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A Descriptive Analysis of Value Creation at Statoil Mongstad and its Supply Chain

Leoncie Nyiramucyo and Debasish Sahabanik

Supervisor: Jens Bengtsson

NORGES HANDELSHØYSKOLE

Abstract

Value chain is a sequence of activities that flow from raw materials to delivery of product or service. Value chain in oil industry extends from exploration and production of crude oil and natural gas up to sales of refined products. Refineries play a key important in the supply chain of an oil company, as it is where crude oil is processed into refined products. The emphasis of this work is on Statoil Mongstad. Statoil Mongstad is a refinery located at Mongstad. In order to get overview of Statoil Mongstad's value chain, this thesis describes and discusses Statoil Mongstad's organisation structure, production processes, costing and pricing principles and policies, and finally its supply chain.

Acknowledgements

Leoncie Nyiramucyo   Debasish Sahabanik

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1. Introduction

In today's every day life, products from oil and natural gas have become more and more important. They are used to fuel cars, heat homes, cook food etc. If one could imagine how the world would be without crude oil, natural gas and their derivative products, one can obviously see how important these products are. They have a big influence on different perspectives of everyday life, environment, and economy. When an economy grows, it is followed by an increase in the demand of these products as they are used to run industries, transport, etc.

To get these products a number of different activities are performed in oil industry. Activities in oil industry are broken down into two broad categories upstream and downstream. Upstream refers to exploration and production activities, finding oil and pumping it out of the ground. Downstream generally refers to everything else required to transform the crude oil and natural gas into useful products. Included among downstream activities are oil refining and marketing and natural gas storage and transmission.

We hear more and more on the news about movements in crude oil prices per barrel and how they affect our lives. However, crude oil is not useful in the state it comes out from the ground. It contains hundreds of different types of hydrocarbons all mixed together. To have anything useful from crude oil, these different types of hydrocarbons need to be separated. This is done in a refinery. In an oil refinery, crude oil is broken down into parts and refined into useful products. An oil refinery is normally a large industrial site where crude oil is processed. The refinery turns crude oil into a whole range of substances such as gasoline, jet fuel etc. It also determines the quality and the specifications of these products. Thus, refineries have a big importance and then become a key link in the value chain of oil industries.

As refineries are important in the value chain in the oil industry, this study considers the oil industry and refineries in general and puts more emphasis on Statoil Mongstad (refinery at Mongstad) in particular. The Statoil Mongstad gets the most attention, as this study is part of the Mongstad pilot project. In this project, there was a need of doing a prestudy that would shed light on the value chain at Statoil Mongstad. To achieve this objective, this prestudy

has described the following aspects: organisation structure, production at Mongstad, pricing structure, cost structure and Statoil Mongstad supply chain.

Mongstad refinery was built in 1972 and then started its activities. From 1989, the refinery was upgraded and extended. Mongstad's annual production is equivalent to 180% of petrol consumption in Norway. Mongstad port is Norway's biggest port by tonnage and Europe's second biggest oil port. The Mongstad refinery primarily converts crude oil into light products, with an annual production capacity of roughly ten million tonnes. Gasoline, jet fuel, diesel oil and gas oils are the principal products from this facility.

At Mongstad, there are four different entities – Crude oil terminal, Vestprosess, Product Technology and Customer Service Centre, and Statoil Mongstad (the refinery). These entities work in collaboration and make a part of the refinery's supply chain. In this thesis, we will discuss the relationship and collaboration between these entities and their role in the oil supply chain. As a good organisation contributes to the success of a business, a study of some organisation, administration and performance measurement tools becomes also necessary.

Crude oil refining is done through different processes. In this study, different production processes used in Mongstad refinery are discussed in order to get insight into activities at Mongstad.

The price of crude oil has a significant importance in the petroleum industry. Crude oil prices behave much as any other commodity with wide price swings in times of shortage or oversupply. An increase in crude oil prices will increase the expected revenue of an oil company. The difference between raw products prices and final products prices gives a gross margin. Refineries are supposed to continuously improve their contribution margin between its buy price of input (crude oil, etc.) and its sales price on refined products. There are different opportunities and threats on this contribution margin. Gross margin could be increased by reducing the price of input and increasing the price of output. Nevertheless, a large gross margin will not have a big importance if the cost of running the refinery is high. Thus the net margin is also important. A discussion on price and costs of running a refinery is presented in this study.

Together, good strategies and efficiency in different activities of organisation, production, pricing, and managing costing are essential to run successfully a refining business. However, to produce most value for the customer at least cost requires an efficient supply chain that responds to changes in the market adequately.

Objective of the study

The study has a purpose to conduct a descriptive study of Statoil Mongstad's business management and operations, in addition to its supply chain. Thus, the study aims to give a comprehensive overview and understanding of different business aspects for a refinery like Statoil Mongstad.

Scope and Limitations

Value creation in a company can be studied from different perspectives. When studied from the shareholder or other stakeholder perspective, the research is mostly based on the information collected from the shareholder or stakeholders. When looked at from the stock market perspective, the information used in the study is collected mainly from the stock market. If the study is based on the company perspective then the information used will mainly be collected from the company. However due to the time limit and the scope of this study, we are obliged to make some limitations.

Value creation at Mongstad is a very broad issue. We limited our thesis to the descriptive level of some perspectives in order to cover a big part of value creation at Mongstad. In our study is tackled from the point of view of the company. We choose this point of view since it is actually the company that puts in place different strategies. We therefore believe that our objectives would be well met if we use the company perspective. We have then collected data and conducted interviews only in Statoil ASA. Although we are conducting this work on that point of view, some secondary data from the oil industry are also used when it is judged imminent.

Some information was not detailed due to the data confidentiality. Many factors can affect value creation of a company such as technology, weak business climate, political situation, etc. We did not cover all the above factors since the background information will be covered

in general and it is not the main focus of our research. However some of them are mentioned or discussed partially when it is necessary.

2. Technical Presentation

2.1 Introduction

In this section, we will give a short presentation of petroleum science and technology so the reader has the minimum required knowledge to understand the problems we will be discussing in this thesis. The science of petroleum is a multi-field area consisting of geology, physics, chemistry and many other fields of science. We will not dwell on a formal presentation but rather explain aspects by simple elaborations.

2.2 From Living Things to Energy Source

Petroleum includes only crude oil but in practice people talk about both crude oil and natural gas when using the term petroleum. Petroleum is a Greek word where petro means rock and oleum means oil. Petroleum is an energy source since it has the ability to burn and create heat. The heat can be used to warm up houses and other infrastructure, in addition to using it as a fuel in combustion engines by using mechanics of temperature and pressure to transform heat energy to mechanical energy.

Petroleum is organic (roughly: molecules containing carbon atoms) material from animal and plants that is trapped in rocks during hundreds of million years. The organic material has been trapped in the rocks, for instance, by rivers transporting dead animals and plants to the sea and the sea bottom with sediment deposits like sand and mud. Additional layers of sediments in the many millions of years to come have put the existing layers of sediments with organic material under heavy pressure and temperature. According to Hyne (2001) a minimum temperature of $65^{o}C$ is required to generate petroleum of the organic material but higher temperature will require less time to transform organic matter to petroleum (see figure below).
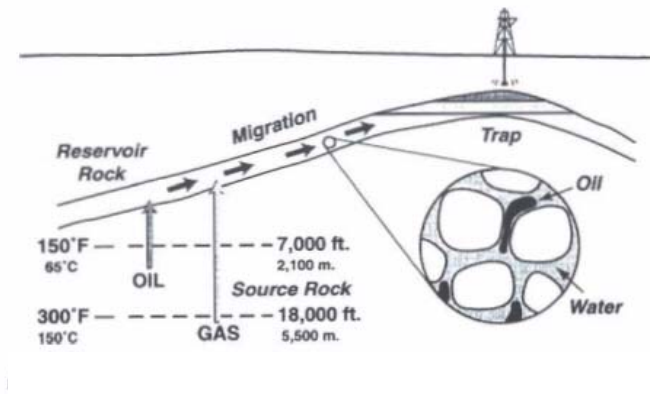
Figure 1 The oil then migrates upwards when the oil is being pumped.
Source: Hyne 2001

This process is generated in the source rocks that contain the organic matter with inorganic mineral grains like sand and mud. Black shale and dark limestone are the most usual source rocks that can have an organic matter content of 1 to 20 per cent. Note that some of the organic matter is lost due to decay (oxidation) in connection with oxygen contact with air on the surface or oxygen in water below surface. So to have the organic matter intact, it must be buried so fast by other sediments before decaying or left in water free of oxygen. However, many sedimentary basins are unproductive due to organic poor source rock or unsuitable depth level, and only about 50 per cent (Hyne 2001) of the organic matter will generate into oil.

