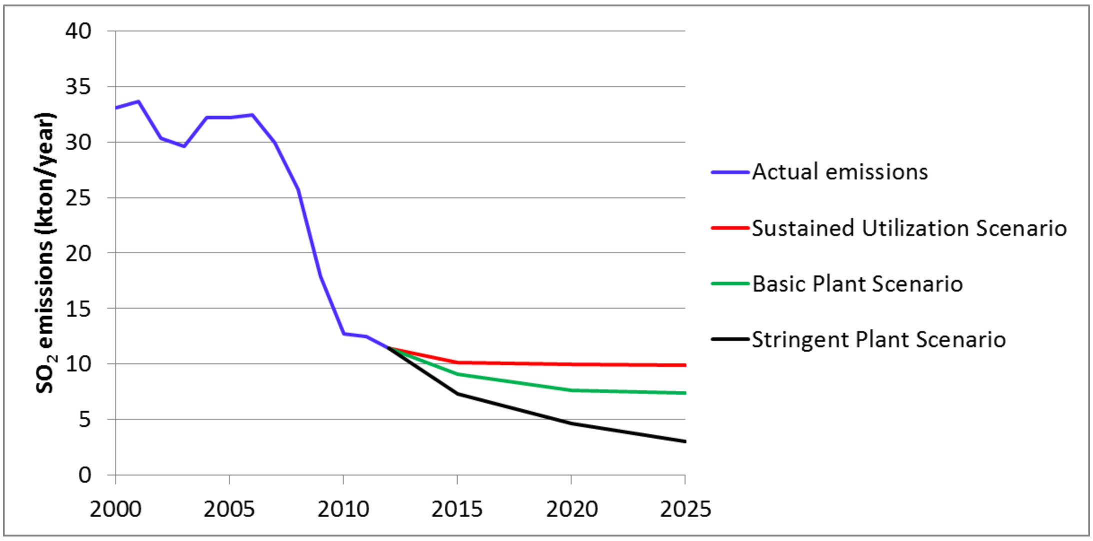
Figure 25: Emission development in the Dutch refinery sector [kton/year]



SO$_2$ emission outlook

Figure 26 depicts the actual SO$_2$emissions and emission outlook for the various scenarios. The reduction in SO$_2$ between 2005 and 2010 is mainly related to the switch from oil firing to gas firing, although reduction has also been achieved at other refining units, such as the sulphur recovery units. There was also a decrease in SO_2 emissions for the SUS, due to the background measures described in **Table 7**. These measures will be implemented in future years. The kink observed for the SUS in **Figure 26** is mainly related to expectations with respect to flaring, which will be kept steady for future years.

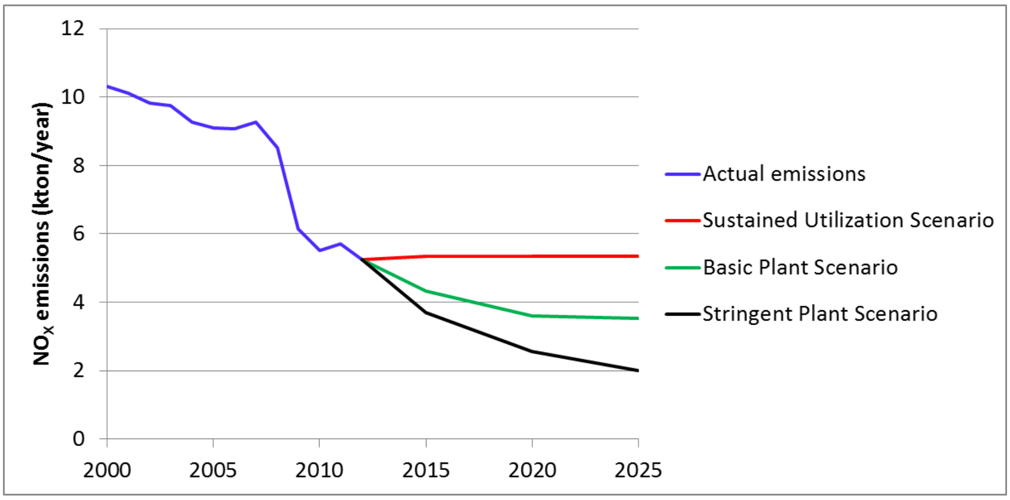
Figure 26: Developments in SO_2 emissions under the different scenarios



NOx emission outlook

Figure 27 depicts the developments in NO_x emissions. The reduction in NO_x emission between 2005 and 2010 is mainly due to the fuel switch from oil to gas as well as the associated investment in new burners, where necessary. $DeNO_x$ aftertreatment technology is in place at some units. NO_x emissions show a small increase in 2011. Due to the use of emission data from the most recent years, calculations for the SUS show a very small increase in emissions compared to 2012.

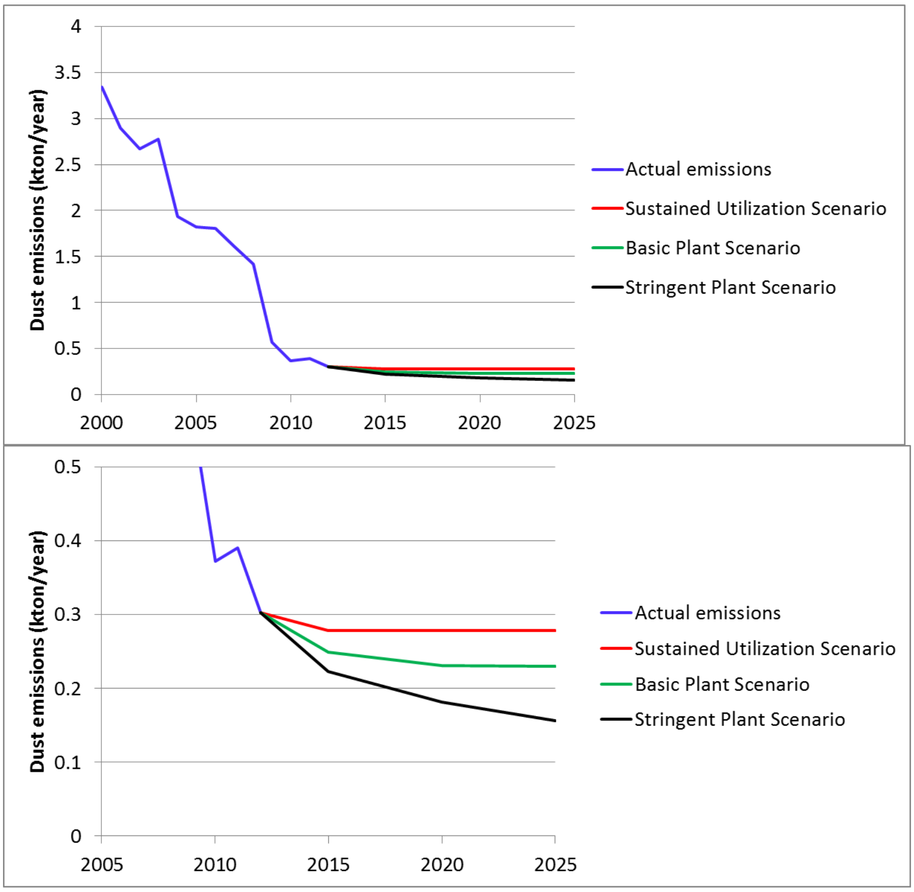
Figure 27: Developments in NO_x emissions under different scenarios



Dust emission outlook

Dust emissions are associated with oil firing. Therefore, **Figure 28** shows a substantial reduction in emissions over the years. The kink observed for the SUS in **Figure 28** is mainly related to expectations with respect to flaring, which will be kept steady for the future years.

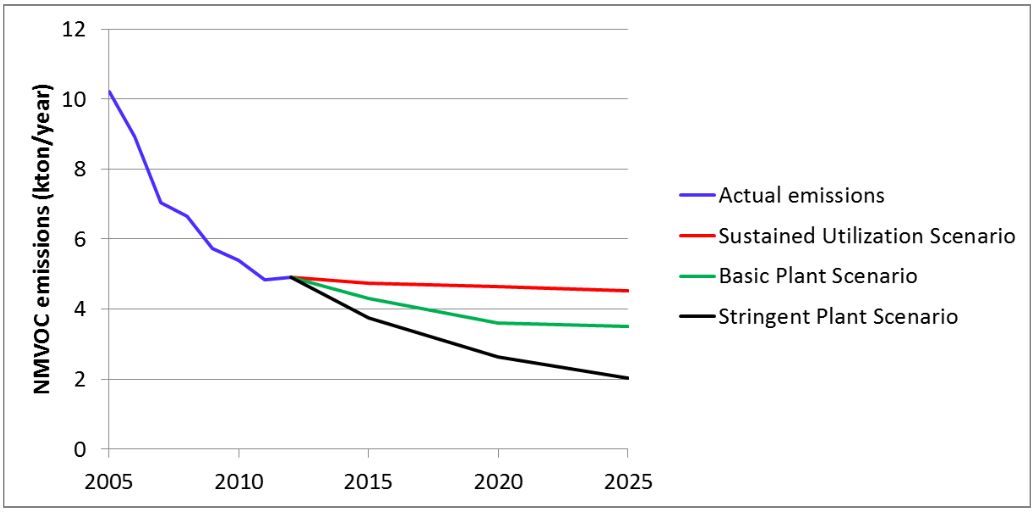
Figure 28: Developments in dust emissions under the different scenarios. The graph below this figure represents a close-up for the outlook years.



NMVOC emission outlook

The observed decrease in actual NMVOC emissions is mainly due to the implementation of measures with respect to leak detection, transit and storage. The outlook for the various scenarios show a further decrease in **Figure 29**. There is a small decrease under the SUS, due to background measures being introduced in future years.

Figure 29: Developments in NMVOC emissions under the different scenarios



4.5 Conclusions

Economic optimisation modelling shows that under the BPS, future utilisation of Dutch refining capacity decreased by approximately 30% or 17 Mton of product compared to the current utilisation. This development is mainly dictated by global trends such as refining overcapacity and decreasing demand in developed countries. The lower utilisation results in a decreasing emission outlook. For the SPS, stringent measures were identified with respect to both costs as well as emission reduction potential. The implementation of stringent measures involves investment costs of EUR 1.3 billion. The potential for the reduction of emission for the relevant pollutants decreases due to the assessed underutilisation of capacity under BPS, but there is still substantial potential for emission reduction.

Apart from the BPS and SPS, an alternative scenario was developed in which refineries were assumed to cope with the relevant developments and continue operations as in current years. The associated emission outlook for this SUS scenario shows limited emission reduction, which is the result of abatement measures being implemented anyway.

5

Cost assessment and impact on competitiveness of SPS

5.1 Methodology

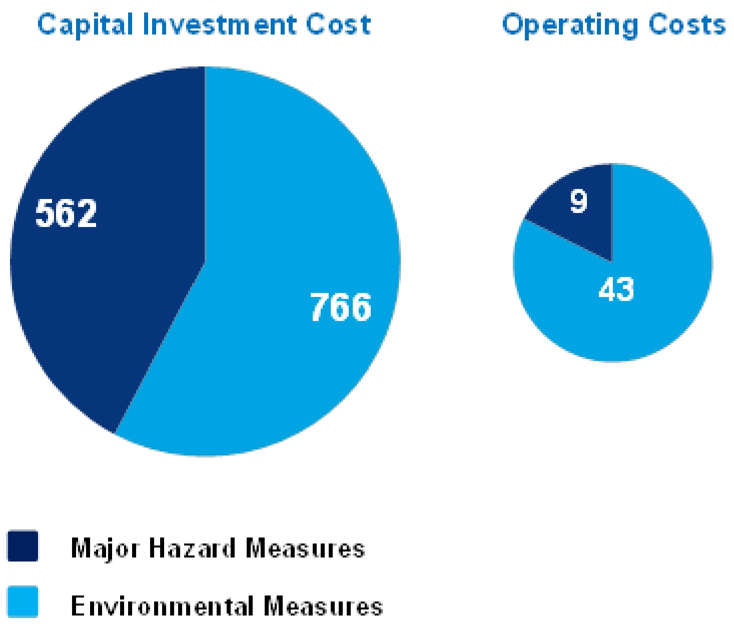
The refinery throughput and yield outlook developed for the BPS were also the basis for the SPS, in order to accurately reflect the impact of the SPS on emissions and competitiveness. No additional product yield upgrading projects were forecast as part of the SPS beyond those already included in the BPS.

The additional cost of emissions abatement was established as described in Paragraph 4.2.2 and the aggregated results are described in Paragraph 4.3.2. These costs were used to assess the impact of the SPS on the sector's competitiveness. In addition to the emissions abatement requirements identified, an additional stringent view was applied to potential future fuel oil prices as a result of the implementation of SECA and IMO Marpol regulations on marine bunker fuels. The effect of a stringent interpretation of this legislation was defined as a reduction in the price of fuel oil products relative to crude oil, leading to a reduction in the potential margins and ultimately the competitiveness of those assets subject to the legislation. These impacts are also included in this analysis.

5.2 Cost results

The additional capital and operating expenses necessary for meeting the legislation requirements under the SPS were investigated. These costs consist of two broad categories; those of meeting the required environmental measures, and those of providing major hazard measures. The costs identified under the SPS are those in excess of any costs which may be required under the BPS. The figure below summarises the incremental aggregated costs associated with the Dutch refinery sector's SPS requirements.

Figure 30: SPS additional cost burden (x mln EUR_{2010})



Source: Refining group, ECN, Wood Mackenzie

The costs needed to comply with legislation under the SPS total EUR 1.3 billion

The total aggregated environmental and major hazard measures capital costs to the Dutch sector under the SPS were estimated to be EUR 1.33 billion. The incremental yearly operating costs associated with these investments were estimated to be EUR 53 million per year.

SPS costs result in an equivalent cost of USD 0.86 per barrel

This aggregated capital cost for the Dutch sector was annualised as per the guidelines laid out by the Dutch Ministry of Infrastructure and Environment. This consists of applying a 10% discount rate over an expected economic lifetime of 10 years. An inflation correction is then applied to align the cost burden correctly with the modelling methodology. This results in an annual cost burden of USD 390 million per year (EUR 295 million) resulting from capital and ongoing operating expenses. Based on current refinery capacity, this represents an equivalent cost of USD 0.86 per barrel of crude processed to the Dutch sector.

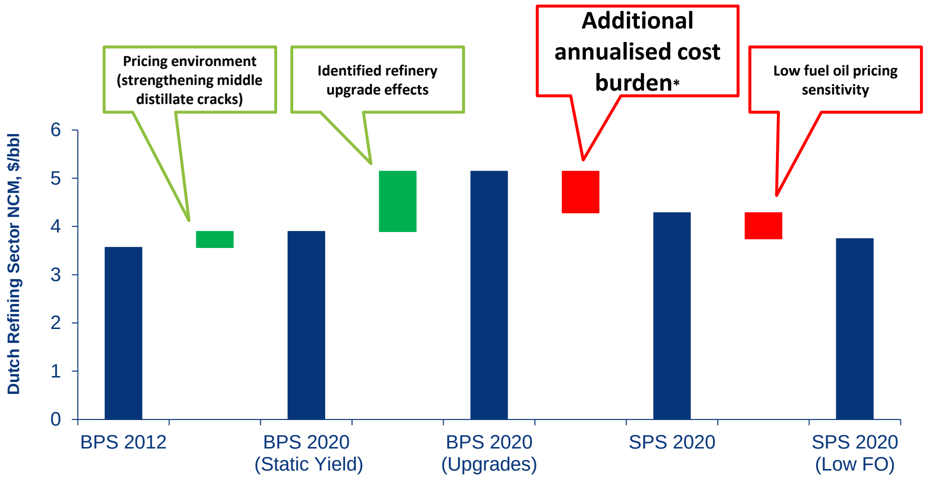
5.3 Impact on competitiveness

5.3.1 Outlook for the Dutch sector

In order to investigate the various effects of pricing environment, product output and SPS cost burden, a bridge was created between the current 2012 refinery competitiveness and a number of different future outlook conditions. The chart below highlights the results of this assessment for the Dutch sector based on Wood Mackenzie's base view. This bridge was created on a net cash margin (NCM) basis, and is described in section 1.6 of this report.

Net cash margin bridge negatively influenced by additional annualised cost burden

Figure 31: Net cash margin bridge for the Dutch sector. Additional annualised cost burden represents the step change due to the SPS costs



Source: Wood Mackenzie

- The base assessment identified the Dutch sector's aggregated net cash margin performance during 2012 at around 3.6 USD/bbl.
- Margin performance is expected to improve slightly by 2020 under the BPS to 3.9 USD/bbl. This is a result of a marginal anticipated improvement in the product pricing and refining margin environment during this period.
- Planned refinery upgrade projects identified under the BPS add an additional 1.3 USD/bbl to the Dutch sector's competitiveness.
- The application of the additional annualised cost burden of 0.86 USD/bbl under the SPS results in a reduction of the net cash margin in 2020 to 4.3 USD/bbl.
- The impact of a low fuel oil price sensitivity further reduces the sector's aggregate competitiveness to 3.8 USD/bbl.