The oil is contained with water and gas (liquid phase due to pressure) in rocks with pores. Petroleum is not, as many people believe, stored in large spaces below surface.
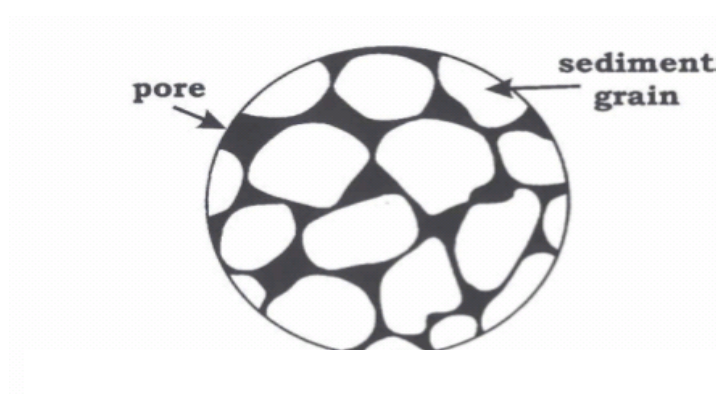
Figure 2 The oil is contained in the pores between the grains, Source: Hyne 2001

To extract oil from the pores of the rock, there are two different rock conditions that should be satisfied and are properties of a reservoir rock (often sandstone):

- High porosity (The number of pores in a rock for a given rock area is relatively high).

- High permeability (The size of the pores that limits the amount of oil through the pores is relatively large). Permeability is measured in Darcy, which is a relatively large unit.

Figure 3 Different critical values for porosity and permeability. *Source: Hyne 2001*

The petroleum in the reservoir rocks ends up there due to migration from, for instance, the shale source rock. Shale rock is little permeable so usually the organic matter there has no way to go. However, when the organic matter changes phase from solid to liquid, there is a decrease in density of the matter and the volume increases. This makes the shale rock crack so that the liquid organic matter can migrate to the reservoir rock (The shale rock returns to its previous condition when all the petroleum is tapped). In addition, the density of water is higher than hydrocarbons so the petroleum rises due to convection (the substance of less density is pushed upwards). If there is no trap, the petroleum will end up to the surface. On average, only 10 % (Hyne 2001) of the petroleum gets trapped. Usually, they are trapped in so-called anticlines or domes where the petroleum has nowhere to go. All upward direction is stopped by a cap rock that has little permeability and porosity.
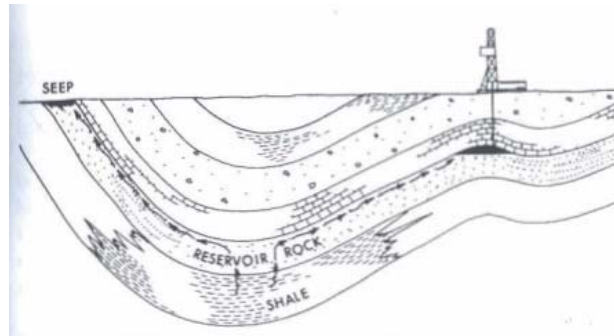
Figure 4 Petroleum migrating from the shale rock to the reservoir rock*, Source: Hyne 2001*

This trap rock can also be shale (chalk and permafrost are also possible) since it has little permeability and porosity. In the trap, for instance, the gas layer will be above the oil layer with the water in bottom like in the case of an anticline. However, there can also only be oil or gas with water in the anticline.
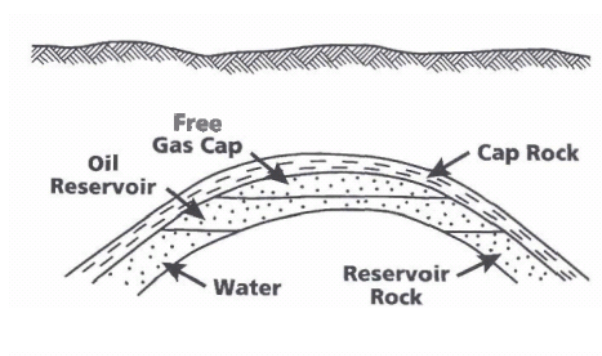
Figure 5 The different layers of rocks and reservoir*, Source: Hyne 2001*

When drilling into an anticline, the well must not go so deep that it passes the oil-water border. This can ruin the reservoir. The well will first prioritise pumping the oil up first since it has a higher market value than gas. When entering the reservoir rock in the anticline, the oil will rush up to the surface due to the high pressure. However, the pressure may get too low when reservoir is getting empty. The figure below shows how the pressure falls when more gas/oil is being extracted. A lower pressure means less production rate.
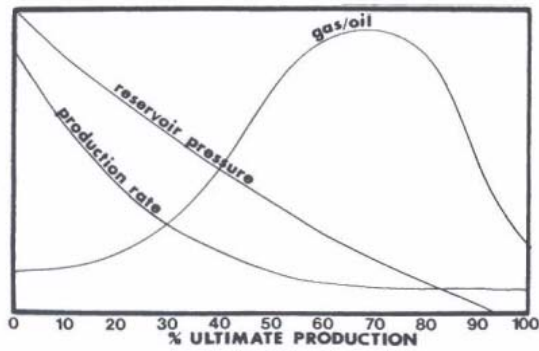
Figure 6 The pressure and production development of a reservoir*, Hyne 2001*

Then gas or water is pumped into the reservoir to keep the pressure up by using the density difference since the oil is pushed upwards, as illustrated in the figure below. Also steam heat and CO_2 are among other new methods that are being used. Especially the interest for CO_2 storage in reservoir and increasing pressure has been rising in the latest years.

It is normal at oil production sites on the Norwegian Continental Shelf (NCS) to have an oil recovery of 50 – 60 per cent, Lien (2004). However, the use of more advanced wells and pressure techniques has increased the oil recovery.
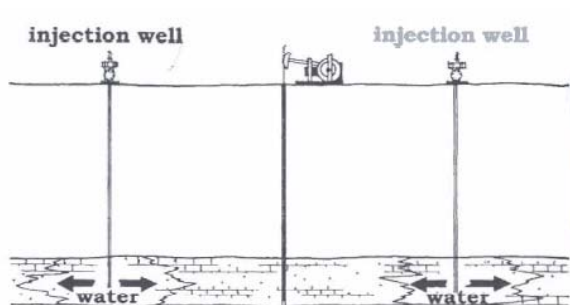
Figure 7 How the pressure is increased in the reservoir, *Hyne 2001*

Arriving to the surface, the oil is processed for separating water residuals and gas residuals from the oil as shown in the figure below. Especially, removing water is important since low temperature can turn water into ice (hydrates) and sabotage transportation of oil in pipeline

systems. This is also a problem that can occur at a refinery. For removing hydrates from the pipes the use of so-called MEG (Mono-Ethyne-Glychol) or TEG is normal to dissolve ice particles.
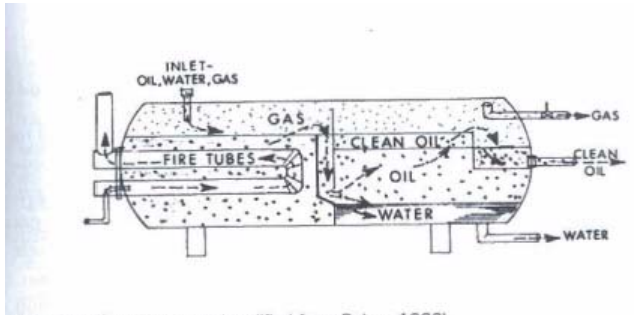
Figure 8 The petroleum from below can be separated by heat into gas, oil and water*, Source: Hyne 2001*

2.3 The Exploration of Petroleum

Extracting petroleum successfully from the world's resources is difficult due to engineering complexity. The total resource base of the world can be divided into this following matrix:

Resources	**Known**	**Unknown**
Profitable	Reserves	Potential Future Reserves
Unprofitable	Present Economic Unviable Resources	Present Unknown Economic Unviable Resources

*Table I***:** The resource base *(modified), Source: Fysikk og energiressurser (Holter et al, 1998)*

When official figures mention the estimated reserved of petroleum reserves, this estimated number includes only what is economic viable to extract and sell. The resource must be technical applicable to comply with competitive prices compared to other petroleum reserves

and alternative energy sources. In addition, the size of the field should be large so that the cash flow of future oil production remains high and sustainable for a long time. In the later years, smaller fields have been explored due to the high oil price and lack of large new reserve findings. Companies like PA Resources and DNO (Den Norske Oljeselskap) have specialised in exploiting the smaller fields that the largest companies find undesirable to invest in.

The level of exploring of new unknown resources on the NCS has peaked and is decreasing. The Norwegian oil companies are in a larger degree more looking abroad for new businesses. However, petroleum exploiting is a risky business. Geophysists say that of 10,000 (PTEK100 notes, 2004) potential findings of oil offshore, only 3-5 of them succeed in putting them into operations.

The first phase of the petroleum exploration starts with geological observations. Areas that are near other reserves with similar and favourable rock are often looked upon as potential reserve areas. Seismic investigations are then used to gather information about the rock layers below sea level. The seismic equipment use waves to find out what kind of rock structure the rock below has. Since there are different types of waves that vary in reflection speed due to different density of rock, the geologists can find out which rocks exists at which depth levels. The waves can be transmitted with the help of, for instance, air guns that compresses the water with air waves. The reflection waves are then picked up by the receivers behind the source.
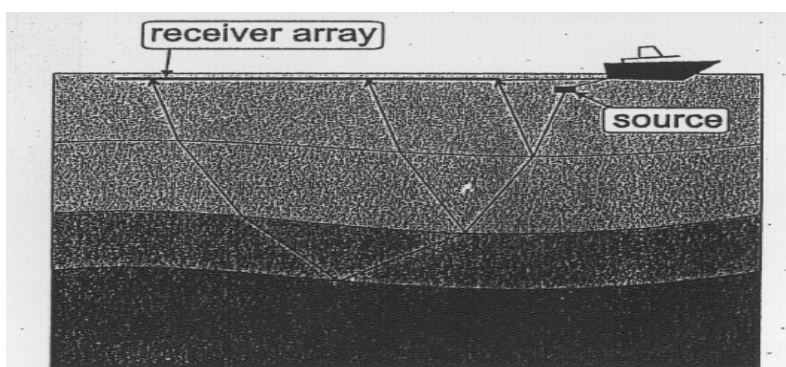
Figure 9 Seismic information gathering, *Source: PTEK100 Notes (Morten Jacobsen, UiB 2004)*

Information on shooting speed, reflection speed and refraction angle of the different waves like S-waves (*shear waves*) and P-waves (*compression waves*) are acquired. S-waves are slower than P-waves and cannot pass through a liquid or gas, by such giving extra information from the seismic investigations.

The study of the seismic information gives the geophysists input on the permeability, porosity and possible lithography (type of rock). Also, the use of 3D-seismic is popular when there is a large suspicion of petroleum resources below but this is very expensive.

The only way to know about the field with high certainty is to do a well drilling and logging. By logging a well an object is sent down where an attached transmitter sends different rays by radioactivity or electrical signals into the rock layers and an attached receiver records the reflected signals. The information on the rock types can be created as shown in the figure below. By noting the gamma rays, neutron level and measured density, one can with high accuracy get a picture of the different layers of the rock and its physics. Sometimes the well logging is done with the well drilling to save time and effort. Also, a *core sample* is taken to investigate the rock layers in detail. The total input information can then be used in a high-technology *cave* that simulates graphically how the rock structure of the potential reserve looks like[1]. Sometimes 4D seismic is being used to include a time dimension.

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[1] Note that this is many times impossible without having information from *well logging*.
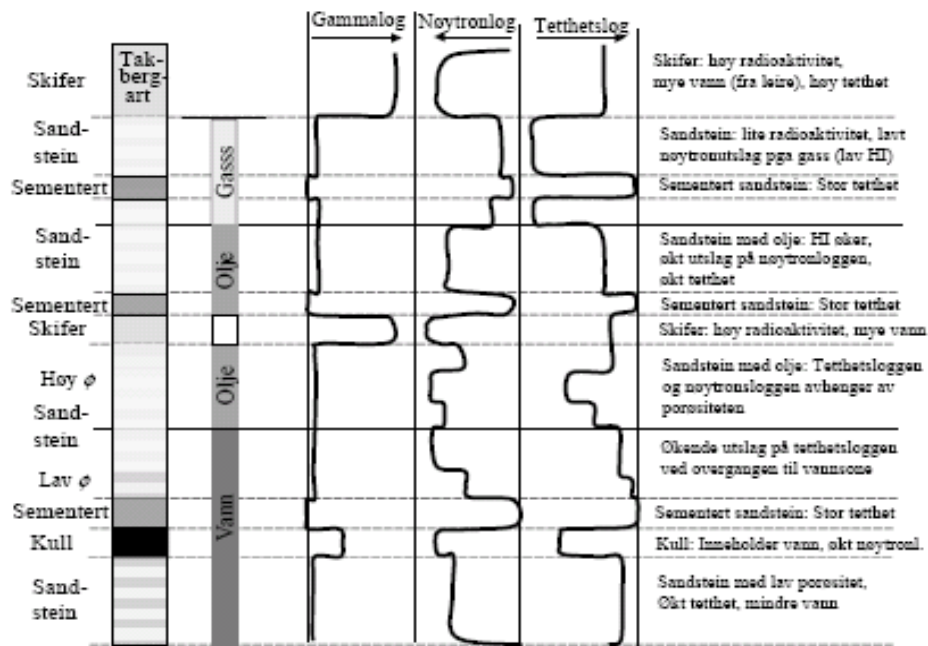
Figure 10 Logging can give information on gamma, neutron and density levels and thereby understanding the formation subsurface*, Lien 2004*

When there is a significant probability of petroleum in a field, the final test drilling will show if there is any petroleum below. The test drilling is done in areas where the geophysists have gathered information that indicate a high probability of a petroleum reserve. If the test drilling is successful with hitting petroleum, the oil company has to consider whether they want to apply for production permit and build the necessary infrastructure.

We will discuss how the petroleum is extracted and transported in the supply chain chapter.

2.4 Chemical Composition

The basic chemical components of petroleum are the hydrogen atom and the carbon atom. Sometimes petroleum components are referred to as hydrocarbons. However, other atoms can also be included in the petroleum molecules, for example sulphur, nitrogen and oxygen. The molecules consisting of carbon atoms are also called organic. The amount of non-hydrocarbon elements in the petroleum affect the quality and thereby the price.

The chemical composition of typical crude oil and natural gas

	crude oil	natural gas
Carbon	84–87%	65–80%
Hydrogen	11–14%	1–25%
Sulfur	0.06–2%	0–0.2%
Nitrogen	0.1–2%	1–15%
Oxygen	0.1–2%	0%

Figure 11 The chemical composition of crude oil and natural gas, *Hyne 2001*

2.4.1. Crude Oil

Crude oil consists of four different types of hydrocarbon groups:

- Paraffin (alkane) molecules are straight chains of five or more carbon atoms that have only saturated bonds. If the chain of carbons consists of more than 18 carbon atoms then it is a wax and forms a waxy crude oil. General formula: C_nH_{2n+2}.
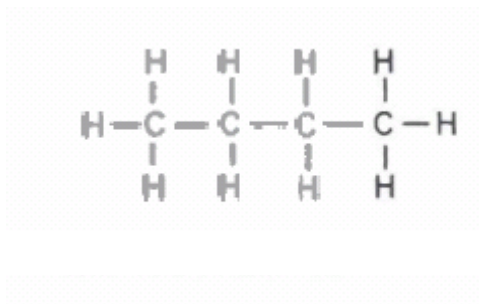
Figure 12: Paraffin Molecule (Hyne 2001)

- Naphthene (cycloparaffin) molecules are chains of closed circle with saturated bonds with carbon atoms. Also, these molecules consist of five carbon atoms or more in length. Since crude oil with high naphthene content usually gives high asphalt

content (heavier oil components) the value of such oils are lower. General formula: C_nH_{2n-6}.
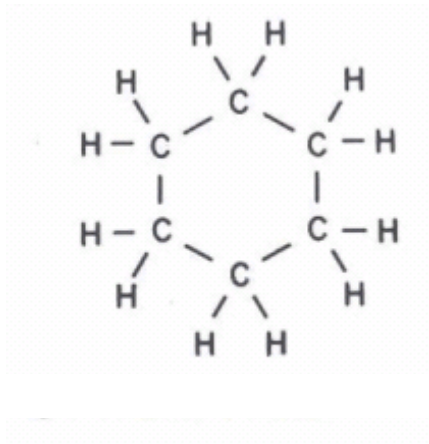
Figure 13: Naphthene Molecule (Hyne 2001)

- Aromatic (benzene) molecules are also chains of closed ring but there are one or more unsaturated bonds between the carbon atoms. The aromatic molecules consist of six or more carbon atoms in length. For a refinery, aromatic rich crude oil gives the highest octane gasoline and thereby being a valuable input. The refiner must pay a higher price for such crude oil.
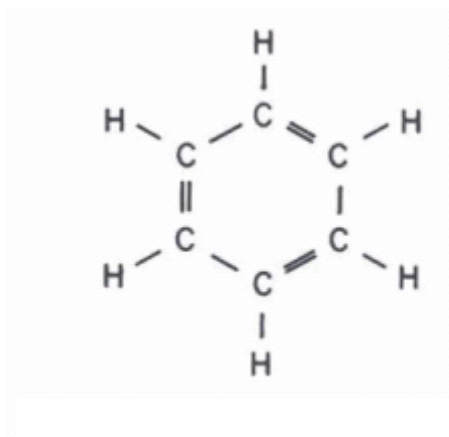
Figure 14: Aromatic Molecule (Hyne 2001)

- Asphaltic molecules are large with more than 40 carbon atoms and therefore have a high boiling point since it is so heavy. Under surface condition, the aspaltic molecules appear in a solid or a semi-solid phase.