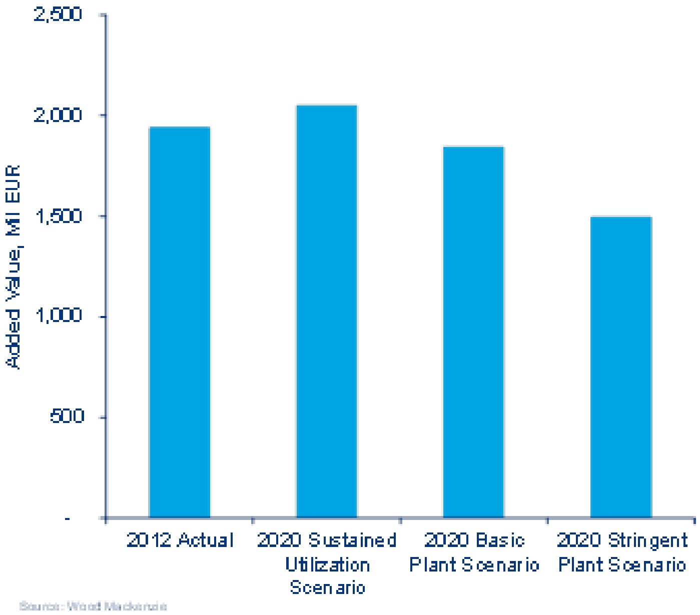
As such the total impact of the SPS is an equivalent reduction in refinery performance of 1.4 USD/bbl. This is a significant cost burden and in low refining margin years may severely risk the profitability of a number of refineries.

It is important to note that the refinery upgrade projects identified will incur a large capital cost element (likely > EUR 1 billion), in addition to the cost burden of the SPS compliance projects (with an estimated capital cost of EUR 1.3 billion).

The impact on the Dutch refining sector's 'added value' was also assessed under the BPS and SPS. This is the 'value' the refining industry adds to the economy of the Netherlands in terms of both operating profits and benefits paid to the employees. Added value is further defined in section 1.6 of this report. The figure below outlines the assessment of this added value.

Added value is negatively influenced under the SPS

Figure 32: Added value scenarios (EUR million/yr)



Source: Wood Mackenzie

The added value of the Dutch refining sector during 2012 was reported to be EUR 1.94 billion, derived from refinery margins and other employee benefits. A forecast was developed based on the refining model outputs to assess added value under a number of key scenarios:

- The SUS results in 2020 in a slight improvement in added value compared to 2012 as feedstock and products remain the same, but the pricing environment in 2020 shows a small upswing. In this scenario, no reduction in refinery throughput is forecasted.
- The BPS sees a slight reduction in added value in 2020, as the overall Dutch sector refinery throughput is decreased. Identified refinery upgrade projects are also included which result in a higher value product yield, therefore supporting the added value and offsetting some of the loss of added value as a result of the reduction in throughput.
- The SPS additional cost burden (reflected as a reduced NCM for 2020) results in a significant reduction in added value, as the increased annualised capital and operating costs reduce the effective margins and therefore the equivalent 'value' added to products.

This results in an ultimate added value of EUR 1.5 billion during 2020 under the SPS, a reduction of over EUR 400 million per year compared to the current 2012 position.

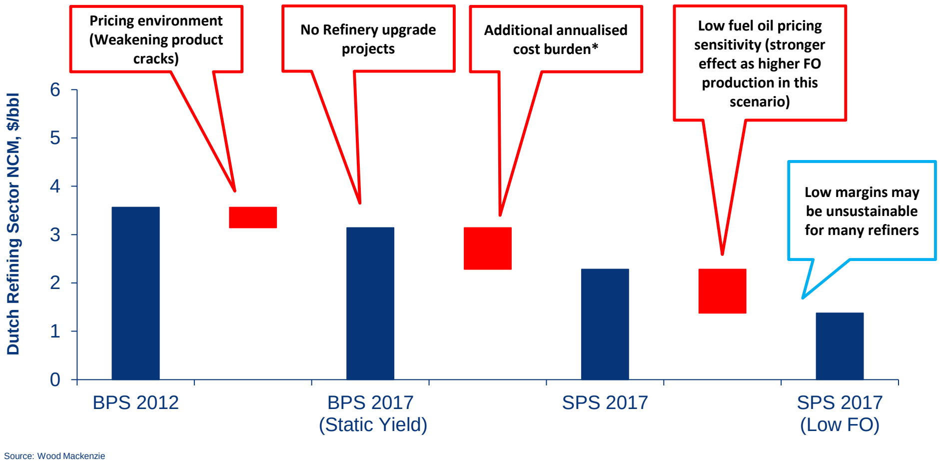
5.3.2 Risks of refinery closure

As described earlier, 2012 was a reasonably profitable year for the EU refining industry, however it is expected that these levels will not be sustained over the next five years. An analysis based on a low refining margin environment was also performed, since the refining market environment is expected to become increasingly challenging in the short term, which is the primary driver for the continued rationalisation within the European refining sector. It was established that the additional high capital costs associated with the SPS requirements may result in refiners not having access to sufficient funds to invest in high cost upgrading projects.

The analysis shows that refining margins will probably become increasingly tight within NWE in the next three to five years, due to the developments described in section 2.1. As such, the Dutch aggregated refining NCM has also been investigated under a low refining margin environment by using 2017 forecast prices as an example. This indicates how a weak pricing environment in addition to the SPS cost burden can result in unsustainably low margins for the Dutch sector.

Under a low margin environment, NCM decreases to a critically low level

Figure 33: Low margin environment bridge for the Dutch sector. Additional annualised cost burden represents the step change due to the SPS costs



Source: Wood Mackenzie

- The base assessment determined that the Dutch sector's aggregated net cash margin performance during 2012 was around 3.6 USD/bbl.
- Assuming that no yield improvement projects occur, the sector's performance is expected to decline under the BPS to 3.1 USD/bbl by 2017. This is the result of an anticipated decline in the product pricing and refining margin environment during this period.
- The application of the additional cost burden of the SPS results in a further reduction of the net cash margin in 2017 to 2.3 USD/bbl.
- The impact of a low fuel oil price sensitivity further reduces the sector's aggregate competitiveness to 1.4 USD/bbl. Critically, this lower fuel oil pricing environment has

a much greater impact in this scenario, as the yield of fuel oil produced without the identified refinery upgrades is significantly larger.

Under this low margin pricing environment, the aggregate Dutch sector net cash margin declines to as low as 1.4 USD/bbl. This represents a risk to the refining sector as such a low margin environment is not typically sustainable in the long term, and could significantly increase the risk of refinery rationalisation within the sector. Such a low margin environment is not typically supportive of upgrading investments and may result in further loss of competitive position to that of competing regions.

5.3.3 Who are the main competitors with the Dutch sector?

In order to adequately assess the competitiveness of the Dutch refining sector, a number of competing regions were also assessed. These include a number of local EU countries which serve similar markets and are also bound by the same EU laws (although not necessarily to their more stringent interpretation). A number of other key regions with which the Dutch sector is expected to compete were also identified . These are largely regions which may compete either directly to supply the local EU region, or within other global regions to which the Dutch sector exports products. Details of the global outlook view are included in section 2.1 of this report.

- EU competing countries were identified as France, Belgium, and Germany.
- Non EU countries in the region include Turkey.
- Non-European competing regions include the US Gulf Coast, US East Coast, Russia and Saudi Arabia. A high level overview of global competitiveness is displayed in the figure below.

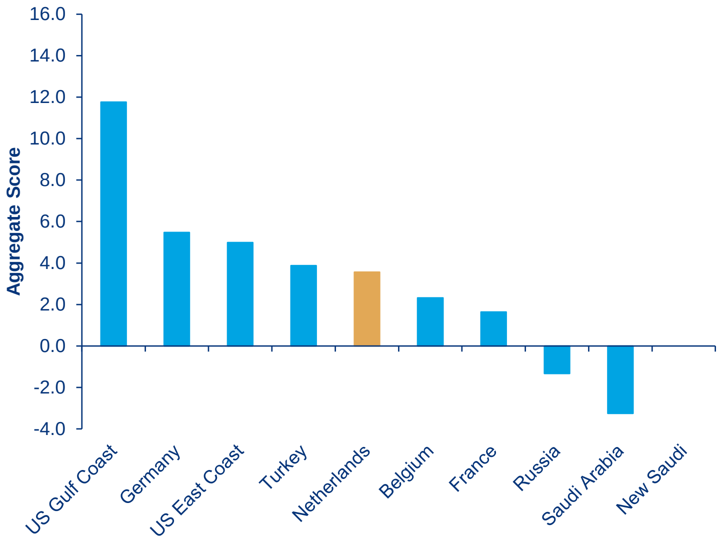
5.3.4 Dutch sector competitiveness results

An aggregated outlook view for refining competitiveness was created for each of the identified competing global refining regions. This assessment is based on the net cash margin assessment as it allows for a direct comparison of refinery competitiveness performance using international feedstock and product pricing, refining configuration and performance, based on the Wood Mackenzie asset by asset models.

The NCM for each refining region under the Wood Mackenzie 2012 view for the BPS was assessed at an asset by asset level and aggregated. The figure below shows the results of this modelling process.

Figure 34: Global aggregate NCM (2012 BPS basis)

The basic Dutch competitive position is relatively strong



Source: Wood Mackenzie

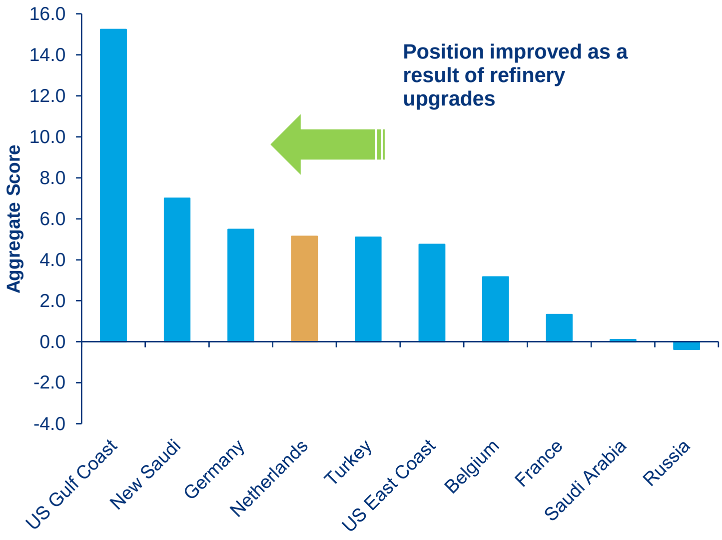
Under the 2012 BPS, the Dutch sector is anticipated to have a net cash margin performance of around 3.6 USD/bbl. The Dutch sector holds a relatively strong competitive position as a result of its location within the key hub location, the large scale of refineries and the relatively high complexity of refining assets compared to its European peer group. The Dutch sector is typically one of the strongest performers within the EU and currently outperforms a number of its regional peers. German refineries typically experience a higher level of performance due to their increased refinery complexity, while Turkish refineries typically see high performance due to the larger product deficits in the region supporting stronger domestic prices.

The Dutch sector is currently less competitive compared to the US Gulf Coast refining region due to the low feedstock and energy costs currently being experienced as a result of the recent tight oil boom. Other global regions such as Russia and Saudi Arabia typically have a lower aggregate NCM than the Dutch sector, but still form a potential competitive threat as a result of local crude and energy price advantages or favourable export tax regimes.

The changing global price environment and the large number of investments in the different global regions were modelled under the 2020 BPS in order to obtain a view of future refinery sector competitiveness. The chart below indicates the aggregated result of these effects.

Intended investments under the BPS increases the competitive position of the Dutch sector

Figure 35: Global aggregate NCM (2020 BPS basis)



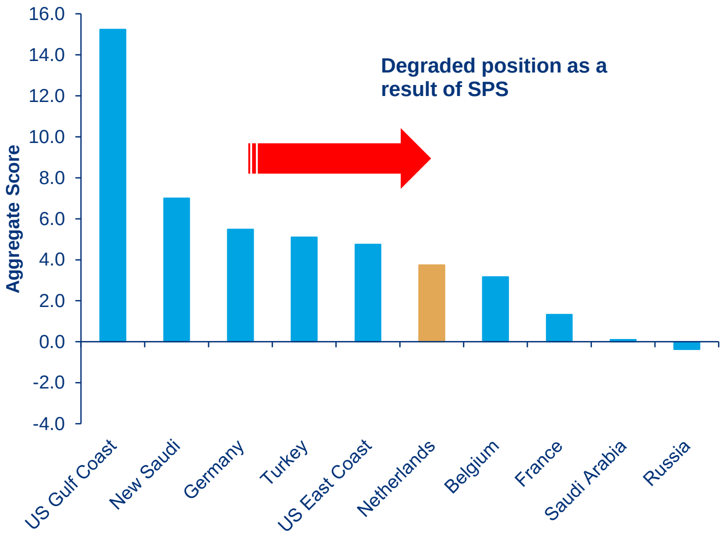
Source: Wood Mackenzie

Under the 2020 BPS, the Dutch sector's aggregate net cash margin is expected to reach 3.9 USD/bbl. A number of other regions also benefit from the improving environment, most notably the US Gulf Coast region, as tight oil developments continue to bring further advantages to the region. A number of new large and highly complex export oriented refineries are currently under construction within Saudi Arabia, and for this reason they have been treated separately in this analysis due to their ability to compete directly with the EU refining regions. A large number of refinery upgrades within Russia will also have a significant impact on the region's performance and ability to compete to supply products into the European market, although many of these assets are not strong performers without the advantages of favourable tax regimes. All known refinery new builds and upgrade investments which have been assessed to be likely to occur have been included in the aggregated results, though recently announced investments in Belgian refineries have not been incorporated in these assessments.

By applying the impact of the SPS to the Dutch sector only, the overall change in the industry's competitiveness can be investigated. The chart below shows the outcome of this assessment.

Figure 36: Global aggregate NCM (SPS 2020 basis)

…but position as a result of SPS degrades



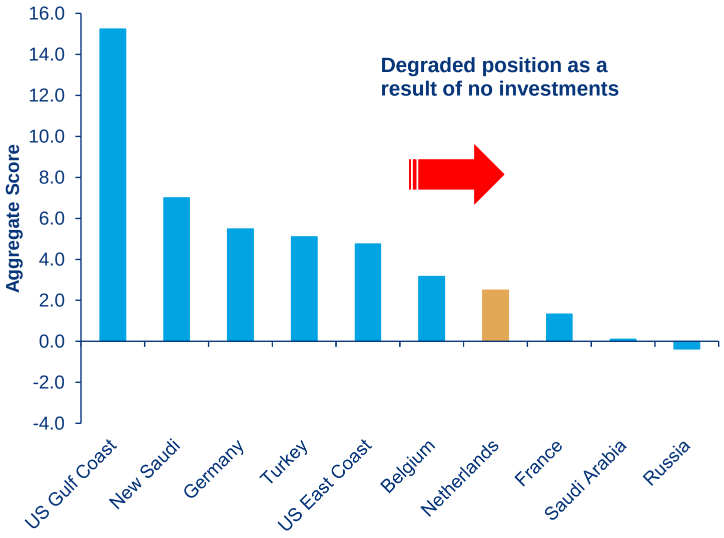
Source: Wood Mackenzie

The impact of the SPS cost burden reduces the competitiveness of the Dutch sector compared to its peers in 2020, with aggregated net cash margins reducing to around 3.8 USD/bbl. This has a marked impact on the overall competitiveness of the sector, placing it below both Turkey and the US East Coast. It is important to note that the sector maintains only a slight advantage over a number of its other European peers.

The high capital cost burden of the SPS may impact the Dutch sector's ability to fund the number of margin improvements or upgrading projects identified by the individual refineries. As such, the competitiveness of the Dutch sector was also evaluated under the 2020 SPS without including the impact of any improvement projects on aggregated Dutch sector performance.

Figure 37: Global aggregate NCM (SPS 2020 basis with no refinery upgrades)

If future investments fail, the competitive position of the Dutch refining sector degrades further



Source: Wood Mackenzie

Without the margin improvement from the identified upgrading projects, Dutch refining competitiveness is further reduced, and margins are reduced to less sustainable levels. It is important to note that without sufficient improvement projects, a refinery's performance will generally decline over time and its competitive position will erode. New refineries are typically highly complex and competitive, while those which close are typically less complex or experience prolonged periods of unsustainably low margins. As this occurs, existing refineries which maintain a static performance will typically see a gradual reduction in their competitive position in the face of the increasingly higher performing new competition.

5.4 Conclusions

The impact of the stringent interpretation of environmental legislation described under the SPS will have a marked impact on the competitiveness of the Dutch refining sector. The additional cost burden will result in a potential reduction in aggregated refining gross and net margins, and a reduced 'added value' contribution to the Netherlands from its refining industry.

The additional capital cost burden may reduce the ability of the sector to access funds to implement a number of planned upgrading projects which could add additional value to the sector. Under a low refining margin outlook the aggregated position of the sector could reach unsustainable levels when hit with the additional cost burden of the SPS, further risking refinery throughput utilisation or refinery closure within the sector.

The Dutch sector is currently one of the stronger performers within North West Europe as a result of the scale, complexity and integration of its refining sector. However a number of highly performing non-EU competitors have emerged from which the Dutch refining sector will face strong competition:

- The US Gulf Coast as a result of highly advantaged crude and energy costs.
- New Middle East refineries as a result of their large scale, high complexity and crude price advantage.
- Upgraded Russian refineries which will continue to increase the volume of high quality product being supplied into the EU. Refineries in the region also significantly benefit from an advantageous crude and product tax regime.