Average and range of hydrocarbon series molecules in crude oil

	weight percent	percent range
paraffins	30	15 to 60
naphthenes	49	30 to 60
aromatics	15	3 to 30
asphaltics	6	remainder

Figure 15 The content of different Hydrocarbons in Crude Oil*, Hyne 2001*

The refining process (discussed in details later in this thesis) uses chemicals, catalysts, heat, and pressure to separate and combine the basic types of hydrocarbon molecules naturally found in crude oil into groups of similar molecules. The refining process also rearranges their structures and bonding patterns into different hydrocarbon molecules and compounds. Therefore it is the type of hydrocarbon (paraffinic, naphthenic, or aromatic) rather than its specific chemical compounds that is significant in the refining process

There are mainly two types of crude oil that a refinery uses: the asphalt based crude oil and the paraffin based crude oil. The asphalt based crude oil has little paraffin wax and its colour is black. The paraffin based crude oil has little asphalt and is a bit greenish. Also, a combination of these two crude oils is used.

The asphalt based crude oil will after a refinery process yield much high-grade gasoline and asphalt. While the paraffin based crude oil will yield much paraffin wax, lubricating oil and kerosene. The figure below shows the yield of the average crude oil but it is strongly dependent on type crude oil and refinery system.

Percent yield of crude oil

gasoline	46%
fuel oil	27%
jet fuel	10%
coke	5%
liquefied gasses	4%
petrochemical feedstocks	3%
asphalt	3%
lubricants	1%
kerosene	1%

Figure 16 The average yield of Crude Oil in percent, *Source: American Petroleum Institute*

The different crude oils have different properties regarding to density, sulphur content and viscosity. We will shortly discuss these different properties but first we present a table of the properties for the different *crude streams*. A crude stream consists of oil from one or several production sites that are blended as one product.

Properties of selected crude streams

crude stream	country	°API	S%	pour point
Arabian light	Saudi Arabia	33.4	1.80	-30°F
Bachequero	Venezuela	16.8	2.40	-10°F
Bonny light	Nigeria	37.6	0.13	+36°F
Brass River	Nigeria	43.0	0.08	-5°F
Dubai	Dubai	32.5	1.68	-5°F
Ekofisk	Norway	35.8	0.18	+15°F
Iranian light	Iran	33.5	1.40	-20°F
Kuwait	Kuwait	31.2	2.50	0°F
North Slope	USA	26.8	1.04	-5°F

Figure 17 Properties of different types of Crude Oil, *Source: Hyne 2001*

Other Hydrocarbons

Alkenes

Alkenes are mono-olefins with the general formula C_nH_{2n} and contain only one carbon-carbon double bond in the chain. The simplest alkene is ethylene, with two carbon atoms joined by a double bond and four hydrogen atoms. Olefins are usually formed by thermal and catalytic cracking and rarely occur naturally in unprocessed crude oil. Example of simplest Alkene: Ethylene (C_2H_4), Typical Alkenes with the same chemical formula (C_4H_8) but different molecular structures: 1-Butene and Isobutene

Dienes and Alkynes

Dienes, also known as diolefins, have two carbon-carbon double bonds. The alkynes, another class of unsaturated hydrocarbons, have a carbon-carbon triple bond within the molecule. Both these series of hydrocarbons have the general formula C_nH_{2n-2}. Diolefins such as 1, 2-butadiene and 1, 3-butadiene, and alkynes such as acetylene, occur in C5 and lighter fractions from cracking. The olefins, diolefins, and alkynes are said to be unsaturated because they contain less than the amount of hydrogen necessary to saturate all the valences of the carbon atoms. These compounds are more reactive than paraffins or naphthenes and readily combine with other elements such as hydrogen, chlorine, and bromine. Example of simplest Alkynes: Acetylene (C_2H_2), Typical Diolefins with the same chemical formula (C_4H_6) but different molecular structures: 1, 2-Butadiene and 1, 3-Butadiene.

Density of Crude Oil

Crude oil is commonly reported in terms of degrees API (American Petroleum Institute) to standardise equipment and procedures in the petroleum industry, obtained from the relative density using the following formula:

$$^{\circ}API = \frac{141.5}{d} - 131.5$$, where d is the specific density at 22°C.

Formula I: Calculation of API - the density of Crude Oil*, Source: Favennec 2001*

The density of water at 22°C is approximately 1 kg/m3, while the density of oil varies around 0.8 kg/m3. This gives clean water at 22°C and °API of 10 while crude oils mainly vary from 25 to 35. However, the °API of crude oil can vary as much as from 5 to 55. Crudes can be classified by gravity into:

- light crude oils, with gravities higher than 33°API

- medium crude oils, with gravities between 22 and 33°API

- heavy crude oils, with gravities less than 22°API

A light crude oil contains a higher proportion of the smaller molecules that make up the light and middle distillates than heavy crude. A heavy crude oil contains a high proportion of the very large molecules, present in fuel oil.

Heavy oils are cheaper since they yield much less of the valuable refined products like gasoline. In addition, heavy oils are more viscous, making them more difficult to transport in pipes. Often the heavy oils have to be heated up somewhat to make the transportation smoother. Sometimes the heavy oil is mixed with lighter oil like the mix of heavy oil from Grane production site with the much lighter oil from Oseberg. In this way, the seller of the oil can achieve a higher sales price than otherwise.

Sweetness of Crude Oil

The sulphur content in a certain crude oil decides if the oil is *sweet* or *sour*. Sweet crude oils have less than one per cent sulphur by weight and sour crude oils have more than one per cent sulphur. A refinery is willing to pay 1-3 USD per barrel (Hyne 2001) in premium for sweet crude oil. Thus sulphur is an unwanted element due to its ability of being an environmental hazard and harming refinery equipment.

Sulphur may be present in crude oil as hydrogen sulphide (H_2S), as sulphur compounds such as mercaptans, sulphides, disulfides, thiophenes, etc. or as elemental sulphur. Each crude oil has different amounts and types of sulphur compounds but as a rule the proportion, stability, and complexity of the compounds are greater in heavier crude-oil fractions. Hydrogen sulphide is a primary contributor to corrosion in refinery processing units. Other corrosive substances are elemental sulphur and mercaptans. Moreover, the corrosive sulphur compounds have an obnoxious odour. Pyrophoric iron sulphide results from the corrosive

action of sulphur compounds on the iron and steel used in refinery process equipment, piping, and tanks. The combustion of petroleum products containing sulphur compounds produces undesirables such as sulphuric acid and sulphur dioxide. Catalytic hydro treating processes such as hydrodesulphurisation remove sulphur compounds from refinery product streams. Sweetening processes either remove the obnoxious sulphur compounds or convert them to odourless disulfides, as in the case of mercaptans.

Pour Point of Crude Oil

As mentioned earlier, if the paraffin molecules are 18 carbon atoms or more in chain they are waxes. A crude oil with significant amount of wax is called a waxy crude oil. A waxy crude oil is liquid in the reservoir where it is very hot but when arriving to the surface it cools down and becomes solid. This can stop the flow in pipes and force maintenance work. The amount of wax is indicated by the pour point of oil. The pour point gives the lowest temperature of the crude oil where the crude oil goes from liquid phase to solid phase, and can vary between minus 60ºC to plus 52ºC.

On the NCS, heat exchangers in the transporting pipeline system are used to heat up cold crude oil with the heat from a warm crude oil. By this way, one can secure the flow of crude oil in the pipelines.

Other Elements of Crude Oil

Oxygen compounds such as phenols, ketones, and carboxylic acids occur in crude oils in varying amounts.

Nitrogen is found in lighter fractions of crude oil as basic compounds, and more often in heavier fractions of crude oil as non-basic compounds that may also include trace metals such as copper, vanadium, and/or nickel. Nitrogen oxides can form in process furnaces. The decomposition of nitrogen compounds in catalytic cracking and hydro cracking processes forms ammonia and cyanides that can cause corrosion.

Metals, including nickel, iron and vanadium are often found in crude oils in small quantities and are removed during the refining process. Burning heavy fuel oils in refinery furnaces and boilers can leave deposits of vanadium oxide and nickel oxide in furnace boxes, ducts,

and tubes. It is also desirable to remove trace amounts of arsenic, vanadium, and nickel prior to processing as they can poison certain catalysts.

Crude oils often contain inorganic salts such as sodium chloride, magnesium chloride, and calcium chloride in suspension or dissolved in entrained water (brine). These salts must be removed or neutralized before processing to prevent catalyst poisoning, equipment corrosion, and fouling. Salt corrosion is caused by the hydrolysis of some metal chlorides to hydrogen chloride (HCl) and the subsequent formation of hydrochloric acid when crude is heated. Hydrogen chloride may also combine with ammonia to form ammonium chloride (NH_4Cl), which causes fouling and corrosion.

Carbon dioxide may result from the decomposition of bicarbonates present in or added to crude, or from steam used in the distillation process.

Some crude oils contain naphthenic (organic) acids, which may become corrosive at temperatures above 232° C when the acid value of the crude is above a certain level.

2.4.2. Natural Gas

Natural gas consists of the molecules with less than five carbon atoms in chain. There are four types of natural gas depending on the amount of carbon atoms in the chain (Hyne 2001):

- Methane (CH_4), 70 to 98 per cent of natural gas amount.

- Ethane (C_2H_6), 1 to 10 per cent of natural gas amount.

- Propane (C_3H_8), trace to 5 per cent of natural gas amount.

- Butane (C_4H_{10}), trace to 2 per cent of natural gas amount.

They are all paraffin type of hydrocarbons and their percentage varies from field to field. However, the methane remains to be the dominating type of hydrocarbon in most fields. In some fields the reservoir contains almost only methane.

The methane gas is sold for home and industry burning purposes. Propane and butane have the ability of creating more heat energy than methane so it is sold separately at a higher price. LPG, liquefied petroleum gas, is made from propane gas.

Also natural gas contains impurities like crude oil. The impurities that do not burn are called *inerts*. Common inerts are water vapour, nitrogen and CO_2. Since the inerts do not burn, they degrade the value of the natural gas. They can be used as a part of the enhanced oil recovery plan by injecting those gases into reservoir to increase pressure. Statoil has been a pioneer to use CO_2 gas as an injection gas to increase pressure. However, also ordinary natural gas is used as an injection gas at many fields since the price of oil favours oil sale rather than gas sale. Note that also natural gas can be sweet or sour, depending on the amount of sulphur.

Due to the high pressure in the reservoir (often hundreds times the atmospheric pressure), the natural gas is often dissolved in the crude oil. Since the pressure increases with depth due to more layers of rock pressuring down on the existing reservoir, the amount of dissolved natural gas that can be dissolved in crude oil increases. However, when the crude oil is pumped up, the pressure on the natural gas is relieved so that the natural gas begins to bubble (*solution gas*). However, natural gas also occurs as *non-associated gas* (gas that is not in contact with crude oil below surface). This non-associated gas consists mostly of methane. *Associated gas* appears as gas in the cap above the crude oil, by such being in contact with crude oil. Associated gas contains both methane and other types of hydrocarbon.

Condensate is created in gas reservoirs of high temperature where short-chained liquid hydrocarbons with five to seven carbon atoms in chain length occur as gas. When the gas is pumped up, the temperature decreases due to the fall in pressure so the liquid hydrocarbons condense out of the gas. The *condensate* has an API of 45 to 62 degree and is also called natural gasoline. Condensate is used to increase the API of the crude oil and its volume. The refinery must pay almost the same amount for condensate as crude oil. Because of the low octane level, the condensate must be mixed with a high octane level gasoline made from cracking at refinery. Usually, this makes the condensate price a bit lower than the crude oil price.

Natural gas with condensate is called wet gas and dry gas when without condensate. Condensate with butane, ethane and propane (all removed from natural gas) is called *natural gas liquid* (NGL).

2.4.3. The Difference between Crude Oil and Natural Gas

The difference between crude oil and natural gas is the size of the hydrocarbon molecules. Given surface temperature and pressure, the amount of carbon atoms of one to four will occur as gas. So natural gas is a mixture of different molecules with one to four carbon atoms. However, by lowering the temperature or increasing the pressure of natural gas to a certain point the gas will appear as fluid. Molecules with five or more carbon atoms will appear as liquid in natural state. However, by increasing the temperature or decreasing the pressure to a certain point crude oil will appear in gas phase.

Crude oil consists of more than 100 different types of hydrocarbon molecules that can have 5 to more than 60 carbons in length. This is due to the molecules do not necessarily have only one shape like a straight chain of carbon atoms but also, for instance, chains that form circles. The carbon atoms are inter-connected to each other and the molecules can consist of single bonds between carbon atoms, or one or more double bonds between carbon atoms. Hydrocarbon molecules with only single bonds are so-called saturated molecules and molecules with one or more double bonds are unsaturated molecules. This difference is essential to understand different components of crude oil.

2.4.4. Refined Products

Gasoline

The most important refinery product is motor gasoline, a blend of hydrocarbons with boiling ranges from ambient temperatures to about 205°C. The important qualities for gasoline are octane number (antiknock), volatility (starting and vapour lock), and vapour pressure (environmental control). Additives are often used to enhance performance and provide protection against oxidation and rust formation. Gasoline is one of the most high-valued products of the refinery due to high margins and large volumes.

Liquefied Petroleum Gas (LPG)

The gases obtained from crude oil distillation are ethane, propane, and n-butane isobutene. These products cannot be produced directly from the crude distillation and require high-pressure distillation of overhead gases from the crude column. That is why the transportation

of LPG is very expensive and limited in size. C3 and C4 particularly are recovered and sold as liquefied petroleum gas (LPG), while C1 and C2 are generally used as refinery fuel. LPG is produced for use as fuel, and it is an intermediate material in the manufacture of petrochemicals.

Naphtha

C5 -205°C ASTM (American Society for Testing and Materials) cut is generally termed naphtha. There are many grades and boiling ranges of naphtha. Naphtha is used as feedstock for petrochemicals either by thermal cracking to olefins or by reforming and extraction of aromatics. Also some naphtha is used in the manufacture of gasoline by a catalytic reforming process.

Kerosene

Kerosene is a refined middle-distillate petroleum product that finds considerable use as a jet fuel and around the world in cooking and space heating. When used as a jet fuel, some of the critical qualities are freeze point, flash point, and smoke point. Commercial jet fuel has a boiling range of about 190°-274°C, and military jet fuel 54°-288°C. Kerosene, with less-critical specifications, is used for lighting, heating, solvents, and blending into diesel fuel.

Distillate Fuels

Diesel fuels and domestic heating oils have boiling ranges of about 205°-371°C. The desirable qualities required for distillate fuels include controlled flash and pour points, clean burning, no deposit formation in storage tanks, and a proper diesel fuel cetane rating for good starting and combustion. Diesel grades have an ASTM end point of 343-371°F. Diesel fuel is a blend of light and heavy distillates and has an ASTM boiling range of approximately 177-357°C.

Vacuum Gas Oil

Vacuum gas oil is the distillate boiling between 371 and 538°C. This is not a saleable product and is used as feed to secondary processing units, such as fluid catalytic cracking units, and hydro crackers, for conversion to light and middle distillates.

Residual Fuel Oil

Hydrocarbon material boiling above 538°C is not distillable and consists mostly of resins and asphaltenes. This is blended with cutter stock, usually kerosene and diesel, to meet the viscosity and sulphur specifications of various fuel oil grades. Many marine vessels, power plants, commercial buildings and industrial facilities use residual fuels or combinations of residual and distillate fuels for heating and processing. The two most critical specifications of residual fuels are viscosity and low sulphur content for environmental control. Residuals have little value for refinery that is without a cracking capacity to convert the large molecules to smaller. For those refineries that do have this option, buying cheap residuals to make high-value refined products can be very lucrative.

Coke and Asphalt

Coke is almost pure carbon with a variety of uses from electrodes to charcoal briquettes. Asphalt, used for roads and roofing materials, must be inert to most chemicals and weather conditions. These two products are low-value products since they have low sales prices in the market.

Solvents

A variety of products, whose boiling points and hydrocarbon composition are closely controlled, are produced for use as solvents. These include benzene, toluene, and xylene.

Petrochemicals

Many products derived from crude oil refining, such as ethylene, propylene, butylenes, and isobutylene, are primarily intended for use as petrochemical feedstock in the production of plastics, synthetic fibres, synthetic rubbers, and other products.

Lubricants

Special refining processes produce lubricating oil base stocks. Additives such as demulsifies, antioxidants, and viscosity improvers are blended into the base stocks to provide the characteristics required for motor oils, industrial greases, lubricants, and cutting oils.

The petroleum products are classified in a wide variety of different ways within oil industry:

- Refiners distinguish between light products (whose molecules have a low number of carbon atoms, i.e. gas and gasolines), middle distillates (kerosene, automotive gas

and gasolines) and heavy products (with long carbon chain molecules, i.e. heavy fuel and bitumen).

- For bulk transport, transport are categorised as white products, i.e. motor gasoline, jet fuel, automotive and heating gas oil; and black products i.e. fuel oil and bitumen.

- Dealers distinguish between main products and specialities, however the boundary is not clear. For main products, volumes are large and differentiation is limited so the product range is not extensive. Margins for main products, e.g. motor fuels, jet fuel, heating gas oil and heavy fuel oil including bunkers, are relatively low. Sales of specialities, e.g. LPG, aviation gasoline, lubricants and bitumen, are low in terms of volume but give a high added value, either in terms of the product itself or the service provided.

2.5 Measurement

Measurement of crude oil and natural gas is quite different due to different properties. Crude oil is measured in barrels and one US barrel equals approximately 159 litres. Barrel is always the unit when noting the price of oil. However, when the production and processing figures of crude oil is presented, cubic meter (m^3) is the most often used unit for describing volume. One cubic meter equals to 6.29 barrels of oil. Note that when working with volume, the same amount of crude oil can have a larger volume when the density decreases like when the temperature increases. By this principle of physics, a crude oil with higher temperature will have a larger volume than one with lower temperature. Pressure can also change the volume. And finally, the API gravity of the oil will adjust the volume. Higher API gravity means lower density and as such larger volume.