The Dutch sector is expected to be threatened by these refining regions under both a basic and stringent interpretation of legislation. The challenge to the Dutch sector is to remain competitive amongst the regional European competing refiners as it is expected that a further volume of refining capacity will need to be closed within Europe over the next five years. The results of the SPS will have a detrimental impact on the Dutch refining industry's competitiveness compared to its neighbouring competitors (Germany, Belgium and France), and will reduce the margins attainable for the refineries operating in the Netherlands. This may ultimately reduce the attractiveness of operating or investing within the Dutch sector and could potentially result in this already challenged Dutch industry facing further loss of competitiveness and an increased risk of refinery closure.

6

Conclusions

The Dutch refining sector is under pressure by demand shortfalls and increasing competitive pressure from abroad. In addition to these developments, the Dutch refining sector fears the implementation of stringent environmental measures and their impact on the economics of the Dutch refining sector. In this study, the potential costs of these stringent measures and their impact on the competitive position of the Dutch refining sector have been assessed using scenario analysis.

The Dutch sector is currently one of the stronger performers within North West Europe as a result of the scale, complexity and integration of the refining sector. The Dutch sector is expected to be threatened by emerging competing refining regions, such as the USA, Middle East and FSU, under both the Basic Plant Scenario, which is the reference scenario, and the Stringent Plant Scenario, which includes the implementation of stringent environmental measures. The challenge to the Dutch sector is to remain competitive amongst its neighbouring competitors, in particular Germany, Belgium and France.

The Dutch refining sector is currently a front runner with respect to environmental performance, together with countries such as Belgium and the USA. The emission levels in Germany and France are declining, but are higher compared to levels in the Netherlands. Emission limit values in competing countries outside Europe and the USA are more lenient in general.

Despite the environmental performance of the Netherlands, stringent environmental measures have been identified which will result in deep emission reductions. Analysis shows that a decrease of 50%-75% is expected up until 2025 as compared to 2012 for all relevant pollutants, namely NO_x, SO_2, NMVOC and dust. SO_2 shows the largest decrease of up to 75%. Part of these reductions must however be attributed to reduced utilisation.

The assessed cost burden broadly consists of two categories; the costs incurred in meeting the required environmental measures, and those incurred in providing major hazard measures. The full cost burden will have a marked impact on the competitiveness of the Dutch refining sector. The additional cost burden will result in a potential reduction of aggregated refining gross and net margins, and a reduced 'added value' contribution to the Netherlands from the industry of approximately EUR 400 million/year compared to the 2012 position. This may ultimately reduce the attractiveness of operating or investing within the sector and may increase the risk of refinery closure.

Abbreviations

APX	Amsterdam Power Exchange, former spot market for gas
Asia Pac	Region of Asia bordering the Pacific
BAT	Best available techniques
BEES A	Besluit Emissie Eisen Stookinstallaties A *(Dutch decree which regulates emission limits for combustion installations)*
BREF	Reference document for best available techniques
BPS	Basic Plant Scenario
CBS	Dutch statistical bureau
CCS	Carbon capture and storage
CDM	Clean development mechanism
CDU	Crude distillation unit
CEE	Central Eastern Europe
COVA	Centraal Orgaan Voorraadvorming Aardolieproducten (Netherlands Petroleum Stockpiling Agency
CPCB	Central Pollution Control Board
CRF	Common reporting format
DCMR	Milieudienst Rijnmond *(competent authority for the harbour of Rotterdam)*
EBITDA	Earnings before interest, tax, depreciation, and amortisation
ECA	Emission control area
EEA	European Environment Agency
EED	Energy Efficiency Directive
EIA	US Energy Information Administration
EMEP	European Monitoring and Evaluation Programme
EPA	Environmental Protection Agency
ESC	Energy Study Centre of the Netherlands
ETS	Emissions trading scheme
FCCUs	Fluidised catalytic cracking units
FQD	Fuel Quality Directive
FSU	Former Soviet Union countries
GAMS	Software modelling language
GVA	Gross value added
HSFO	High sulphur fuel oil

IEA	International Energy Agency
IED	Industrial Emissions Directive
ILUC	Indirect land use change
IMO	International Maritime Organisation
IPIC	International Petroleum Investment Company
KNPC	Kuwait National Petroleum Company
LNG	Liquefied natural gas
LP	Linear programming
LSFO	Low sulphur fuel oil
LRTAP	Long-range transboundary air pollution
MARPOL	International Convention for the Prevention of Pollution from Ships
Mb/d	Million barrels per day
MDEA	Methyl diethanolamine
Med	Mediterranean
MEE	Meerjarenafspraak energie-efficiëntie (long-term agreement for energy efficiency)
MEPC	Marine Environment Protection Committee
MGO	Marine Gas Oil
MJA	Meerjarenafspraak (long-term agreement for energy efficiency)
MMcf	Unit of volume, i.e. x 1,000,000 cubic feet
MVP	Minimalisatie-verplichte stof (pollutants for which there is a requirement for minimisation in force)
NCM	Net cash margin
NEa	Nederlandse Emissieautoriteit (Dutch Emission Authority)
NEC	National emission ceilings
NEOMS	National Energy Outlook Modelling System
NREAP	National Renewable Energy Action Plan
NWE	North West Europe
OECD	Organisation for Economic Cooperation and Development
OMS	Odour management system
PBL	Planbureau voor Leefomgeving (Netherlands Environmental Assessment Agency)
PGS	Publicatiereeks Gevaarlijke Stoffen (Hazardous Substances Publication Series)
NMVOC	Non-methane volatile organic compounds
RED	Renewable Energy Directive
REM	Refining evaluation models
RUD	Regionale Uitvoeringsdienst (i.e. a competent authority)
RVO	Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency)
SECA	Sulphur emission control area
SER	Sociaal-Economische Raad
SERUM	Static ESC Refinery Utility Model
SPS	Stringent Plant Scenario
SRU	Sulphur recovery unit
SUS	Sustained Utilisation Scenario
TTF	Title Transfer Facility, a virtual trading point for natural gas in the Netherlands
ULSD	Ultra low sulphur diesel

UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework – Convention on Climate Change
USGC	US Gulf Coast
VPAC	Instrument which measures valve leakage based on acoustic measurements
VOC	Volatile organic compounds
VRU	Vapour recovery unit
WTI	West Texas Intermediate
Wva	Wet Voorraadvorming Aardolieproducten (legislation for oil stockpiling in the Netherlands)

References

Avis, M.J., C.H. Birch (2009): *The impact on the EU refining industry & market of IMO specification changes & other measures to reduce the sulphur content of certain fuels*, Purvin & Gertz, London.

BImSchV (2013): *Dreizehnte Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung über Großfeuerungs-, Gasturbinen- und Verbrennungsmotoranlagen - 13. BImSchV)*. Ausfertigungsdatum: 02.05.2013.

BPO (2012): 'Implications of new regulation regarding sulphur content in ship's fuel on maritime transport sector within Baltic Sea Region.' *The TransBaltic and Baltic Ports Organisation's Port debate: Implications of the IMO regulations on the future pattern of the cargo flow in the Baltic*, June 15, 2012, Helsinki, Finland.

COM (2012) 595 final: *Proposal for a Directive of the European Parliament and of the amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources*. European Commission, October 17, 2012. (http://ec.europa.eu/clima/policies/transport/fuel/docs/com_2012_595_en.pdf).

CONCAWE (2011): *Cost effectiveness of emissions abatement options in European refineries. Report no 6/11*. CONCAWE, Brussels.

COVA (2014): *Website of Centraal Orgaan Voorraadvorming Aardolieproducten.* http://www.cova.nl (last visited January 2014).

Daniëls, B.W., J. Gerdes, P.G.M. Boonekamp, P. Kroon, K. Stutvoet-Mulder, C. Tigchelaar, W. Wetzels (2013): *Energie Efficiency Directive Artikel 7. Nederlandse invulling.* ECN-E--13-061, ECN, Petten, December 2013.

Donald, R. (2014): *Carbon briefing: Who killed the EU's transport fuel standards?* Internet blog: 30 Jan 2014. http://www.carbonbrief.org/blog/2014/01/who-killed-the-fuel-quality-directive/.

Draft BREF (2013): *Best Available Techniques (BAT) Reference Document for the Refining of Mineral Oil and Gas.* Final draft, July 2013. Online available via: http://eippcb.jrc.ec.europa.eu/reference/ (under the name *Refining of Mineral Oil and Gas*, last visited August 2014).

Dril, T. van (2012): *Financial effects of ETS set aside*. ECN Policy Studies' note: ECN-N--12-019 (project number 6.00637), ECN, Petten, 26 November 2012.

EC (2012): *Commission Staff Working Document Information provided on the functioning of the EU Emissions Trading System, the volumes of greenhouse gas emission allowances auctioned and freely allocated and the impact on the surplus of allowances in the period up to 2020.* SWD(2012) 234 final, European Commission, Brussels, 25 July 2012.

EU (2012): *Directive 2012/33/EU of the European Parliament and the Council of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels*. Official Journal of the European Union L 327/1, 27.11.2012.

EU (2013a): *Proposal for a directive 2012/33/EU of the European Parliament and the Council on the deployment of alternative fuels infrastructure*. COM(2013) 18 final, European Commission, Brussels, 24 January 2013.

EU (2013b): *Report from the Commission to the European Parliament and the Council; Report from the Commission on the reviews undertaken under Article 30(9) and Article 73 of Directive 2010/75/EU on industrial emissions addressing emissions from intensive livestock rearing and combustion plants*. COM (2013) 286 final, European Commission, Brussels, 17 May 2013.

EU (2013d): *Proposal for a Directive of the European Parliament and the Council on the reduction of national emissions of certain atmospheric pollutants and amending Directive 2003/35/EC*. COM(2013) 920 final, European Commission Brussels, 18 December 2013.

EU (2014a): *Communication from the Commission to the European Parliament and the Council the European Economic and Social Committee and the Committee of the Regions; A policy framework for climate and energy in the period from 2020 to 2030*. COM (2014) 15 final, European Commission, Brussels, 22 January 2014.

EU (2014b): *Commission Staff Working Document. Impact Assessment accompanying the Communication A policy framework for climate and energy in the period from 2020 up to 2030*. Draft version, European Commission, Brussels, 22 January 2014.

EU (2014c): *2030 climate and energy goals for a competitive, secure and low-carbon EU economy European Commission*. IP/14/54, press release, European Commission, Brussels, 22 January 2014.

EU (2014d): *Energy Efficiency Directive, additional information and Directive 2012/27/EU*. Information via EC's website, http://ec.europa.eu/energy/efficiency/eed/eed_en.htm (last visited February 2014).

FQD (2009): *DIRECTIVE 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC*. European Commission, Brussels, 5 June 2009. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0088:0113:EN:PDF) .

Gary, James H, Glenn E. Handwerk, Mark J. Kaiser (2007): *Petroleum refining, technology and economics.* CRC Press, London, 5th edition.

Handbook of Refining Processes (2011): *Hydrocarbon processing 2011 refining processes handbook.* Hydrocarbon Processing.

IEA (2014): *Closing oil stock levels in days of net imports.* http://www.iea.org/netimports.asp (last visited January, 2014).

IED (2010): *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).* Official Journal of the European Union, L 334/17, 17 December 2010.

IMO (2014): *Sulphur oxides (SOx) – Regulation 14*. http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx (last visited 15 January 2014).

Kok I.C., P. Kroon (1997): *Raffinagemodel SERUM in hoofdlijnen*. ECN-C--96-066, ECN, Petten.

Lloyd's (2012): *LNG-fuelled deep sea shipping. The outlook for LNG bunker and LNG-fuelled newbuild demand up to 2025*. Lloyd's Register Group Limited, London. http://www.lr.org/Images/LR%20bunkering%20study_Final%20for%20web_tcm155-243482.pdf (last visited DATE).

Lloyd's (2013): *Owners opt for scrubbers as SOx emissions deadlines loom*. Lloyd's. http://www.lloydslist.com/ll/sector/ship-operations/article425383.ece (last visited DATE).

MEFN 2008: *Environmental (protection) Amendment Rules 2008*, The Gazette of India: Extraordinary, New Delhi 18 March 2008. http://cpcb.nic.in/Industry-Specific-Standards/NewItem_48_notification.pdf (last visited DATE).

NEa (2014): *Bijlage 1 van het nationaal toewijzingsbesluit broeikasgasemissierechten 2013-2020 kenmerk IENM/BSK-2013/226553*. www.emissieautoriteit.nl (last visited August 2014).

Nielsen, C.K., C. Schack (2012): 'Green ship of the future. Vessel emission study: Comparison of various abatement technologies to meet emission levels for SECA.' Presentation from *9th Annual Green Ship Technology Conference*, Copenhagen, 2012.

NREAP (2010): *National renewable energy action plan (NL); Directive 2009/28/EC*. http://ec.europa.eu/energy/renewables/action_plan_en.htm (last visited DATE).

Oostvoorn F. van, P. Kroon, A.V.M. de Lange (1989): *SERUM: Een model van de Nederlandse raffinage-industrie*. ESC-49, ECN, Petten, October 1989.

PennEnergy (2014): *Worldwide refinery survey and complexity analysis*. http://ogjresearch.stores.yahoo.net/worldwide-refinery-survey-and-complexity-analysis.html (last visited September 2014).

RED (2009): *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. European Commission, Brussels, 5 June 2009. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF (last visited DATE).

Smeets, W.L.M., R.M.M. van den Brink, H.E. Elzenga, A. Gijsen, K.W. van der Hoek, D.S. Nijdam, W. Weltevrede (2004): *Potentieel effect op emissies van* SO_2, NO_x, NH_3, *NMVOS en PM10 en kosten van door VROM aangedragen beleidsopties*. RIVM Rapport 725501008/2004, RIVM, Bilthoven.

Smeets, W. (2014): Personal communication on work in progress, Netherlands Environmental Assessment Agency (PBL), Den Haag/Bilthoven, 13 January 2014.

Stienstra, G.J. (2007): *Documentation of the Dutch refinery model SERUM.* ECN-E--06-029, ECN Policy Studies, Petten, 4 January 2007.

TA Luft (2002): *Erste Allgemeine Verwaltungsvorschrift zum Bundes Immissionsschutzgesetz (Technische Anleitung zur Reinhaltung der Luft – TA Luft) vom 24. Juli 2002.* Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit. http://www.umweltbundesamt.de/ (last visited August 2014).

Taneco (2014): *Information from the website.* http://www.taneco.ru/en/ (last visited August 2014).

VLAREM (2014): *VLAREM II; Besluit van de Vlaamse regering van 1 juni 1995 houdende* *algemene en sectorale bepalingen inzake milieuhygiëne, Afdeling 5.20.2. Petroleumraffinaderijen.* http://navigator.emis.vito.be/milnav-consult/faces/consultatie (last visited August 2014).

de Wilde, H.P.J., P. Kroon (2011): *Timing of technology roll-out for climate targets in transport*. ECN-E--11-055, ECN, Petten, September 2011.

Wilde, H.P.J.; H.M. Londo; S.M. Lensink; L.W.M. Beurskens; P. Kroon (2013): *Effecten van het Europese wijzigingsvoorstel inzet biobrandstoffen voor hernieuwbare energie in transport.* ECN Policy Studies' note: ECN-N--13-032, ECN, Petten, 15 August 2013.

Worldwide Refining Survey (2014): *2014 Worldwide Refining Survey*. Editor Leena Koottungal, figures as of January 1, 2014. Overviews available via Oil & Gas Journal.

Wva (2012): *Wet voorraadvorming aardolieproducten 2012, Memorie van Toelichting*. Kamerstuk 33 357, nr 3 van de Tweede Kamer der Staten-Generaal. Available via https://zoek.officielebekendmakingen.nl.

Appendix A. Legislation

A.1. Global legislation

A.1.1 IMO Marpol

In October 2008 the International Maritime Organisation (IMO) adopted amendments to Annex VI of the MARPOL Convention. New sulphur limits for ship fuels (bunker fuels) have been introduced and will enter into force in various future years (see **Table 8**). This legislation distinguishes emission control areas (ECA) and non-ECA. ECA areas for SO_2 (called SECA) are the Baltic Sea area, the North Sea area, the North American area and since January 1, 2014 the United States Caribbean Sea area. This means that in the USA and in North West Europe a certain amount of bunker fuel for ships will have a maximum mass fraction of sulphur of 0.1% in 2015[1]. It will be unprofitable for refineries in this region if these refineries cannot produce this fuel and need to export additional bunker fuel with a higher sulphur content outside the ECA.

The entry date of 2020 for the worldwide maximum sulphur concentration of 0.5% is not final yet. Depending on the outcome of a review, to be concluded in 2018, as to the availability of the required fuel oil, the entry date may be postponed to January 1, 2025. The year 2020 was chosen to enable refineries to design and implement installations to produce low sulphur bunker fuel or gasoil instead of high sulphur bunker fuel. The EU has already decided that the 0.5% limit will be introduced in the EU in 2020 (EU, 2012).

Table 8: IMO sulphur limits for 2008

Outside an ECA	Inside an ECA
4.5% prior to 1 January 2012	1.5% prior to 1 July 2010
3.5% after 1 January 2012	1.0% after 1 July 2010
0.5% after 1 January 2020	0.1% after 1 January 2015

The main option for shipowners is to purchase low sulphur fuel, although there are several other options to comply with the 2015 and 2020 sulphur restrictions:

- Change of fuel type to low sulphur content. Currently, LNG in ships gets major attention (BPO, 2012).
- Removal of SO_2 emissions[2]. From the IMO site: 'In terms of secondary control methods, guidelines (MEPC.184 (59)) have been adopted for exhaust gas cleaning systems which operate by water washing the exhaust gas stream prior to discharge to the atmosphere, in using such arrangements there would be no constraint on the

---

[1] Since 1 January 2010, the maximum sulphur content for ships at berth in all EC ports was already 0.1% (Directive 2005/33/EC of the European Parliament and the council).

[2] IMO also mentions the option to buy high sulphur fuels, but takes primary measures which avoid the formation of SO_2 emissions. There are no commercially available examples of this kind of measure.

sulphur content of the fuel oils as bunkered other than that given the system's certification' (IMO, 2014).

So the implementation of the IMO regulation could lead to:

- Additional investments in refineries before 2020 and/or before 2025 to produce less high sulphur bunker fuel and/or more low sulphur bunker fuel.
- A lower demand for bunker fuel due to the growing use of LNG, and refinery investments to produce less bunker fuel[3].
- A growing number of ships with flue gas desulphurisation, which could still use the high sulphur bunker fuel.

Currently, all three developments can be observed in practice.

In 2009, Purvin & Gertz estimated that bunker fuel costs could increase by 60%-70% for SECA quality and 30%-50% for non-SECA quality (Avis, 2009). They also concluded that EU refineries were unlikely to invest prior to 2015 to achieve the new quality due to current low refinery profitability and uncertainty regarding the uptake of ship-stack gas scrubbing. The main options described in the Purvin & Gertz report to meet the IMO specifications by refinery measures are atmospheric residue desulphurisation, delayed coking and hydrocracking.

LNG

A study by Lloyd's calculated the potential effect of LNG ships on the bunker fuel market in relation to the IMO limits (Lloyd's, 2012). First they concluded that heavy fuel oils with a high sulphur content accounted for 76% of the bunker fuel market in 2010. Lloyd's also developed various scenarios. In the high LNG case Scenario, 8% of the global bunker fuel consumption is substituted by LNG in 2025 (and about 0.6% in 2020). In this scenario, 1963 LNG-fuelled new vessels were forecasted for the period up to 2025 (12.6% of global deliveries from 2012 to 2025). They also asked shipowners about their intentions to mitigate SO_x emissions. A substantial number (about 60%) answered that they did not know yet. In the short term, about 25% of the shipowners who answered the questions intended to use scrubbers and 75% MGO (marine gas oil). In the long term, the percentage of MGO declines substantially in favour of the use of LNG or LNG dual fuel. This study used MGO as a reference and no desulphurised bunker oil, which might be a shortcoming for a robust analysis of this subject.

For LNG the infrastructure availability is of major importance. In order to stimulate the use of LNG, the EU has started with LNG infrastructure (EU, 2013a). The proposal for the deployment of alternative fuels infrastructure states: 'Member States shall ensure that publicly accessible LNG refueling points for maritime and inland waterway transport are provided in all maritime ports of the Trans-European Transport (TEN-T) Core Network by 31 December 2020 at the latest'.

It is important that new emission limits are also introduced with respect to the NO_x emissions of ships. These limits may favor the use of LNG or dual fuel LNG, with a small

---

[3] There are also reports which calculate a small increase in land-based transport due to the increased cost of transport by sea due to the cost of the implementation of the IMO Annex (more diesel demand and less bunker fuel demand). A discussion of the 2015 ECA limit in the Baltic sea mentions a shift in volume from 2 to 30% depending on the study, the route and the price of the 0.1% sulphur fuels (BPO, 2012).

amount of diesel oil. The most stringent one, Tier III, will apply to new ships constructed from 1 January 2016 onwards and sailing in a designated NO_x ECA (at this moment only the two USA ECAs). New ships sailing on heavy or diesel oil have to use flue gas cleaning such as SCR (selective catalytic reduction) to fulfil the Tier III requirements in these areas.

Future developments will mainly depend on price developments for the relevant fuels. In the period 2012-2013, LNG was 20-40% cheaper than MGO and was in the same price range as heavy fuel oil.

Scrubbers
Where LNG technology mainly focuses on new ships, scrubbers might also be used on existing ships. Potential market penetration may go substantially faster, although standstill of vessels for scrubber installation is expensive. In June 2013, less than 40 ships were either on order or retrofitted with scrubber systems (Lloyd's, 2013). Compared to LNG, the business case for scrubbers is more straightforward. From 2015 onwards, the 0.1% sulphur regulation will enter into force and scrubbers are of interest for ships sailing mainly in a SECA (Nielsen, 2012). The driving force is the clear price differential of MGO with 0.1% S and bunker fuel with ±2.5% S[4] (HSFO).

The use of scrubbers might penetrate faster in the European area before 2020, since the European Union has already set the 0.5% sulphur limit in a European directive for the European continental shelf in 2020 irrespective of the final IMO decision on the worldwide limit. The driving forces observed here are both MGO versus HSFO (high sulphur fuel oil) in the SECAs as well as 0.5% LSFO (low sulphur fuel oil) versus HSFO[5] in the remaining part of the European continental shelf.

A.2. European and Dutch legislation

A.2.1 Industrial Emissions Directive (IED)

The Industrial Emissions Directive 2010/75/EU (IED, 2010) is designed to bring several separate EU directives on industrial emissions under one directive. The IED entered into force on 14 December 2010. The old limits are valid for all permits which were granted before 7 January 2013 or were in use before 7 January 2014.

The IED does not apply to the following combustion plants:
- Combustion plants with a total rated thermal input lower than 50 MW.
- Facilities for the regeneration of catalytic cracking catalysts.
- Facilities for the conversion of hydrogen sulphide into sulphur.

---

[4] To use 2.5% S after 2015 in a SECA area, the scrubber efficiency has to be above 96%. Wash water containing NaOH increases scrubber efficiencies by up to 98% and enables the use of up to 3.5% sulphur fuel.

[5] For the use of 2.5% S HSFO on locations where only 0.5% S LSFO is allowed, a scrubber removal efficiency of 80% is needed.

A simplified overview of the emission limit values can be found in **Table 9**, showing the different values for existing and new installations. The majority of emission limit values for gaseous and liquid fuels are given at dry conditions (273.15 K, 101.3 kPa) and 3% O_2. The figures for gas turbines and gas engines are at 15% O_2.

Governments have to make a plan for when those installations with a permit from before 27 November 2002 will meet the limits in the transition period from 1 January 2016 to 30 June 2020. They are allowed to make exceptions for installations with a limited lifetime.

The IED limits mentioned are not the only limits for combustion plants. The IED also includes the old IPPC directive, so permit conditions should also be set on the basis of the best available techniques (BAT). The Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries is discussed later on in this chapter.

The emission limits of the IED are clear and should be used in the permits for all countries in the European Union. Countries outside the EU can have other limits. The BAT interpretation can differ between countries. Local circumstances (air quality, proximity to protected nature) and expected life time of the refinery (renewal plans) can also influence the limit values.

Table 9: Emission limits in the IED (simplified)

In mg/Nm^3		Permit before Jan. 2013 / Permit after Jan. 2013		
	% O_2	SO_2	NO_x	PM10
Liquid fuels 50-100 MW	3	350 / 350	450 / 300	30 / 20
Liquid fuels >100-300 MW	3	250 /200	200 / 150	25 / 20
Natural gas	3	35 / 35	100 / 100	5 / 5
Gas with low calorific gases from gasification of refinery residues.	3	35 / 35	200 / 100	5 / 5
Other gas	3	35 / 3 5	200 / 100	5 / 5
Gas turbines natural gas	15		5-0 / 50	
Gas turbines other gas	15		120 / 50	
Gas engines	15		100 / 75	

There are some exceptions that should be mentioned:

- For existing installations using liquid fuels and a permit from before 27 November 2003 with less than 1500 hours per year, the following SO_2 limit may be applied: a five year mean value of maximum 850 mg SO_2/Nm^3 at <200 MW and 400 mg SO_2/Nm^3 at > 300 MW.
- Instead of 35 mg SO_2/Nm^3 for gases, combustion plants firing low calorific gases from gasification of refinery residues, which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003, shall be subject to an emission limit value for SO_2 of 800 mg/Nm^3.
- In the case of multi-fuel firing combustion plants, which use the distillation and conversion residues from the refining of crude oil for their own consumption, an

average emission limit value for SO_2 might be applied. For combustion plants which were granted a permit before 27 November 2002 or the operators of which had submitted a complete application for a permit before that date, provided that the plant was put into operation no later than 27 November 2003: 1,000 mg/Nm^3 and for other combustion plants: 600 mg/Nm^3.

In 2013, the commission evaluated some articles of the IED, including refinery combustion plants and lowering the limits below 50 MW (EU, 2013b). It concluded:

- 'For the combustion of fuels in plants with a rated thermal input less than 50 MW, a clear potential for cost-effective abatement of air emissions was demonstrated and in a next step options for potential regulatory action will be further assessed in an impact assessment, which will support the on-going review of the Thematic Strategy on Air Pollution.
- For the large combustion plants listed in Article 30(9) of the IED, the Commission considers that there is no need to amend existing or establish new EU-wide emission limit values at this stage, given that the relevant BAT conclusions will continue to be published and incorporated into the operating permits of installations as these are progressively updated'.

Reference document on Best Available Technologies (BREF)

BREF documents are composed as a result of the former IPPC directive, currently the IED. They are composed per industrial sector and assess various technologies for relevant processes in the sector. For the mineral oil refineries sector, a BREF dated 2003is available and there is currently a revision under way. A draft BREF was published in 2013 (Draft BREF, 2013), but the final BAT conclusions are not yet complete.

In general, BAT conclusions are set as a range, which results inevitably in there being a strict and lenient side for prescribed emission limit values. Member states may enforce various limit values at this point. Another important issue is the so-called bubble approach, by which an entire site's emissions are regarded as originating from one source, which needs to comply with a single emission limit value. Via this approach, refineries may choose the most cost-effective abatement techniques on installations of their own choice to meet the emission limit value. Currently, this bubble approach and the definition of included installations are also under revision for the BREF. Final decisions have not yet been made. The Dutch refining sector takes advantage of the current bubble approach in the Netherlands.

A.2.2 National Emission Ceilings (NEC) Directive

In December 2013, the European Commission published a proposal for new National Emission Ceilings for SO_2, NO_x, NMVOC, NH_3, $PM_{2.5}$ and CH_4 for the years 2020 and 2030 (EU, 2013d). The ceilings are formulated in reduction percentages compared to the emissions in 2005 for the years 2020 and 2030 (see **Table 10**). A final decision in the European Parliament is not expected before the end of 2014.

Table 10: Proposed emission reductions in the EU 28 compared to 2005

	SO_2	NO_x	NMVOC	$PM_{2.5}$	NH_3	CH_4
Netherlands						
2020	28%	45%	8%	37%	13%	-
2030	59%	68%	34%	38%	25%	33%
Europe 28						
2020	59%	42%	28%	22%	6%	-
2033	81%	69%	50%	51%	27%	33%

Based on the reduction percentages for 2020 and 2030, PBL made a figure of the expected emissions in 2025 based on current policy scenarios, versus the ceiling in a pathway towards 2030 (see **Table 11**) (Smeets, 2014). The table shows also the additional reduction which is needed, with a range based on uncertainties in future scenarios. The scenario emissions include the emission limits for cars (euro 6) and trucks (euro VI) and the expected effect of those limits. It has not yet been decided in which sectors additional reductions have to take place. Based on emissions and cost effectiveness analyses, the refining sector might be in charge of the SO_2 reduction and a small part of the NO_x reduction, while $PM_{2.5}$ reduction may potentially also become relevant. NMVOC reductions remain unclear because the cost effectiveness analyses does not include all of the necessary options.

Table 11: Reduction versus current expectation in the Netherlands (2025 estimate)

[kton/y]	Expected emission current policy	Ceiling	Additional reduction needed
SO_2	34	30	4 (range 2 - 6)
NO_x	167	144	24 (range 9 - 41)
NMVOC	154	131	23 (range 11 - 41)
$PM_{2.5}$	11.3	11.7	0 (range (0 - 0.5)
NH_3	113	109	4 (range 0 - 7)

It can be concluded that a stringent scenario contains additional measures for SO_2 and NO_x reduction.

A.2.3 Renewable Energy Directive (RED)

In 2009 the European Commission set a renewable energy target of 20% in 2020. Part of this directive is a 10% biofuel target for transport fuels in 2020; the earlier target for 2010 was 5.75%. Hydrogen and electric cars may also contribute to this target. If the mean CO_2 reduction by using biofuels for transport is 60%, a 10% penetration would lead to a 6% reduction in greenhouse gas intensity for transport fuels, which would perfectly fit with the 6% reduction target of the FQD (see also Paragraph A.2.4). The share of renewables in transport had already risen to 4.7% in 2010 from 1.2% in 2005 (EU, 2014a). The 2012 figure is about 5%, which means that the growth rate declined after 2010.

On 17 October 2012, the European Commission published a proposal (COM (2012) 595 final) to amend the Renewable Energy Directive, RED (RED, 2009) and the Fuel Quality Directive, FQD (FQD, 2009).

The European Commission proposes to adjust the target for renewable energy in the transport sector by distinguishing three types of biofuels:

- Conventional biofuels made from food crops. These are allowed to count for up to five percentage points towards the target of 10% renewable energy in the transport sector in 2020.
- Advanced biofuels, which do not result in additional demand for land. Based on the types of raw materials for these biofuels, this group is broken down into:
  2a) biofuels that count twice for the target,
  2b) biofuels that count four times for the target.

The main changes in this proposal, compared to the original directive, are the capping at 5% of conventional biofuels from food crops, and the introduction of a group of biofuels that count four times. In the original directive all advanced biofuels counted twice.

Implementing the European Commission's amendments will result in a shift in the mix of energy sources needed to achieve the 10% target for renewable energy in the transport sector. Due to the 5% ceiling for the use of conventional biofuels from food crops, advanced biofuels will be deployed to go beyond the 5% ceiling, in line with outlooks of the Dutch National Renewable Energy Action Plan (NREAP, 2010)[6].

The total fuel consumption for transport in 2020, based on the calculation methodology used in the Renewable Energy Directive, amounts to around 445 PJ in the Netherlands. Therefore, the target of 10% renewable energy in transport corresponds to 44.5 PJ, of which, according to the proposed adaptation of the EU Directive, up to half (about 22.2 PJ), can be comprised of conventional biofuels from food crops. In the Action Plan (NREAP, 2010) a contribution of approximately 27 PJ is foreseen. The difference of 4.8 PJ should be made up of advanced biofuels, according to the amendment to RED and FQD.

If 4.8 PJ were to be made up of biofuels that count twice for the transport target, the contribution of biofuels to the target for renewable energy would decrease by 2.4 PJ (4.8 PJ / 2). In the case of those biofuels counting four times for the transport target, the contribution to the renewable energy target would only be 1.2 PJ (4.8 PJ / 4), which means a decrease in the contribution of biofuels of 3.6 PJ. In other words, depending on the degree of supply of those biofuels that count for twice or four times, there would be a deficit of 2.4 to 3.6 PJ compared to the biofuels mix as foreseen in the NREAP.

The use of biofuels that count twice and four times in meeting the renewable energy target makes it difficult to achieve the FQD target regarding a CO_2 chain emission reduction by 6% in 2020, because the fact that the biofuels count twice and four times

---

[6] It is also possible to increase the use of electricity in the transport sector. However, this is not considered here because it is assumed that this would not be a cost efficient approach in the short term.

does not apply to fuel quality. Their use, therefore, would lead to a smaller share of biofuels in the fuel-to-the-pump, and a relatively higher CO_2 chain emission.

The higher CO_2 chain emissions will have to be compensated for by other measures if the 6% limit in the FQD is enforced. This could include improving the energy efficiency of the refining step or reducing gas flaring, but also using more conventional biofuels, above 5%[7]. The relation between the RED and the FQD is rather complex, but as will be concluded in Paragraph A.2.4, the FQD may not be very relevant in the future for various reasons.

The 2030 greenhouse gas policy of the European Commission also mentions sustainable energy. The proposed renewable energy target for 2030 is at least 27% of energy consumption. The Commission anticipates a substantial increase in the percentage of renewable energy in electricity production. Therefore, the establishment of new targets for renewable energy or the greenhouse gas intensity of fuels used in the transport sector or any other sub-sector after 2020 is not regarded as appropriate.

For the blending of biofuels into transport fuels, investments in biofuel storage and blending facilities, including fuel quality control equipment, have been made or need to be made by refineries and oil depots. There might also be some direct refinery effects, because the quality of the fossil-based fuel has to be tuned to the type and amount of biofuels with which it is blended. All oil companies delivering transport fuels to the European market face the same biofuels situation, and the price of European transport fuels will probably compensate for the additional cost. The economic position of refining sectors in various countries is therefore deemed to be equally influenced when supplying the same market.

The RED can have a direct effect on refineries via another route: a higher percentage of biofuels leads to lower demand for the fossil-based part of diesel and gasoline, so the demand for these refinery products will be lower. This is a relevant effect for oil demand scenarios. If a biofuel growth rate of 0.3 percentage points per year (compared to the total gasoline and diesel demand; range 0.15-0.44) is assumed, demand for fossil gasoline and road transport diesel might be 1.5% lower in 2025.

Next to biofuels, hydrogen and electric cars will affect the oil demand[8]. Also the CO_2 limits for passenger cars will affect the oil demand. At the end of 2013 a compromise was reached on the CO_2 emission limit for passenger cars. The limit of 95 g CO_2/km will enter into force in 2021 instead of 2020, which affects the demand for transport fuels by less than 0.5%.