Also natural gas varies in volume with temperature and pressure when measured in cubic meters. The cubic meter as a unit is often a larger number for natural gas than crude oil when compared. One often speaks of million cubic meters of produced gas but seldom about the same amount of crude oil. Note that one cubic meter equals 35.32 cubic feet.

Sometimes the unit of measure is Btu (British thermal unit) that measures the heat content in both crude oil and natural gas. One Btu is the amount of heat that is given of by burning one

wooden match. The pipeline natural gas is about 1000 Btu per cubic feet, however this number varies with the amount of inerts (mentioned earlier) and the hydrocarbon composition. Sometimes the pipeline contract specifies a Btu adjustment clause where the price is adjusted for the Btu, Hyne (2001).

Like we said previously, the figures for natural gas in cubic meters is much higher than crude oil in cubic meters. The energy in one cubic meter of crude oil is much higher than in one cubic of natural gas. Hyne (2001) says that: "the Btus in one barrel of crude oil equals the Btus in 6040 cubic feet of average natural gas". This is also called *barrel of oil equivalent*. This unit can vary from place to place, depending on the oil and gas composition.

As a final word, it is worth mentioning that cubic meters are often measured in standard terms so that productions from different sites or processing sited are comparable. The standard cubic meter is mentioned at a temperature approximately 15ºC and at pressure of 1 bar (equivalent of one the pressure on the surface).

3. Organization Structure

3.1 Introduction

Refining is a key link in the oil value chain. It is where crude oil is transformed into products that can be used for transport and industrial use, etc. Refineries can be divided in two groups:

- Refineries belonging to integrated companies with oil production, refining and marketing. Such companies include:

  a. International companies often with refinery capacity exceeding their crude oil production.

  b. National oil companies of producing states, which have built refineries to meet the requirements of their domestic markets for their products.

- Independent refineries owned by companies with neither their own crude oil production nor marketing networks for their products. There are a number of such refineries, for example in Italy. They often operate as processing refineries, treating crude oil for third parties at an agreed processing fee.

Mongstad Refinery belongs to integrated companies because it is owned in partnership by Statoil ASA (79 %) and Shell (21%). As Mongstad is not an independent refinery, Mongstad operations are interdependent of Statoil ASA's other operations in general. Therefore in order to get insight into the way tasks and operations are organised and conducted at Mongstad, we first want to explore the relationship between Mongstad and other parties in Statoil ASA, and thereafter the way operations are organised at Mongstad. To do so, we will use the organization structure of Statoil ASA.

3.2 Organisation Structure Theory

The information presented in this section is based on Favennec (2001) and Bedeian and Zammuto (1991).

The word organization has two different meanings in this area of study. First, it is defined as an institution or functional group such as a business or a society. Another definition refers to a process of organising. This is the way in which work is arranged and allocated among members of an organisation so that the goals of the "organisation" can be most efficiently achieved. This is done by breaking down jobs or dividing up the work that is done among areas and employees and linking together these areas and jobs in order to form a unified whole organization.

Organisational Structure (OS) can be seen as the framework that defines reporting relationships between different positions within an organization. It shows the hierarchy, levels of authority and responsibility and an organization's formal channels of communication. An efficient structure facilitates the delegation of authority, coordination and smooth intertwining of employees, communication systems, allocation of resources, and decision-making within the organization. The choice of OS depends on the organisation's area and methodology of work and operation as well as different stages of its lifecycle. The organisation structure can be changed in accordance with the needs of the organisation.

A clear structure makes it easier to see which part of the business that is responsible of a given task. There exist many ways to structure a business. Bedeian and Zammuto (1991) distinguish three main organisation structures. These are the functional structure, the divisional structure and the matrix structure.

Functional Structure

In this structure, jobs and activities are grouped together on the basis of the functions required to achieve the organizational objectives. For this purpose, all the functions to be performed are classified into basic, secondary and supporting functions according to their nature and importance. This structure has several advantages. It promotes specialisation as each department focuses on its own work and facilitates specialized learning that enables to

better maintaining performance standards. Accountability is created as one is responsible for the section and this helps effective environment monitoring. It makes the work clear because one knows his and others' roles and also facilitates communication inside each function. There are several disadvantages of the functional structure. This structure may lead to high differentiation that may create barriers to communication across different functions. Employees may care more about their own function than about organisation as a whole. In this case, departments may resist to changes that can have good effects on the organisation as a whole but with little or no clear effect on a given function. In large organisations, coordination of different functions may take more time and resources.

Divisional Structure

A divisional structure groups workflow interdependencies together. This increases an organization's ability to simultaneously manage operations in several markets. Unit grouping in this structure is referred to as *market based grouping*. This grouping can be based on product, location or customer.

- **Geographical structure:** as a firm grows, it sometimes needs to set up branches in other locations. A firm may wish to allow these branches to work as autonomous units, this means that they are like little organisations of their own making local decisions but guided by the policy decisions made at the head office. This structure facilitates a clear focus on the market geographic segment that helps to get effective communication between firm and local customers and thereafter better meet customers' needs. This structure can lead to a positive competition between geographical units. However, there is a duplication of jobs and resources in this structure type that may lead to high expenses. Conflicts between local and central management may also be hard to avoid.

- **Structure by Product or Customer:** in an organisation that has different products or different customers, jobs may be grouped on the basis of product line or on the basis of common customers. In these types of functions, there is a clear focus on market segment that helps meet customer needs. There is a positive competition between different divisions and a better control as each division can act as a separate

profit centre. However, there may be a duplication of functions for example each division may have its own sales force.

The Matrix Structure:

Sometimes an organisation needs to run according to the projects to be conducted. In these situations people usually work together in a team to achieve their projects goals. A person working on a project would have two managing directors to report to, the director of the department that they work in and the leader or manager of the particular project that they are working on at the moment. A project may cover some or all of the organisation's departmental areas. A matrix arrangement can allow an organisation to benefit from the contributions of highly skilled specialists that the organization sometimes cannot afford to assign exclusively to one particular project. However, it can be extremely difficult to manage or work within from an administrative standpoint. If for example a project manager has different ideas or priorities than the department managers, the employee can be caught in a very uncomfortable position. Sometimes the enforcement of work deadlines and priorities can primarily suggest a persuasion personality from the managers. This may lead to conflicts between managers, and between managers and employees.

In the following sections, we will present the organisation structure of Mongstad and other departments in Statoil by using their organisation charts.

3.3 Organisation chart for Statoil

The information presented in this section is based on data collected from different meetings at Statoil Mongstad with Signy Midtbø Riisnes, Eivind Blindheim and from www.statoil.com.

At Mongstad, there are four entities: Mongstad Refinery, Mongstad Crude oil terminal, Vestprosess and Product technology and customer service centre. Before describing these entities, we want to elucidate the position they have in Statoil. We will do that by describing the organisation chart for Statoil from the main office down to Statoil Mongstad. Here, we consider only the main sections or divisions of Statoil that have direct connections with

Statoil Mongstad. The objective of this part is to help the reader to get insight in the relationship between Mongstad and other sections in Statoil because these parties will be often used or mentioned in this work.

In Statoil, departments and sections are normally referred to using a combination of letters usually the initials of the department names. These initials are important as most of the internal documents refer to sections by these 'letters codes'. These letters are found in the chart in the parentheses after the names of departments or sections. By referring to a department using the combination of letters, they normally use all the acronyms from the main department down to the section considered i.e. Statoil Mongstad is referred to as F&M FOR SM.
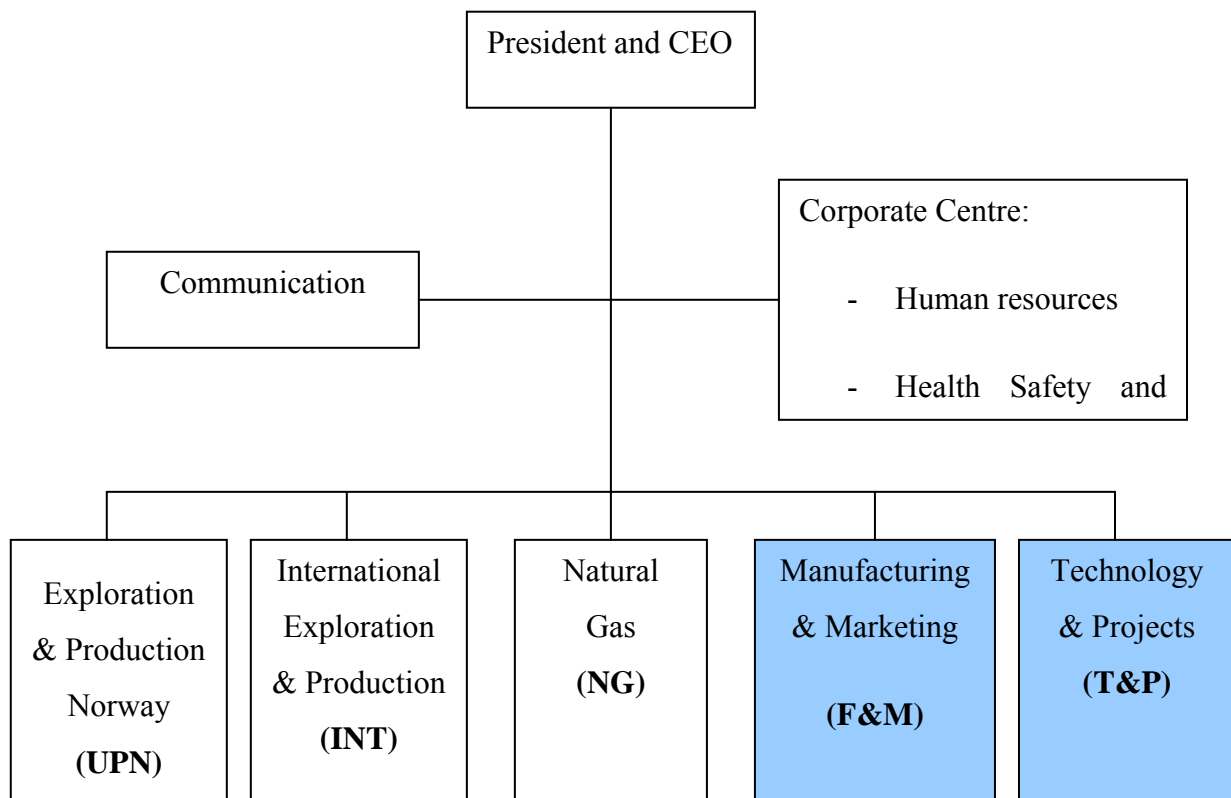
Figure 18 Organisation chart for Statoil (Headquarter). *Source: Statoil Mongstad internal web*

Figure 18 shows the main departments of Statoil ASA. These departments are designed using different organisation structures. There is a functional structure as jobs are grouped based on type of work or task for examples Manufacturing & Market department, Technology & Projects department, and Exploration & Production departments. There is

also a structure by product as jobs are grouped according to a product line, which is shown by the Natural gas department. Finally, we have a geographical structure because jobs are grouped based on locations. In this case, Norway's exploration is separated from other areas' explorations; we have Exploration & Production Norway department, and International Exploration and Production. By using different organisation structures, Statoil may benefit from advantages of these structures.

Procurement and logistics of materials will be discussed in the supply chain chapter. The procurement and logistics of all products and services that Statoil needs for its new projects, operations and maintenance of facilities such as cables, screws, food, and pipes is organised under the Technology and Projects department (P&T). In addition to this, there are local entities connected to different facilities. Statoil Mongstad has its 'acquisition entity' (anskaffelsesenhet) under Maintenance, Modifications and projects section (VMP) in the new organisation (see figure 23).

As the emphasis of this work is on Statoil Mongstad, which is found under the Manufacturing and Marketing department (F&M), we continue by looking at the Manufacturing and Marketing department. Therefore, we will not show organisation charts of other departments of Statoil ASA.

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                    ┌─────────────────────┐
                    │   Manufacturing &   │
                    └──────────┬──────────┘
                               │
        ┌──────────────────────┼──────────────────────┐
┌───────────────────┐  │              ┌───────────────────┐
│ Oil Sales Trading │  │              │   Business Dev.   │
│  and              │  │              │                   │
│ Supply (O&S)      │  │              │ Strategy & Projects│
└───────────────────┘  │              └───────────────────┘
┌───────────────────┐  │              ┌───────────────────┐
│ Business Controlling│ │             │ Health, Environment│
└───────────────────┘  │              └───────────────────┘
┌───────────────────┐  │              ┌───────────────────┐
│ Human Resources (HR)│ │             │   Retail Europe   │
└───────────────────┘  │              └───────────────────┘
┌───────────────┐ ┌──────────────┐ ┌──────────────────┐
│ Manufacturing │ │ Retail (DET) │ │ Nordic Energy (NE)│
│  (FOR)        │ │              │ │                  │
└───────────────┘ └──────────────┘ └──────────────────┘
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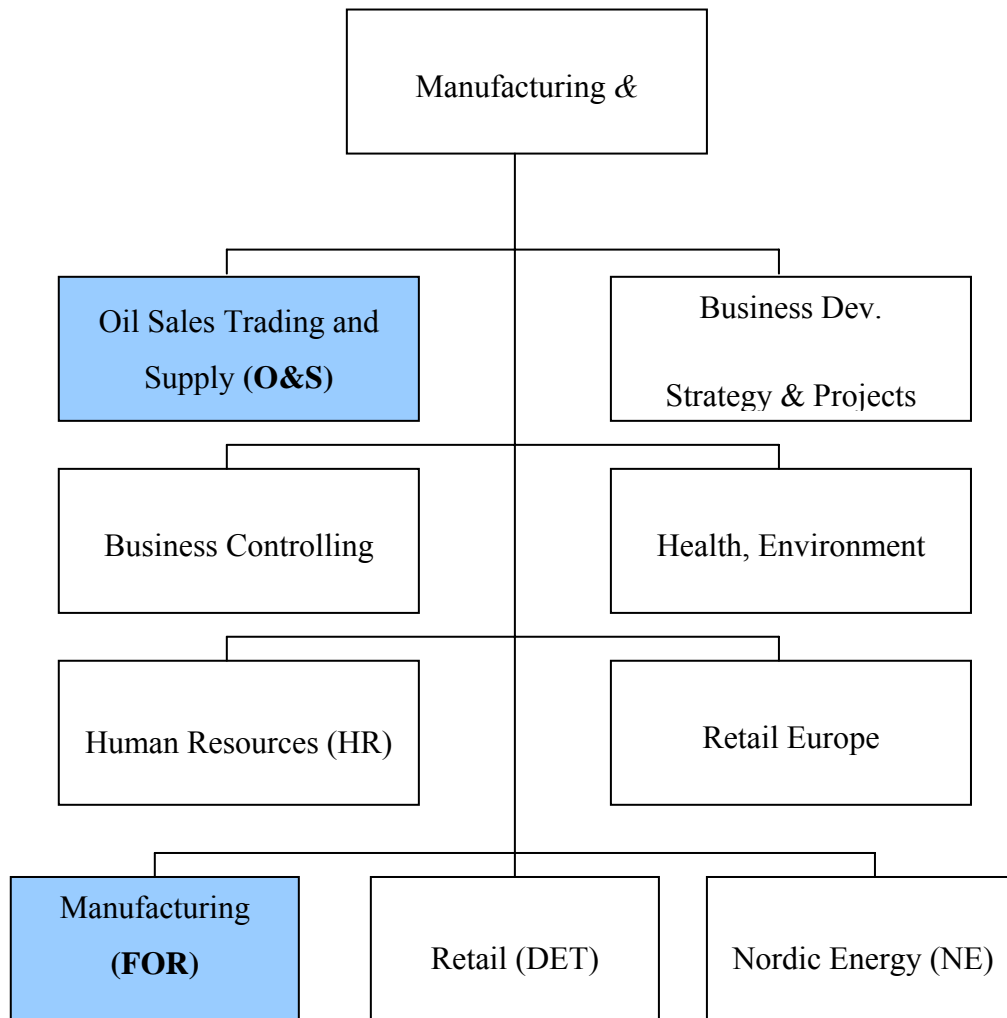
Figure 19 Organisation chart for Manufacturing & Marketing (F&M).
Source: Statoil Mongstad internal web

The Manufacturing and Marketing department (F&M) is divided also in different divisions. F&M is designed according functional structure such as Business Controlling & Support department versus Human Resources department. A geographical structure is applied for example Retail Europe division versus Retail department. We can also see a structure by product such as Nordic Energy division.

Under F&M, we consider only two divisions. The Oil Sales Trading and Supply that will be later referred to as *'O&S'* and Manufacturing referred to as *'FOR'*. We consider these two divisions because Mongstad Crude oil terminal is under the O&S department while other entities: Vestprosess, Product Technology and Customer Service centre, and Mongstad Refinery are under Manufacturing department. We will first look at the organization chart for F&M FOR, and thereafter the O&S's organisation chart.