---

[7] The amendment proposes no limit to the amount of conventional biofuels that might count for the FQD target.

[8] To give an idea of the possible size of the effects: in a more ambitious plan than the commission proposed, with 40% CO_2 reduction in transport in 2030 (excluding bunker fuels), the use of hydrogen en and electric cars can lead to a 4% reduction effect on oil demand for transport in 2025. In this scenario also, a higher percentage of biofuels lead to a 5% lower demand (Wilde, 2011). Possible effects in 2020 are much lower.

A.2.4 Fuel Quality Directive

The Fuel Quality Directive (FQD)[9] sets standards for gasoline and diesel quality. In 2009 the FQD was extended with specific articles related to sustainable biofuels and full life-cycle emissions. The directive contains a 10% greenhouse gas reduction target for fuel suppliers, made up of:

- A 6% reduction in the greenhouse gas intensity of fuels by 2020, with intermediate indicative targets of 2% by 2014 and 4% by 2017.
- An additional 2% reduction subject to developments in new technologies such as carbon capture and storage (CCS); and a further 2% reduction to come from the purchase of Clean Development Mechanism (CDM) credits.

The FQD contains a list of standard values for the greenhouse gas emissions of different biofuel sources. For calculating the greenhouse gas reduction of certain biofuels a reference value of 83.8 g CO_{2eq}/MJ gasoline or diesel is defined. In 2010 the Commission proposed to include indirect land use change (ILUC) in the calculation method for biofuels. Despite this, the 2012 proposal COM (2012) 595 final for changing the FQD only contains a reporting article and no new calculation method (COM (2012) 595).

If in 2020 transport fuels were to contain 10% biofuels, the calculation method for the 10% target is clear. The remaining 90% is problematic. In the first reading, the FQD demands an oil track and trace system from the well to the tank. This is almost not feasible, and a better option is to use standard values. But the question arises as to whether there should be one value for crude oil and one for oil from tar sands, or different values depending on the crude type and origin. This issue resulted in a lot of discussion about oil from tar sands, resulting in a potential trade conflict between the EU and Canada, which has a great quantity of tar sand resources. A committee was asked to advise the Commission on this subject, but was not able to deliver positive advice. As a result, the Commission cancelled its proposal and promised an impact assessment in which the competitive position of the European oil industry would also be taken into account. Based on this study the Commission intended to make a new proposal. According to a communication from the Dutch government on 3 October 3 2013, neither has yet been published.

A more recent EU publication states: 'The obligation of the amended Fuel Quality Directive for all fuel suppliers to reduce the life cycle greenhouse gas emissions from their supply of road fuels by 6% in 2020 has proven to be complex to implement but has the benefit that it will apply equally to importers and domestic producers of fuels' (EU, 2014b). Another publication notes: 'But although the directive has existed for nearly five years – and is used to calculate biofuels' overall emissions – it has never been used to regulate fossil fuels. That's because member states can't agree on a methodology for calculating lifecycle emissions' (Donald, 2014).

In COM (2014) 15 in January 2014, the Commission proposed a new policy framework for climate and energy in the period from 2020 to 2030 in the European Union (EU, 2014b). From this communication: 'The Commission does not think it's appropriate to

---

[9] http://ec.europa.eu/clima/policies/transport/fuel/index_en.htm.

establish new targets for renewable energy for the greenhouse gas intensity of fuels used in the transport sector or any other sub-sector after 2020'. Although this is still a proposal and interpretations may differ, it is possible that after 2020 there will be no direct limitation on well-to-wheel greenhouse gas emissions of transport fuels like gasoline and diesel.

The Commission proposes a target of 40% less greenhouse gas emissions in 2030 compared to 1990. This is an intensification of policies, since the current reduction target of 20% in 2020 is expected to lead to 32% reduction in 2030 only. This means that there will probably be other instruments in place after 2020. The Commission mentions the ETS as an instrument and in staff documents the option to incorporate transport into the ETS is discussed, though actual use of this instrument remains uncertain.

It can be concluded that the 6% target of the FQD is probably not very relevant for future scenarios.

A.2.5 EED and national energy efficiency policy instruments

The Energy Efficiency Directive (EED), i.e. Directive 2012/27/EU, was adopted by the European Commission and entered into force on 4 December 2012. Most of its provisions had to be implemented by the Member States by 5 June 2014 (EU, 2014d). Within this directive, article 7 is the one of major relevance in determining the energy efficiency target for each Member State, and it allows some freedom for Member States in the determination of the target. In some other articles, best-effort obligations with respect to energy efficiency are prescribed as well; such obligations are non-binding and do not prescribe any target.

In the Netherlands, a report on article 7 of the EED has been written by the ECN at the request of the Dutch Ministry of Economic Affairs (Daniëls et al., 2013). Based on the choices of the Dutch Ministry of Economic Affairs, the target was calculated and is 482 PJ_{final} total saved energy. This target is determined based on final energy use and not on primary energy use, meaning that the energy used by conversion sectors such as the power plants and oil refineries are excluded from this target definition.

The EED contains many exception rules for the target definition, but it is stressed here that the target definition and the realisation of the target are primarily separate. For the conversion sectors it is of major importance that they are out of the scope for target definition. In addition, the realised savings in the conversion sector, including the refining sector, also do not count for target realisation.

There is a chance that the target for article 7 may not be met with existing policies and additional policies (mainly the Energy Agreement of the SER) (Daniëls et al., 2013).

For some other articles in which best-effort obligations are prescribed, potential consequences for the Dutch refining sector may exist, such as article 14 (Promotion of efficiency in heating and cooling) and article 15 (Energy transformation, transmission and distribution). Residual heat in the refining sector may be the subject of a cost-benefit analysis for district heating, for example.

In the Netherlands, there is a long tradition of Long-Term Agreements (in Dutch abbreviated as MJA) on energy efficiency. These so-called MJA-covenants have evolved over time and currently, ETS companies may sign up to the MEE covenant. The MEE covenant is voluntary in principal and sets a non-binding energy efficiency target for the members. Although guidelines are provided for the energy saving measures, such as a pay-back period of five years, the voluntary character of the covenants is relatively strong.

There are a few advantages for the members. The most important advantages are that no supplementary national policy governing CO_2 reduction or energy conservation will be imposed on these companies and no specific national energy tax will be levied on these companies.

Apart from these covenants, an energy agreement has recently been made in the Netherlands, under the supervision of the SER. All major sectors were represented in this agreement. The SER Energy Agreement is less clear on its additional policies with respect to industrial energy savings. Upon inquiry it seems that so-called one-to-one agreements may be put into place and ultimately result in the implementation of energy saving measures with a pay-back period of up to five years, in line with the Environmental Protection Act. At the moment however, it is concluded that there are no additional stringent policies expected compared to existing policies.

A.2.6 EU ETS 2013-2020

Backloading

The EU ETS has built up a growing surplus of allowances over the last few years. The economic downturn is regarded to have been a major cause of the oversupply and the low CO_2 allowance price. From 2013 onwards, the ETS will enter its third phase in which a substantial portion of the current allowances will be auctioned. In summer 2012, the European Commission proposed a draft Regulation to adjust the timing of auctions of emission allowances (EC, 2012). The Commission states that it is not wise to feed a market that is already oversupplied and wants to auction fewer allowances in the coming years (set aside). These set aside allowances would then be auctioned in the later years of the 2013-2020 ETS period (backloading). The proposal document does not suggest permanent withdrawal of allowances, since this requires amending the ETS Directive. However, permanent withdrawal (cancellation) is certainly considered as an option to reinforce the ETS (Van Dril, 2012).

Table 12 gives an overview of the scenarios and set aside alternatives. An additional 'XL' is included with a total set aside of 2300 Mtonnes. In the baseline scenario, the emissions are based on existing policy instruments. The reference scenario assumes full achievement of the EU 2020 targets for renewables. Renewable power generation will replace fossil fuel based generation more than in the baseline. In **Table 12** the set aside scenario values are mutations of the annual allocation. For the cancellation scenarios (set aside without backloading), the values for 2016-2020 are zero.

Table 12: Annual allocation, baseline and reference supply and demand and set aside (Mtonne) scenarios

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Annual allocation (excl. aviation)		2082	2044	2005	1967	1929	1891	1853	1814
Quantity to be auctioned		1116	1104	1092	1080	1067	1055	1043	1031
Baseline emissions		2170	2170	2170	2170	2170	2170	2170	2170
Reference emissions		2150	2140	2130	2100	2060	2020	2000	1980
Surplus baseline (end of year)	2325	2237	2111	1946	1743	1502	1223	906	550
Surplus reference (end of year)	2325	2257	2161	2036	1903	1772	1643	1496	1330
Set aside scenarios		withdrawal			backloading				
Large		-550	-400	-250	240	240	240	240	240
Medium		-400	-300	-200	180	180	180	180	180
Small		-200	-150	-50	80	80	80	80	80
X large		-766	-766	-766	460	460	460	460	460

Source: Van Dril, 2012.

The Dutch Ministry of Finance has estimated the auctioned volumes and revenues for the Netherlands. When the EU set aside scenarios are implemented, a proportionally smaller volume of auctioned allowances is assumed for the Netherlands. This leads to the overview of auctioned volumes in the Netherlands, as presented in **Table 13**.

Table 13: Baseline and set aside scenario volumes (Mtonne) for auction in the Netherlands

	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Planned auctioning	5	29	28	30	29	29	28	28	27	233
With large set aside	5	15	18	23	35	36	34	34	33	234
With medium set aside	5	19	20	25	34	34	33	33	32	234
With small set aside	5	24	24	29	31	31	30	30	29	233
Large cancellation	5	15	18	23	29	29	28	28	27	202
Medium cancellation	5	19	20	25	29	29	28	28	27	210
Small cancellation	5	24	24	29	29	29	28	28	27	223
X large cancellation	5	9	9	9	29	29	28	28	27	173

Source: Van Dril, 2012.

Van Dril (2012) has studied the expectations of the market parties on supply and demand of emission allowances, as well as the expectations regarding the allowance price, concluding that the carbon price is not substantially affected by setting aside allowances when they are backloaded. However, when the amounts proposed by the EC are set aside and cancelled, a moderate increase in the allowance price will occur. A cancellation of more than the 400 to 1200 Mtonnes the EC has proposed will lead to a great impact, in which case, the carbon price will more than double.

Latest ETS developments for the Dutch refining sector

Under the current qualifications set by the European Commission, the oil refining sector is probably deemed to be exposed to carbon leakage for the period 2015-2019. A final decision for the period 2015-2019 is expected by the end of 2014. The latest free allocation set by the Nederlandse Emissieautoriteit (NEa), was published in October 2013 (NEa, 2014) and includes a correction, which is calculated using a cross-sectoral correction factor. The latest correction has been set by the EC to meet the entire European CO_2-cap.

The latest free allocations for the entire Dutch oil refining sector for the EU ETS-trading period 2013-2020 are summarised in **Table 14**. The required purchase for the entire sector has been calculated based on the average annual emissions based on NEa-publications for the period 2008-2013, and has been assumed to remain constant.

Since all European refining sectors are exposed to ETS, the refining sectors in all European Member States are assumed to be affected equally by the ETS. For BPS analysis, costs have been assumed as input to address the effect of cost disadvantage. For the Netherlands, this is set at a level of ~EUR 10 million per year, which equals current price levels of EUR 5 per ton (see **Table 14**).

Table 14: Aggregated free emission allowances for the Dutch refining sector and required purchase of emission allowances, based on the average annual sector emission of 10,574,244 ton CO_2 during 2008-2013. Average annual costs for various CO_2 price assumptions have been included.

	2013	2014	2015	2016	2017	2018	2019	2020
Allocated free emission allowances	8,961,529	8,804,599	8,645,883	8,485,574	8,323,597	8,160,105	7,994,633	7,828,641
Required purchase based on reference	1,612,715	1,769,645	1,928,361	2,088,670	2,250,647	2,414,139	2,579,611	2,745,603
Average annual costs if EUR 5/ton CO_2	2,170,000 (average required purchase) x 5 EUR/ton = EUR 10.9 million							
Average annual costs if EUR 12/ton CO_2	2,170,000 (average required purchase) x 12 EUR/ton = EUR 26.0 million							
Average annual costs if EUR 30/ton CO_2	2,170,000 (average required purchase) x 30 EUR/ton = EUR 65.1 million							

A.2.7 Compulsory oil stocks

During the oil crisis in 1973, like several other countries, the Netherlands was cut off from oil supply. At the same time, the OPEC countries agreed to increase oil prices by using their leverage over the world price-setting mechanism for oil. Due to the heavy dependence of Western countries, including the Netherlands, the price increases resulted in dramatic inflation in the targeted countries and suppressed the economies of these countries. A wide variety of initiatives was deployed by these countries to control their dependence. As a direct result of this oil crisis, the International Energy

Agency (IEA) was founded by the Organisation for Economic Cooperation and Development (OECD). The IEA requires that Western countries keep minimum compulsory oil stocks equal to 90 days of net oil imports in the previous calendar year. The IEA coordinates these stocks in case of crisis situations (COVA, 2014).

The Dutch Oil Stockpiling Act entered into force, and from the beginning, the Dutch oil industry was affected by this obligation, although the law has changed over time (COVA, 2013). In the last few decades, a substantial part of the obligation was guaranteed by the Netherlands National Petroleum Stockpiling Agency (COVA). On behalf of and at the instruction of the Dutch Minister of Economic Affairs, the COVA fulfils that portion of the Dutch stock obligation which is not met by the Dutch oil industry, and aims to do so at the lowest cost. Costs incurred by COVA are levied to the final consumers similarly to the energy tax, which was EUR 8 per cubic meter in 2012 (COVA, 2014). The costs of meeting the obligation incurred by the Dutch oil industry are to be paid by the industry itself (Wva, 2012).

The Dutch oil crisis system has complied for years with the IEA regime. The EU directive has been changing more to conform with the IEA regime, therefore hardly affects the current Dutch policy with respect to compulsory oil stockpiling. The majority of the stockpiling obligation is met by the COVA, while a smaller part is fulfilled by the Dutch oil industry itself, thereby making use of the operational stocks present in the Netherlands. The EU directive prescribes that part of the compulsory oil stockpiling must be made up of ready-to-use oil products (Wva, 2012).

In the Netherlands, the Oil Stockpiling Act of 2001 obliged the Dutch oil industry, i.e. oil refineries and oil traders, to meet up to 15% of the compulsory oil stockpiling. Another 15% of the compulsory oil stockpiling was met by COVA using a so-called 'ticket system', whereby the oil industry, either in the Netherlands or in foreign countries, was paid to keep oil or oil products in stock. The remaining 70% was made up of COVA-owned stocks. The compulsory stockpiling for the Dutch oil industry combined with the ticketed stockpiling has added up to roughly 30% of the total national compulsory oil stockpiling for some years already. There was previously no obligation to keep stocks of ready-to-use products. In practice, the compulsory oil stockpiling was comprised mostly of crude. Via the 'ticket system', the Dutch oil industry generates an income of EUR 50-100 million per year (Wva, 2012).

A new Oil Stockpiling Act was implemented in 2012 and a relatively larger part of the obligation must now be fulfilled by the Dutch oil industry. One of the reasons is that the 'ticket system' is regarded as a risk: the Dutch oil industry may need to fulfil its obligations by selling tickets to other countries than the Netherlands, and COVA-owned tickets, bought outside the Netherlands, may result in claims from foreign countries. Reducing the amount of compulsory oil stockpiling via tickets reduces this risk. Furthermore, it also reduces costs for COVA (Wva, 2012). Another reason for implementing a new Oil Stockpiling Act, is that over the years and for various reasons the ratio of compulsory oil stockpiling between industry and COVA has shifted from 15%-85% to 10%-90%. The new Act means that the ratio of compulsory oil stockpiling between industry and COVA will shift to 20%-80% (Wva, 2012).

Since 30% of the total Dutch compulsory oil stockpile is owned by the Dutch oil industry and the absolute non-ticketed oil stockpile will probably increase from 10% to 20%, the financial loss in income is about half of the generated income of EUR 50-100 million per year, thus EUR 25-50 million per year.

Table 15 shows an overview of net importing days for IEA members (Wva, 2012). The last column are calculations made by ECN. As can be observed in **Table 15**, the total stockpiling days for many IEA countries exceed the IEA requirement of 90 days of net import. Since the majority of the IEA Member States, including the Netherlands, hardly have any industrial stockpiling abroad, it is concluded that the operational stockpiling is relatively large and in combination with the public stockpiling results in an excess of the 90 days of net import. The publicly-owned stockpile in the Netherlands as part of the IEA requirements is relatively large compared to the total IEA stockpile in Europe. However, as a portion of the total stockpile, the publicly-owned stockpile of the Netherlands is quite similar to countries such as Belgium, Germany and France. The website of the IEA provides data on oil stocks as well as a description of the compulsory oil stockpiling legislation. In Germany, 100% of the compulsory stocks are funded publicly. Belgium is shifting in the short-term towards 100% public funding of the compulsory oil stocks. In France, the industry is responsible for 27% of the compulsory oil stocks and the remainder is publicly funded. For these countries, it is therefore concluded that the division between public and industry owned oil stock is in the same range. Although stocks change over time, other periods have also been checked on the IEA website to support this conclusion (IEA, 2014).

Table 15: Overview of net import days in stock, December 2011 (source IEA). For regional totals, only net importing IEA-countries are added.

EU countries that are also IEA members	Total stockpiling days(*)	Stockpiling days held by industry (**)	Stockpiling days held publicly (***)	Agency	Of which held abroad (****)		Percentage stockpiling days of IEA requirement (i.e. 90 days) held by public
					Industry	Public	
Austria	99	99	0		11	0	0.0%
Belgium	122	50	72	APETRA	9	40	80.0%
Czech Republic	131	38	93	ASMR	6	3	103.3%
Denmark	net exporter	0	0	FDO	0	0	0.0%
Finland	138	80	57	NESA	0	0	63.3%
France	99	35	64	CPSSP/ SAGESS	0	2	71.1%
Germany	136	35	101	EBV	3	0	112.2%
Greece	92	92	0		0	0	0.0%
Hungary	148	47	101	MSZKSZ	0	0	112.2%
Ireland	99	33	67	NORA	0	34	74.4%
Italy	122	122	0		15	0	0.0%
Luxembourg	96	96	0		86	0	0.0%
Netherlands	**159**	**84**	**74**	**COVA**	**0**	**51**	**82.2%**
Poland	123	107	16		0	0	17.8%
Portugal	105	71	34	EGREP	2	12	37.8%
Slovakia	141	57	84	ASMR	0	0	93.3%
Spain	105	64	41	CORES	1	0	45.6%
Sweden	118	118	0		8	0	0.0%
United Kingdom	438	438	0		101	0	0.0%
Total IEA Europe, net importers	**123**	**76**	**47**		–	–	52.2%
Total IEA	**176**	**104**	**72**		–	–	80.0%
Total IEA net importers	**143**	**82**	**61**		–	–	

* IEA stock levels in days of previous year's net imports using IEA methodology. Total may not equal sum of Industry and public due to rounding.

** The portion of total days of net imports covered by industry stocks. This includes stocks held for commercial and operational purposes as well as stocks held by industry to meet minimum national stockholding requirements (including stocks held for this purpose in other countries under bilateral agreements).

*** The portion of total days of net imports covered by government-owned stocks and stockholding organisation stocks held for emergency purposes (including stocks held in other countries under bilateral agreements).

**** The portion of a country's total stocks which are held in another country under a bilateral agreement. In specific instances, member countries can count stocks held in the territory of other countries as part of their stocks to fulfil their minimum IEA stockholding requirements. Sometimes these stocks are indeed owned by the entities having the stockholding obligation; in other cases these stockholding amounts are in the form of tickets.

Appendix B. Comparison of international legislation

B.1. Regulation in France

Information with respect to emission regulation in France has been obtained via institute CITEPA in Paris. In general, French regulation sets emission limit values either in line with the IED or in line with BAT-levels set in the BREF. The local authority is allowed to set stricter emission limit values if deemed necessary to serve the local air quality.

- With respect to SO_2 emissions, a bubble is applied at 850 mg/Nm^3 for all utilities and processes; this bubble will decrease to 600 mg/Nm^3 in the near future.
- The required efficiency of sulphur recovery units (or Claus-units) needs to comply with the formulated BAT-standards for this activity.
- Requirements for flares and catcracking units are linked to the BAT-standards in the BREF.
- NO_x and PM emission limit values for combustion installations need to comply with new acts, which have been adopted to implement the IED.

B.2. Regulation in Belgium

Information was retrieved with respect to legislation as well as additional comments from the competent authority. Though emission limit values are provided by law, the competent authority is allowed to set even more stringent values if the local air quality makes it necessary to do so.

In Belgium, all refineries are located in Antwerp, Flanders. This means that the VLAREM II-legislation, part 5.20.2 Petroleum refineries, is relevant for this sector (VLAREM, 2014).

Sulphur recovery
For Sulphur recovery units, article 5.20.2.7, paragraph 3, the following requirements are in place.

Claus installations (i.e. a sulphur recovery unit) with a production capacity of 50 metric ton sulphur per day, need to comply with the following sulphur removal efficiencies:

1 Installations with a first permit to operate, dated 1 January 2007: 99,5%;
2 Installations other than under 1): 97%.

Additional information requested from the competent authority revealed that all Belgian Claus installations from 2006 and earlier exceed 98,5% efficiency, which is in line with the Gothenburg Protocol. The VLAREM II will be updated as soon as the revised BREF Refineries is adopted.

Bubble concept

The VLAREM II sets a maximum ceiling (bubble concept) on the total emissions from combustion and processes. The maximum emission levels, based on year average are:

- SO_2: 350 mg/Nm^3; old installations (before 1 July 1987) fall under this limit but together have a second limit of 1700 mg/Nm^3 month average.
- NO_x: 200 mg/Nm^3 (expressed as NO_2).
- Dust: 50 mg/Nm^3.

The processes include sulphur plants, FCC units and other transformation plants, flares, asphalt oxidisers and all other process units with these types of emissions.

Combustion installations

The VLAREM II sets limits for combustion installations on liquid fuels and gaseous fuels as well. There are separate limits for gas turbines and stationary engines. The limits for combustion installations depends on the size and the date of permit request. The limits will also change as of 1 January 2016. **Table 16** provides the figures for the existing and new installations.

Table 16: VLAREM II emission limits

Type	Thermal power	Emission limit in mg/Nm^3 at 3% O_2		
		Dust	SO_2	NO_x
Liquid fuels				
Installations before 28 November 2003 Until 31 December 2015	≥ 50 – 300	50[1]	1700[3]	450
	> 300-500	50[1]	Linear from 1700 to 400[3]	450
	> 500	50[1]	400[3]	400
Installations before 28 November 2003 per 1 January 2016	≥ 50 – 300	30[2]	350[3]	450
	> 300-500	25[2]	250[3]	200
	> 500	20[2]	200[3]	150
Permit request after 6 January 2013	≥ 50 – 300	20	350	150
	> 300-500	20	200	100
	> 500	10	150	100
Gaseous fuels				
Installations before 28 November 2003 Until 31 December 2015	≥ 50 – 500	5	35[4]	300
	> 500	5	35[4]	200
Installations before 28 November 2003	≥ 50 – 500	5	35[4]	100
	> 500	5	35[4]	100

Type	Thermal power	Emission limit in mg/Nm^3 at 3% O_2		
		Dust	SO_2	NO_x
Per 1 January 2016				
Permit request after 6 January 2013	≥ 50 – 500	5	35[4]	100
	> 500	5	35[4]	80[5]

Notes

[1] If there is more than 0.06% ash the limit is 100 mg dust/Nm^3

[2] For residues the limit is 50 mg dust/Nm^3

[3] For residues the limit is 1000 mg SO_2/Nm^3

[4] For installation on liquefied gas the limit is 5 mg SO_2/Nm^3

[5] For residues the limit is 100 mg NO_x/Nm^3

NMVOC measures

Article 5.10.2.7 mentions NMVOC requirements:

Upon loading or unloading of output, intermediate and final products, emissions of organic compounds with a vapour pressure of over 13.3 kPa at a temperature of 35°C must be reduced by appropriate measures, like a vapour balancing system, exhaust hood and transfer to an exhaust gas purification system.

There is also a special part on storage in VLAREM II, namely paragraph 5.17. This paragraph refers to several appendixes like: VOC emission reduction in 5.17.9, gasoline vapour recovery stage 1 in 5.17.10 and stage 2 in 5.17.11, VOC emission calculation in 5.17.12, and overfill protection in 5.7.17. For details on those measures, this report refers to the original VLAREM II text.

B.3. Regulation in Germany

In Germany, the TA Luft and BImSchV legislation are relevant (TA Luft, 2002; BImSchV, 2013).

Sulphur recovery

Article 5.4.4.1.p.1 (TA Luft, 2002) sets the sulphur removal efficiencies for sulphur recovery units or Claus installations. For new installations, the required removal efficiency varies between 97% and 99.8%, depending on the installation capacity. For a capacity of 50 metric ton per day, a removal efficiency of 99.8% is required.
For existing Claus installations, the same removal efficiencies are valid, with the exception that installations larger than 50 metric ton per day may vary between 99.4% and 99.8% removal efficiency.

Small combustion installations on refinery gas

According to article 5.4..1.2.3 (TA Luft, 2002), the emission limit values for small combustion installations smaller than 50 MW_{th} on refinery gas shall not exceed:

- 5 mg total dust/Nm^3 (dry, 3 vol-% O_2).
- 50 mg SO_2/Nm^3 (dry, 3 vol-% O_2).

Large combustion installations

For large combustion installations, i.e. larger than 50 MW_{th}, the BImSchV legislation is relevant (BImSchV, 2013). Emission limit values for liquid fuels are described under paragraph 6 of this legislation, together with exception rules for existing installations. Emission limit values for large combustion plants on gaseous fuels are described under paragraph 7 of this legislation:

- Article (1)1, a, bb: 5 mg total dust/m^3 relevant for 'other gases', such as natural gas and refinery fuel gas
- Article (1)1, c, aa, aaa: 100 mg NO_x/m^3 for natural gas
  aa, bbb: 200 mg NO_x/m^3 for 'other gases', such as refinery fuel gas*
  Article (1)1, c, bb: 100 mg NO_x/m^3 for all gases, installations > 300 MW_{th}
- Article (1)1, d, dd: 35 mg SO_2/m^3 for all 'other gases', including natural gas and refinery fuel gas.

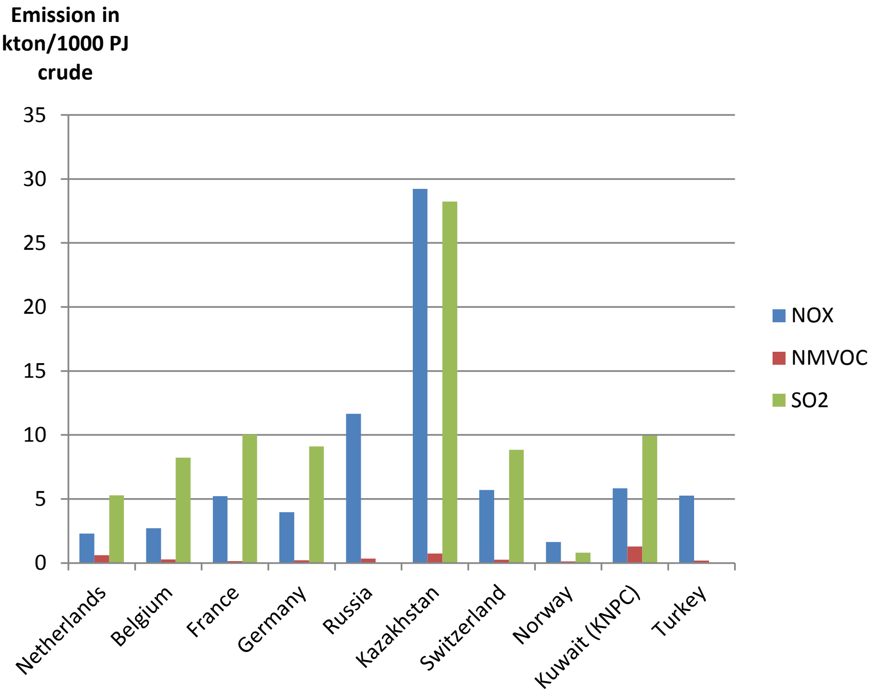
*For existing refinery installations, the emission limit value is more lenient: 300 mg/Nm^3 (daily average) and 600 mg/Nm^3 (half hour average).

These emission limit values are applicable as a daily average, under dry conditions at 3 vol-% O_2 for gaseous and liquid fuels, 15 vol-% O_2 for gas turbines and 5 vol-% O_2 for gas engines.

B.4. Comparison of international NIR data

European countries need to deliver National Inventory Reports for the UNFCCC with respect to their emissions. Activity data for the refining sectors are also often provided in these reports.

Figure 38: Refinery sector emissions in different countries divided by the crude oil throughput for the year 2010



The majority of the data in **Figure 38** are taken from the CRF tables of the National Inventory Report of the European countries for the UNFCCC (table 1s1 and table 1.b.c)[10]. Unfortunately, not all the data are available:

- For Turkey, data on SO_2 emissions and amount of oil processed are missing.
- For the Russian Federation, data on SO_2 emissions are missing.
- For the USA, data on emissions of NO_x, NMVOC and SO_2 are missing.
- There is no obligation to report for the Middle East countries or India.

Data from some other sources is included in the figure and will be described per country in this chapter.

Comparison of this data leads to the conclusion that the reported NMVOC emissions are not reliable, since these are mainly based on calculations (Paragraph 3.1.2.5, Draft BREF, 2013). Countries use various methods to calculate these emissions, and emission reports are mainly not based on measurements. The Swedish data show differences of a factor of 2 between measurement and calculation[11]. It is also possible that emissions from tank storage or oil transfer to and from the refinery complex are not reported in this sector. Therefore, NMVOC emissions will not get much attention in this chapter.

---

[10] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php.

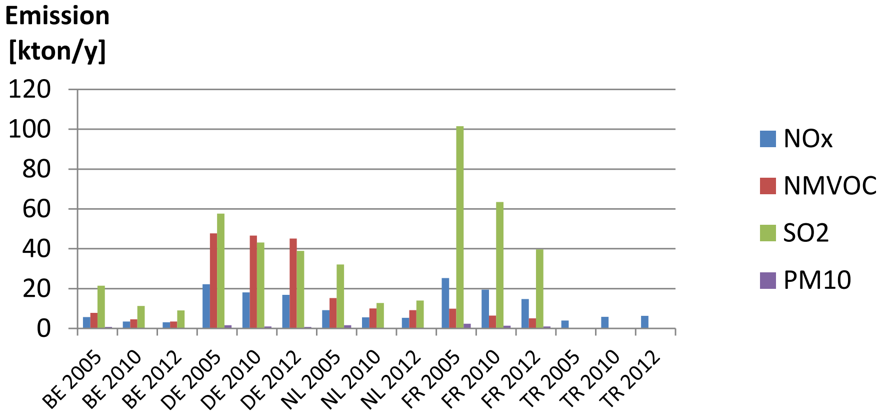
[11] Frisch, L. (2004): *Fugitive VOC-emissions measured at Oil Refineries in the Province of Västra Götaland in South West Sweden – a success story – development and results 1986-2001 – commissioned by The County Administration of Västra Götaland*. The County Administration of Västra Götaland, Göteborg, Sweden.

B.5. European comparison

Another source of emission data is the reports for the UNECE (United Nations Economic Commission for Europe) for the Convention on Long-range Transboundary Air Pollution (CLRTAP)[12]. Those emission data also include particulate emissions.

The results for European countries (Belgium, Germany, The Netherlands, France and Turkey) are shown in **Figure 39**. Data on crude oil throughput was added from CBS (Netherlands) and the US Energy Information Administration (Turkey)[13].

Figure 39: Emissions figures according to UNECE reports



According to the explanation of the data from Turkey for the combustion emissions standard 'EMEP/EEA (2009)', calculation factors were used and not actual emission data. Process emissions ('1 B 2 an iv Refining / storage') were not added because there were no activity data. Emissions from flaring ('1 B 2 c Venting and flaring') were also not included. Based on this explanation, it is concluded that the data from Turkey are not comparable with the other four countries. **Table 17** displays the emissions of the four countries, related to the crude throughput. Note that the sector emissions for the Netherlands as calculated and reported in Paragraph 4.4 may differ from the data used in **Table 17**. For reasons of comparison, the overview in **Table 17** is based on data as reported by all Member States.

---

[12] http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2014_submissions/.

[13] http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm.

Table 17: Emissions in EU countries related to the crude throughput

[kton]		NO_x [kton/1000 PJ crude]	NMVOC [kton/1000 PJ crude]	SO_2 [kton/1000 PJ crude]	PM10 [kton/1000 PJ crude]	Crude [PJ]
Belgium	BE 2005	3.67	4.96	13.73	0.46	1560
Belgium	BE 2010	2.49	3.30	8.21	0.13	1380
Belgium	BE 2012	2.27	2.55	6.69	0.09	1360
Germany	DE 2005	4.60	9.88	11.92	0.33	4830
Germany	DE 2010	4.54	11.68	10.81	0.24	3990
Germany	DE 2012	4.18	11.19	9.65	0.20	4030
Netherlands	NL 2005	3.47	5.79	12.22	0.63	2630
Netherlands	NL 2010	2.23	4.03	5.12	0.12	2490
Netherlands	NL 2012	2.21	3.84	5.81	0.09	2400
France	FR 2005	6.96	2.72	27.86	0.65	3640
France	FR 2010	6.73	2.21	21.88	0.45	2900
France	FR 2012	5.97	2.06	15.98	0.40	2480

The data are also shown in **Figure 40**, **Figure 41**, **Figure 42** and **Figure 43**. It is concluded that, within the limits of this analysis method, the emission levels of the Netherlands are in the same range as Belgium. Emission levels in Germany are declining, but are still not at the same level as Belgium and the Netherlands. Emission levels in France are declining too, but are still much higher than the other countries. All four countries should fulfil the same BREF-based emission levels.

Figure 40: NO_x emission in EU countries related to the crude throughput

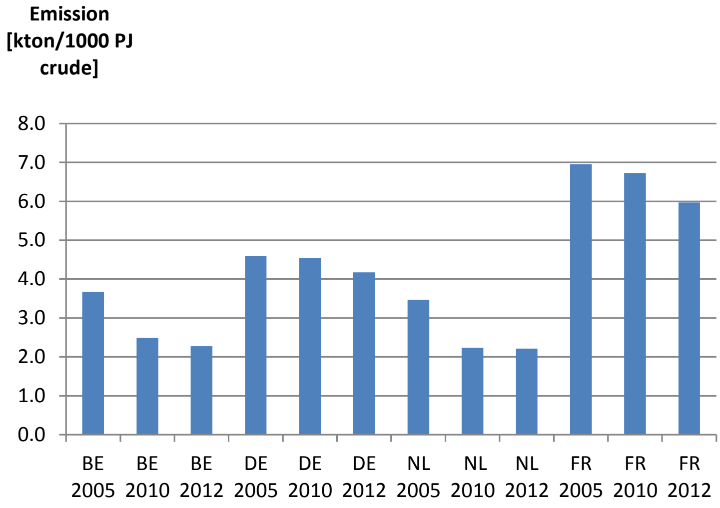
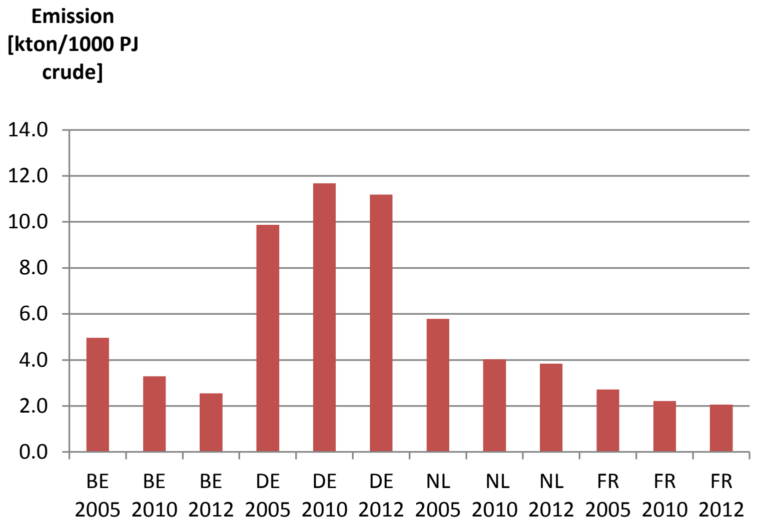


Figure 40 compares NO_X emissions for four EU countries. Although a decline can be observed, the NO_x emissions of French refineries are substantially higher than those of Belgium, Germany and the Netherlands.

Figure 41: NMVOC emissions in EU countries related to the crude throughput



Due to the different calculation methods used to estimate NMVOC emissions, it is complex to compare international data and to make robust conclusions. A comparison is depicted in **Figure 41**. The data for the Netherlands contain about 30% NMVOC emissions from storage facilities, not directly related to refineries. The remaining emissions for the Netherlands are at the same level as reported by the Dutch Statistical Bureau (CBS) for the refining sector.

Since most of the NMVOC data are calculated and calculation factors and methods probably differ between the countries, it is difficult to draw robust conclusions based on this comparison. Studies show substantial differences between measured and calculated data.

Figure 42: SO_2 emissions in EU countries related to the crude throughput

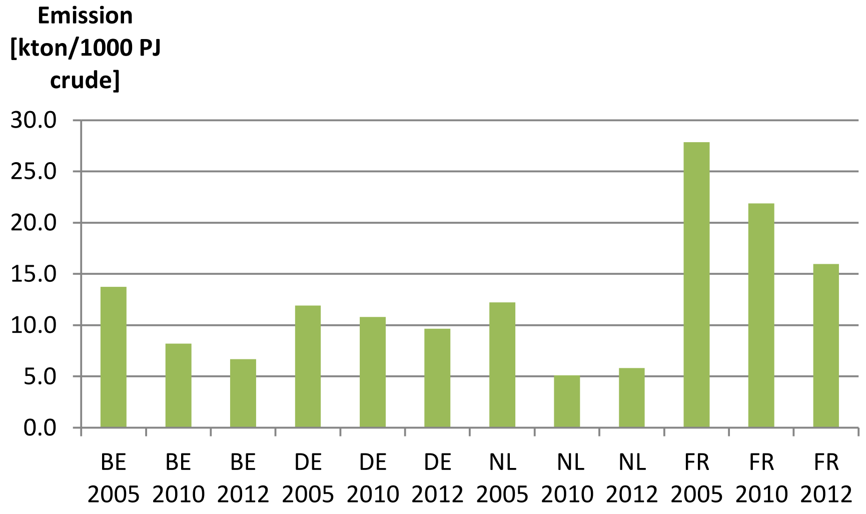


Figure 43: PM10 emissions in EU countries related to the crude throughput

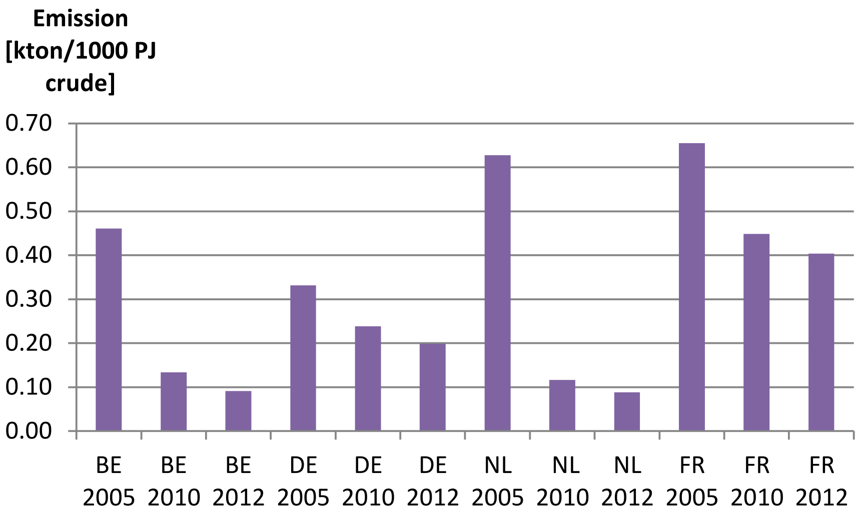


Figure 42 compares SO_2 emissions **Figure 43** compares dust (PM10). For both emission profiles, the switch from oil firing to gas firing in the Netherlands leads to a clear decline in emissions. For the most recent years, Belgium is at an equal emission profile.

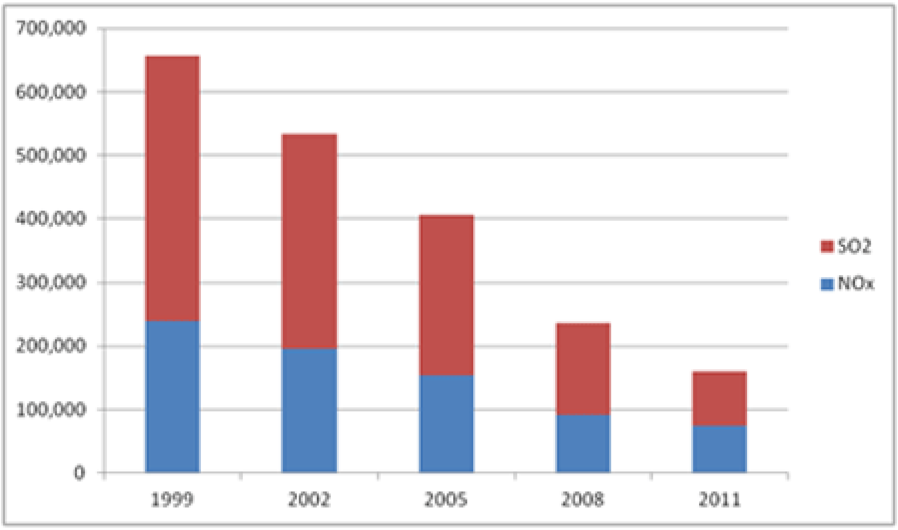
B.6. USA

In the USA, the Environmental Protection Agency (EPA) has an active policy on reducing refinery emissions[14]. According to the EPA site: 'Since March 2000, the Agency has entered into 32 settlements with US companies that refine over 90 percent of the Nation's petroleum refining capacity. These settlements cover 109 refineries in 32 states and territories, and on full implementation will result in annual emissions reductions of more than 93,000 tons of nitrogen oxides and more than 256,000 tonnes of sulphur dioxide. Negotiations are continuing with other refineries.'
Data reported by the petroleum refining sector to EPA's National Emissions Inventory shows a significant and steady decline in SO_2 and NO_x emissions in this sector (see **Figure 44**). The current decline is about 75%.

---

[14] http://www2.epa.gov/enforcement/petroleum-refinery-national-case-results.

Figure 44: Development of refinery emissions in the USA in ton/y (source EPA website).



The EPA policy has resulted in the investment of more than USD 6.5 billion in control technologies and payment of civil penalties worth more than USD 93 million, and the performance of supplemental environmental projects worth over USD 80 million. The EPA's settlements require significant reductions of nitrogen oxide and sulphur dioxide, and additional emission reductions of benzene, volatile organic compounds and particulate matter.

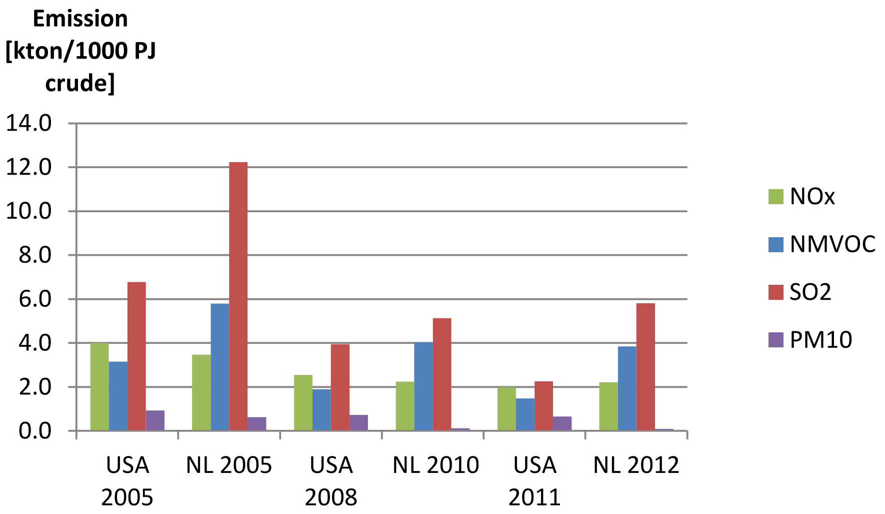
A new source review has been made of fluidised catalytic cracking units and heaters and boilers. There are also new source performance standards for flares, sulphur recovery units, fuel gas combustion devices (including heaters and boilers), leak detection and repair requirements. For benzene there are national emissions standards for hazardous air pollutants. The resulting emissions, in the same format as for the European emissions, are shown in **Table 18**.

Table 18: Emissions in the USA related to crude throughput

		NO_x		NMVOC		SO_2		PM10]		Crude
	Year	kton	kton per 1000 PJ crude	kton	kton per 1000 PJ crude	kton	kton per 1000 PJ crude	kton	kton per 1000 PJ crude	[PJ]
USA	2005	146	4.0	115	3.1	247	6.8	34	0.9	36536
USA	2008	92	2.5	69	1.9	143	3.9	26	0.7	36318
USA	2011	74	2.0	56	1.5	85	2.3	25	0.7	37623

Figure 45 compares the US emissions with those of the Netherlands. This clearly shows that the emissions of NO_x are in the same range. Emissions of SO_2 are lower in the USA and emissions of particulates are lower in the Netherlands. As already stated, emissions of NMVOC are not comparable due to possible differences in calculation methods.

Figure 45: Comparison of emissions of the Netherlands and the USA



B.7. Middle East - Kuwait

Information was found on the three major refineries in Kuwait of KNPC (see **Table 19**). The data from the sustainability report of 2012-2013[15] was combined with production data. There was no data on the emission of hydrocarbons or particulates.

Table 19: Emission of KNPC in Kuwait related to crude throughput

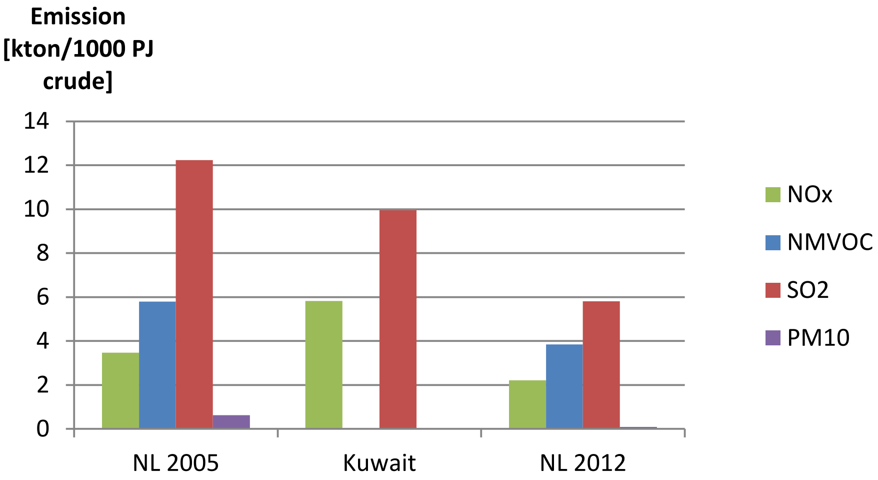
[kton]		NO_x [kton/1000 PJ crude]	NMVOC [kton/1000 PJ crude]	SO_2 [kton/1000 PJ crude]	PM10 [kton/1000 PJ crude]	Crude [PJ]
Kuwait (KNPC)	2012-2013	5.8	NA	10.0	NA	1990

Figure 46 compares the Kuwait data with the Dutch data. Although the relative emissions in Kuwait are higher, it shows that there are certainly abatement measures implemented in Kuwait refineries.

---

[15] http://www.knpc.com.kw/en/MediaCentre/Documents/SUSTAINABILITY%20REPORT%202012-2013.pdf.

Figure 46: Comparison of emissions of the Netherlands and KNPC refineries in Kuwait



The sustainability reports and a presentation[16] provide information about the emission limits. However, the actual emissions differ from the emission limits[17]:

- Fossil fuel fired in boilers and furnaces 30 MW: SO_2 512 g/GJ or 1760 mg/Nm^3 (about 1% S in the fuel oil). Based on the collected information KNPC does not use fuel oil, but uses mainly gas.
- Oil firing in heaters and boilers: 130 g/GJ (about 450 mg/Nm^3 at 3% O_2).
- Gas firing in heaters and boilers >30 MW: 86 g/GJ (about 310 mg/Nm^3 at 3% O_2)[18]. Actual emissions mentioned are: 246 mg/Nm^3 (two burners) and 141 mg/Nm^3 (burners at five boilers).
- Emission of dust in stacks < 115 mg dust/Nm^3.
- FCC boiler: limit 1 kg particulates/ton coke burned; actual about 0.5.
- H_2S in fuel gas has been 400-500 mg/Nm^3, but is currently below the limit value of 230 mg/Nm^3.
- Claus unit for sulphur recovery and capacity exceeding 20 ton/day: maximum SO_2 emissions of 250 ppmv in stack with oxidation or reduction and incineration.

Measures taken at KNPC:

- Flare gas recovery units have been installed: the objective is to cut down gas flaring to 1% of the throughput.
- Tail gas treatment units have been installed.
- The fluidised catalytic cracking units (FCCUs) are equipped with a cyclone separator and an electrostatic precipitator.

---

[16] Abhay Kumar Kashyap (2013): 'Air Emission Management – KNPC Experience.' *The 2nd Joint Qatar-Japan Environment Symposium Sustainable Environment, Climate Change and Renewable Energy for Oil and Gas Industry*, February 5-6, 2013, Doha, Qatar.

[17] 'Environmental Requirements and Standards in the State of Kuwait.' (2001): *Kuwait Al Youm* Appendix of issue no 533 year 47, October 2, 2001.

[18] Limits in the presentation in mg/Nm^3 are 10% higher. It is not clear where the differences come from.

- There is an odour management system (OMS). A team carries out a systematic and regular check of identified bad actors (valves) using an acoustic meter (VPAC) and a thermal IR camera.
- An LDAR program is in place to control fugitive emissions from leaky components like valves, flanges, pumps drains and vents etc.

To give an indication of the environmental investment costs in the next five years a table was copied from the KNPC website (see **Table 20**). The total 'environmental' investment in major projects for the three refineries is about EUR 180 million[19].

Table 20: KNPC HSE capital projects for the FY2012/2013-2017/2018

KNPC HSE capital projects for the FY2012/2013-2017/2018	EUR million
Provision of Low NOx burners in boilers/heaters at Mina Al-Ahmadi Refinery.	0.2
New Facilities for H_2S Removal From SWS Flash Drum Off-Gas in Sour Water Stripper Unit U-26 (MAB).	0.6
Gas Recovery Facilities in U-49 MAB Refinery.	8.1
New Flare Gas Recovery Unit at MAA Refinery (KNPC).	4.3
Upgrading of Obsolete Fire Detection, Alarm and Suppression Systems at KNPC Sites Including the Phase-out of Halon System.	32.2
Gasoline vapour recovery project in filling stations (Phase II).	1.5
Revamp of MAA ground Burnery for smokeless operation.	2.2
New Acid Gas Removal Plant and Revamp of Existing AGRP.	96.3
New Tail Gas Treatment Unit at MAA Refinery.	13.4
Revamp of Effluent Treatment Facilities at three refineries.	22.8
Nature Reserve Project at Wafra.	0.3

B.8. Middle East - Saudi Arabia

In Saudi Arabia[20], environmental limits are set in a general environmental law[21]. The limits are substantially less stringent than those of the Netherlands. For the refining sector the following articles are relevant:

Article 11-A: Combustion facilities:
All fossil fuel fired boilers and furnaces having a heat input capacity equal to or greater than 30 MW shall utilise appropriate gas cleaning equipment to limit emissions to the following rates:

- 43 ng/j of total particulates (about 150 mg/Nm^3 at 3% O_2).
- 1 microgram/joule of sulphur dioxide (about 3500 mg/Nm^3 at 3% O_2).
- 130 ng/j of NO_x for oil fired facilities (about 460 mg/Nm^3 at 3% O_2).
- 86 ng/j of NO_x for gas fired facilities (about 300 mg/Nm^3 at 3% O_2).

---

[19] http://www.knpc.com.kw/en/HSE/Pages/hsepro.aspx.

[20] *General Environmental Law and Rules for Implementation*. 28 Rajab 1422 H (15 October 2001).

[21] http://www.pme.gov.sa/en/env_prot.asp.

Article 11-B Petroleum and petrochemical facilities:
B-1- Storage vessels for petroleum liquid greater than 1000 barrels shall be equipped with vapour emission control systems as follows:

- Vapour recovery or equivalent systems are required for volatile organic compounds (VOC) having a vapour pressure in excess of 570 mm Hg. Floating roof tanks shall be considered adequate for crude oil storage providing that a consistent seal inspection and reporting program is implemented by the owner.
- Floating roof with double boot seal or equivalent systems are required for VOC having a vapour pressure in excess of 78 mm Hg (1.5 psi) but less than 570 mm Hg (11 psi).

B-2- FCC unit catalyst regenerators:
FCC unit catalyst regenerators shall utilise:

- Carbon monoxide boilers or high temperature regeneration to limit carbon monoxide emissions to 500 ppm.
- Appropriate air cleaners to limit particulate emissions to 1.0 kg per metric ton of coke burn off.

B-3- Fuel gas combustion process:
Fuel gas combustion processes shall utilise amine scrubbing or other appropriate gas cleaning process to limit hydrogen sulphide content of fuel gases to 230 milligrams/dry standard cubic metre (150 ppm).

B-4- Claus sulphur recovery plants:
Sulphur recovery plants shall utilise a two or three stage Claus process to achieve at least 95% recovery of total sulphur.

B-5- Fugitive emissions:
Fugitive emissions of VOC from petroleum and petrochemical processes shall be limited through the utilisation of good maintenance and inspection procedures as well as monitoring of potential VOC emission points.

The environmental law also contains articles relating to soil contamination and water pollution. A special article in Appendix 3.2 concerns the treatment of contaminated soil, for example petroleum contamination.

B.9. India

The Central Pollution Control Board (CPCB) in India was entrusted with powers and functions under the Air (Prevention and Control of Pollution) Act, 1981. It serves as a field formation and also provides technical services to the Ministry of Environment and Forests of the provisions of the Environment (Protection) Act, 1986. Information on air pollution limits can be found on their internet site (http://cpcb.nic.in/). The newest emission limits for refineries were published in 2008 (MEFN, 2008)(see **Table 21**, **Table**

22 and **Table 23**). Limits range from the first Dutch national emission limits of 1987 (BEES A) to levels in the European BREF 2003.

Table 21: Air emission limits for refineries in India

In mg/Nm^3		Existing refineries	New refineries, furnaces, boilers
Sulphur dioxide (SO_2)	Gas firing	50	50
	Liquid firing	1700	850
Oxides of nitrogen (NO_x)	Gas firing	350	250
	Liquid firing	450	350
Particulate matter (PM)	Gas firing	10	5
	Liquid firing	100	50
Carbon monoxide (CO)	Gas firing	150	100
	Liquid firing	200	150
Nickel + vanadium (Ni + V)	Liquid firing	5	5
Hydrogen sulphide (H_2S) in fuel gas	-	150	150
Sulphur content in liquid fuel, weight %	-	1	0.5

Note: Installation above 11.7 MW requires continuous measurement of SO_2 and NO_x

Table 22: Indian standards for emissions from FCC regeneration

In mg/Nm^3, unless stated otherwise	Hydro-processing of FCC feed (existing)	Other than hydro-processing of FCC feed (existing)	New refineries or FCC
Sulphur dioxide (SO_2)	500	1700	500 (for hydro-processed feed) 850 (for other feed)
Oxides of nitrogen (NO_x)	400	450	350
Particulate matter (PM)	100	100	50
Carbon monoxide (CO)	400	400	300
Nickel + vanadium (Ni + V)	2	5	2
Opacity, %	30	30	30

Table 23: Indian standards for sulphur recovery units

Plant capacity (Tonnes/day)	Parameter	Existing refineries	New refineries or SRU
Above 20	Sulphur recovery, %	98.7	99.5
Above 20	H_2S, mg/Nm^3	15	10
5 – 20	Sulphur recovery, %	96	98
1 – 5	Sulphur recovery, %	94	96
All capacity	Oxides of nitrogen (NO_x) mg/Nm^3	350	250
All capacity	Carbon monoxide (CO) mg/Nm^3	150	100

The emission legislation also contains measures for storage tanks. Depending on total vapour pressure, tanks need to have an internal or external floating roof with vapour control systems and double seals (10-75 kPA) or a fixed roof with a vapour control system with >95% efficiency (>76 kPa). For the storage of benzene the removal efficiency for fixed roof tanks must be >99.9% and for floating roof tanks >99%.

There is also an approach and standard for equipment leaks. This includes for instance a permanent leak detection and repair (LDAR) programme, ppm limits for what is defined as a leak and a monitoring and repair schedule.

B.10. Russia - old figures

Statistical information on refinery emissions in Russia remain inadequate, since only a total figure for the sum of different air polluting substances is published. The most recent detailed figures found were for 1999 (see **Table 19**). This shows relatively low NO_x emissions, but high emissions of NMVOC and SO_2. As these data are 15 years old already, it is difficult to draw robust conclusions.

Table 24: Emissions from Russian refineries in 1999 related to crude throughput

[kton]		NO_x [kton/1000 PJ crude]	NMVOC [kton/1000 PJ crude]	SO_2 [kton/1000 PJ crude]	PM10 [kton/1000 PJ crude]	Crude [PJ]
Russia	RU 1999	2.8	60.2	19.2	1.0	7098

B.11. Russia - Taneco refinery

In 2005 a new refinery was established in Tatarstan, a part of Russia. Emission data for this new complex was not found, but there is information available about the environmental measures for this 6.2 million ton/y Taneco refinery (Taneco, 2014):

- Natural gas of own-production and desulphurised hydrocarbon gas are used as fuel in the process furnaces.
- Burners with extra-low formation of nitrogen oxides are used in furnaces.
- Decrease in gaseous and liquefied hydrocarbons emissions from the equipment is achieved by use of flange connections packed with highly effective modern materials, A-class valves and tight pumps with double mechanical seals.
- A closed system for vessel drains is accepted.
- Catalytic treatment of flue gases of nitrogen oxides is applied with an efficiency of up to 80%; the contractor is Haldor-Topsøe.
- Absorption of hydrogen sulphide (MDEA treatment) and its segregation (MDEA regeneration) are provided.
- Tanks with oil are equipped with floating pontoons of the type 'Ultra flout', an internal floating design that covers an oil surface to prevent its evaporation.
- A minimum number of flange connections is used on pipelines.
- The loading of light oil products into railway tanks is carried out at the installation with 'John Zink' vapour recovery blocks with an efficiency of more than 99%.

- There is a possibility for reception and burning of emergency emissions at the three separate flare systems. The package unit for recycling of gases of GARO (Italy) allows the return after amine treatment of about 4700 Nm^3/hour of purge gases into a fuel network at the complex.

B.12. Kazakhstan

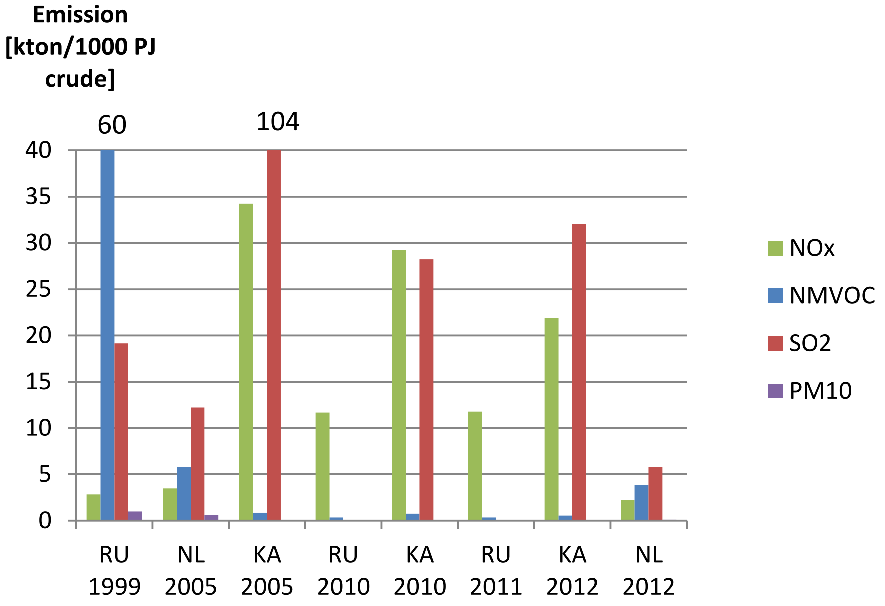
To construct a better view of the situation in Russia, an inventory was made for Kazakhstan and compared to Russia.

Table 25: Emission data from Russia and Kazakhstan related to crude throughput

		NO_x	NMVOC	SO_2	PM10	Crude [PJ]
Russia	RU 1999	2.8	60.2	19.2	1.0	7098
Kazakhstan	KA 2005	34.3	0.9	103.8		454
Russia	RU 2010	11.7	0.4			10468
Kazakhstan	KA 2010	29.2	0.7	28.2		573
Russia 2011	RU 2011	11.8	0.3			10810
Kazakhstan	KA 2012	21.9	0.5	32.0		586

Figure 47 compares these emissions with the Dutch situation. This figure shows that the 1999 data for Russia for NMVOC and NO_x reports extreme levels.

Figure 47: Comparison of emissions of Russia, Kazakhstan and the Netherlands



B.13. Turkey

Table 26 provides the emission data for Turkey. For reasons of comparison, Dutch data from 2012 have been added as well. As already mentioned, process emissions, fugitive emissions and flares are missing. Moreover, emission reports are not based on measurements, but have been calculated using standard emission factors. No robust conclusions can be made based on these data.

Table 26: Reported but incomplete emission data from Turkey related to crude throughput

		NO_x	NMVOC	SO_2	PM10
Turkey	2005	5.27	0.20	0.02	0.06
Turkey	2010	3.33	0.14	0.02	0.05
Turkey	2012	6.21	0.17	0.03	0.07
The Netherlands	2012	2.21	3.84	5.81	0.09

B.14. World Bank Limits 2007

A reference for non-European countries is the limits provided by the World Bank[22]. This section discusses some relevant limits laid down by the World Bank, including:

- Low-NO_x burners should be used to reduce nitrogen oxide emissions.
- Source gas reduction measures should be implemented to the maximum extent possible.
- Minimise SO_x emissions through desulphurisation of fuels, to the extent feasible, or by directing the use of high sulphur fuels to units equipped with SO_x emission controls.
- Recover sulphur from tail gases using high efficiency sulphur recovery units (for example, Claus units).
- Abate dust emissions. Install cyclones, electrostatic precipitators, bag filters, and/or wet scrubbers to reduce emissions of particulates from point sources. A combination of these techniques may achieve >99 percent abatement of dust.
- Minimise flaring from purges and pilots, without compromising safety, through measures including the installation of purge gas reduction devices, flare gas recovery units, inert purge gas, soft seat valve technology where appropriate, and installation of conservation pilots.
- Recommendations to prevent and control fugitive emissions include the following: Identify streams and equipment (from pipes, valves, seals, tanks and other infrastructure components, for example) likely to lead to fugitive VOC emissions and prioritise their monitoring with vapour detection equipment followed by maintenance or replacement of components as needed.

---

[22] World Bank (2007): *Environmental, Health, and Safety Guidelines for Petroleum Refining*. World Bank Group.

Table 27: Air emissions levels for petroleum refining facilities

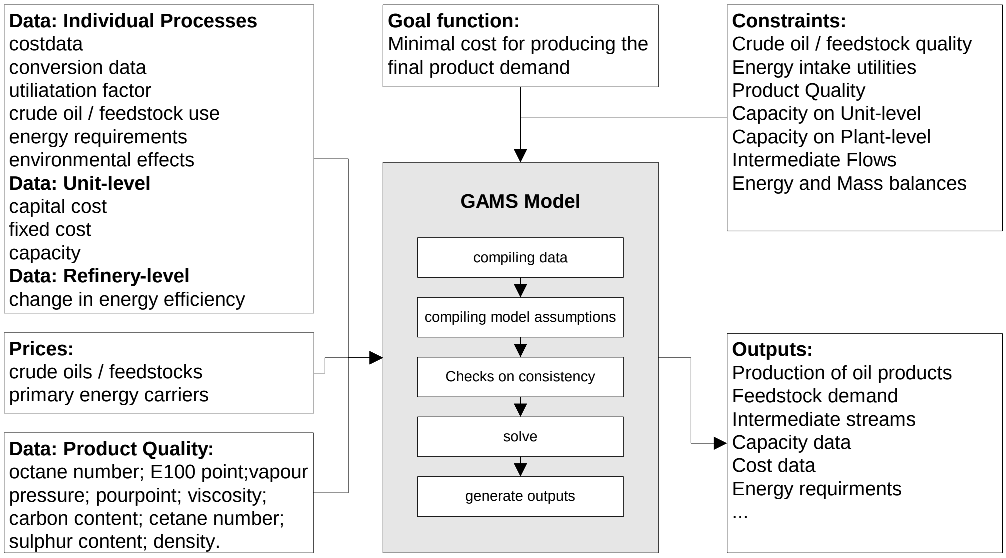
Pollutant	Guideline value (dry at 3% O_2)
NO_x	450 mg NO_x/Nm^3
SO_x for sulphur recovery units;	150 mg SO_x/Nm^3
SO_x for other units	500 mg SO_x/Nm^3
Particulate matter	50 mg/Nm^3
Vanadium	5 mg/Nm^3
Nickel	1 mg/Nm^3
H_2S	10 mg Nm^3

Appendix C. Description of the SERUM model

The ECN SERUM model

In 1988, at the request of the Ministry of Economic Affairs, the Unit Policy Studies of the Energy research Centre of the Netherlands (ECN) developed a model for the refining industry in the Netherlands (Oostvoorn, 1989; Kok, 1997). The LP model, called SERUM (Static Energy study centre Refinery Utility Model), is used as a part of the National Energy Outlook Modelling System (NEOMS) for the long-term energy scenarios developed at ECN and used by the Dutch government. SERUM is able to calculate the effect of various changes in crudes, feedstocks, product demand, product specification, energy use and SO_2 emissions. An overview of the model is shown in **Figure 48** (Stienstra, 2007). The model is based on separate units such as atmospheric distillation, gasoil hydrotreating and hydrocracking, with input, output and energy demand figures for each. The units are crude specific and sometimes more options are available to model the refinery flexibility and different conversion rates. The units are connected in the GAMS software framework. By changing the allowed units, the model can define and calculate various refinery configurations.

Figure 48: Typical inputs and outputs of the SERUM-GAMS model for scenario studies



For sectoral calculations, the model normally contains three different refinery configurations which equally fulfil the product demand for the Dutch sector and three modelled crudes. Each configuration has its own processing units, energy supply and blending facilities.

For this project all four standard crudes: Sahara Blend, Brent Blend, Iranian Light and Arabian Heavy are used in the model. Condensate and different feedstocks (short and long residue, vacuum gasoil) are also used. All Dutch refineries were modelled and calculated separately in SERUM and the individual results were communicated with the individual companies. The aggregated results for the entire Dutch sector are reported here.

Appendix D. Costs for other emission reductions

Table 28: Some information has been provided by the Dutch refining sector on measures that are not incorporated in this study due to project agreements. This information has been aggregated for the entire Dutch sector and is classified under water, soil and other measures. This information has not been validated by ECN or Wood Mackenzie.

Type of measures	Lump sum investment costs (x million EUR_{2010})	O&M costs (x million EUR_{2010}/year)
Measures to abate emissions to water	**97.50**	**0.58**
Measures to abate emissions to soil	**34.00**	**0.95**
Other measures	**17.60**	**0.88**
TOTAL	**149.10**	**2.41**

Appendix E. SPS aggregated emission reduction potentials

Table 29: Aggregated emission reduction of the environmental measures under the Stringent Plant Scenario. Due to underutilisation of capacity as determined under the BPS, these emission reduction potentials decrease. The emission reduction potentials in this table have been determined under the 2012 operations and emission profiles and would be valid for the SUS. The SPS however, takes underutilisation into account and the emission reductions due to stringent measures in Paragraph 4.4 are therefore lower compared to the emission reduction potentials in this appendix.

Type of emissions	Emission reduction (ton/year)
SO_2	**6261**
NO_x	**2359**
NMVOC	**1854**
Dust	**93**

ECN

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 ZG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ecn.nl
www.ecn.nl