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                    ┌──────────────────────┐
                    │    Manufacturing     │
                    └──────────────────────┘
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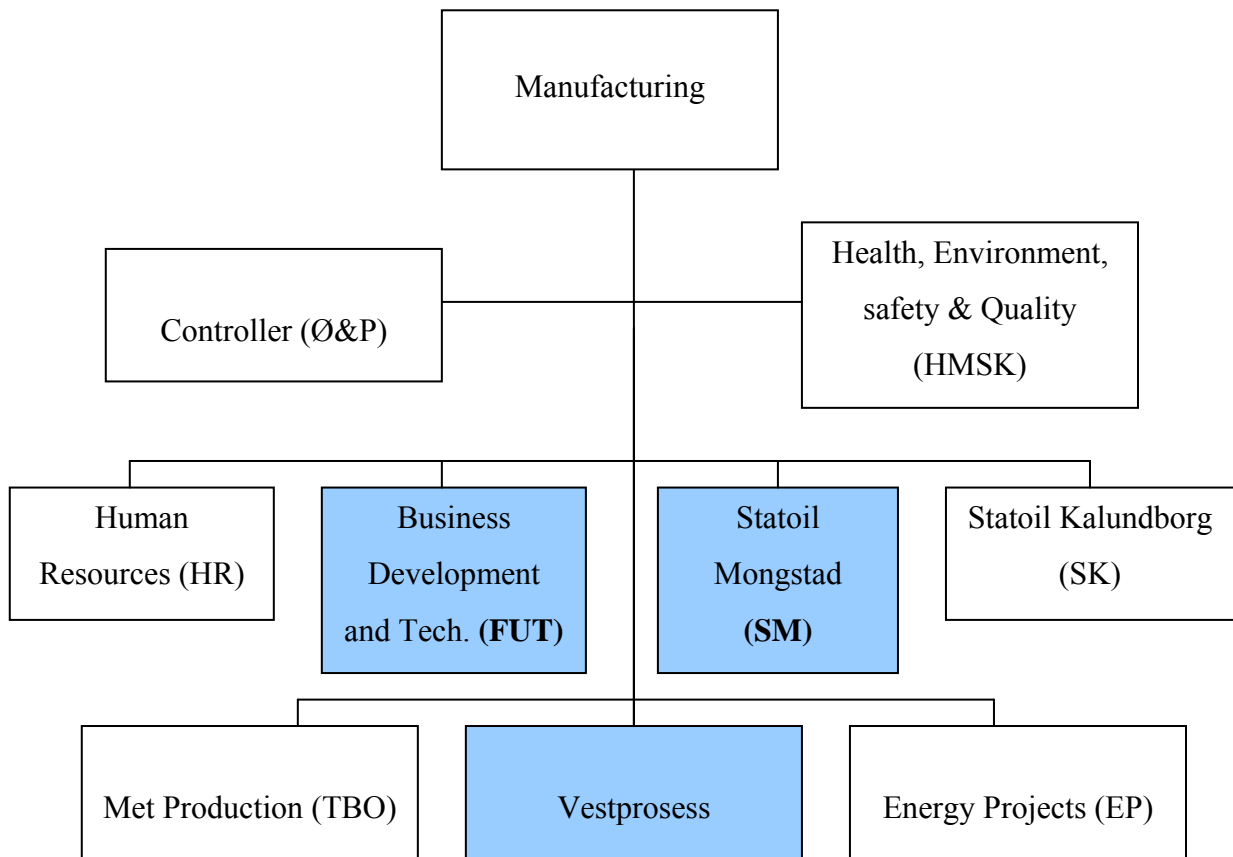

Figure 20 Organisation chart for Manufacturing (F&M FOR). Source:
Statoil Mongstad internal web

The above organisation structure of Manufacturing (figure 20) is designed using a functional structure (example: Human resources), the geographical structure (example two refineries at two different locations: Statoil Mongstad versus Statoil Kalundborg), and the product structure (example: Energy Projects).

Three entities at Mongstad are under the F&M FOR department. On figure 20, we can see Vestprosess and Statoil Mongstad (the refinery). Product technology and customer service (*PKS*) is under Business Development and Technology (FUT).

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┌─────────────────────────────────────┐
│      Oil Sales Trading and Supply    │
└─────────────────────────────────────┘
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┌─────────────────────────────┐   ┌─────────────────────────────┐
│ -Business Processes &   │   │ -Strategy, Analys. Business │
│ Info. Systems (BIS)   │   │ Develop (SAB)   │
│   │   │   │
│ -Human Resources (PO)   │   │ -Finance and Risk Control   │
│   │   │ (ØRK)   │
└─────────────────────────────┘   └─────────────────────────────┘

┌─────────────────────────────┐   ┌─────────────────────────────┐
│ Statoil Marketing &   │   │   │
│ Trading -US (SMT)   │   │ Processing (PROS)   │
└─────────────────────────────┘   └─────────────────────────────┘

┌─────────────────────────────┐   ┌─────────────────────────────┐
│ Natural Gas Liquid   │   │ Crude Oil (RÅ)   │
│ (NGL)   │   │   │
└─────────────────────────────┘   └─────────────────────────────┘

┌─────────────────────────────┐   ┌─────────────────────────────┐
│ Products (PRO)   │   │ Statoil Asia Pacific   │
│   │   │ (STAP)   │
└─────────────────────────────┘   └─────────────────────────────┘
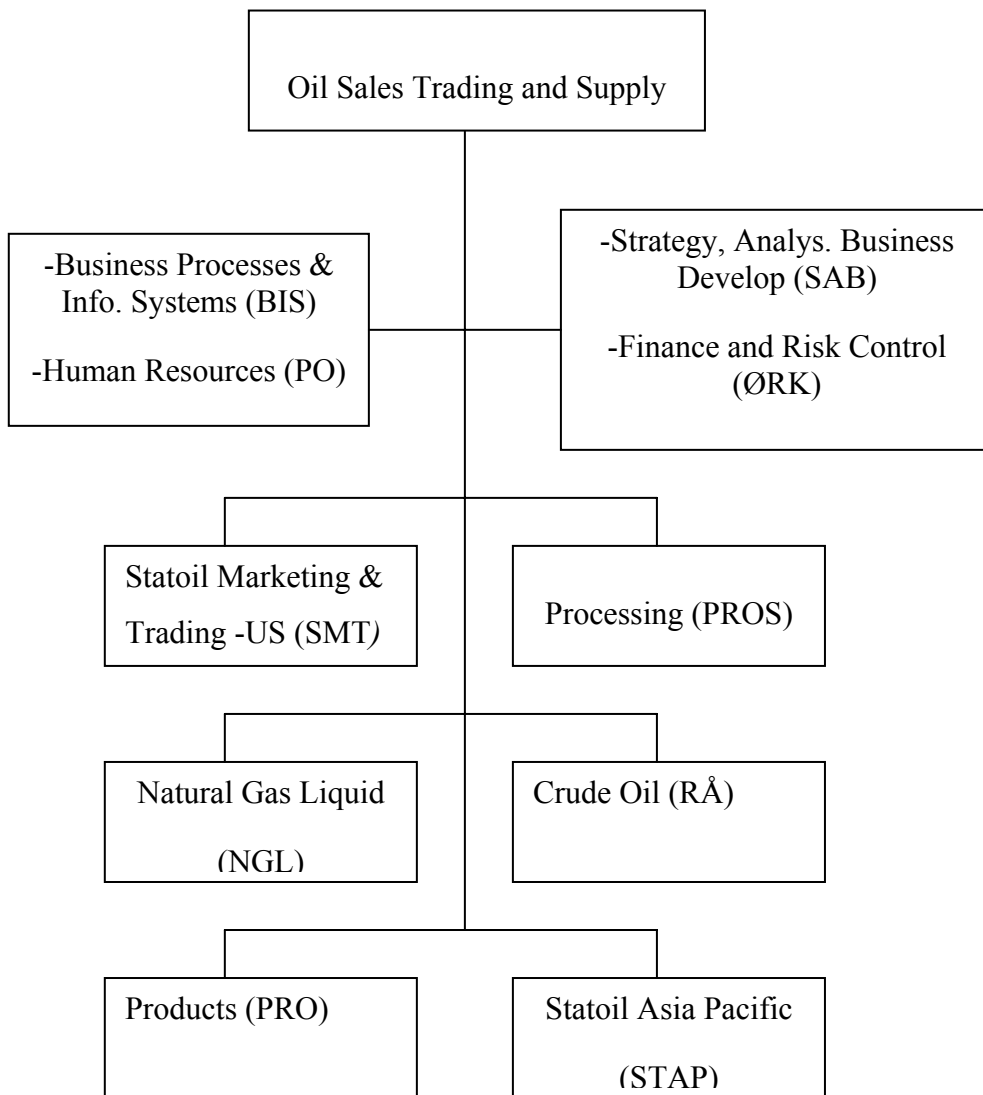
Figure 21 Organisation chart for Oil Sales Trading and Supply (F&M O&S).
Source: Statoil Mongstad internal web

O&S (figure 21) is also organised using functional structure (example: Finance and Risk Control versus Processing), the geographical structure (example: Statoil Marketing & Trading –US versus Statoil Asia Pacific) and the product structure (example: Crude Oil versus Natural Gas Liquid).

This O&S department is responsible for marketing, buying and selling crude oil and other products, making delivery schedule, making contracts with customer, and many more activities connected to sales and purchase of products. Mongstad Crude oil Terminal is under this department. This department has a close collaboration with Statoil Mongstad as it is in charge of purchasing crude oil, and selling intermediates and refined products. Everything that has to do with procurement and logistics of oil value chain, crude oil, components and

refined products such as contracts, buying, selling, storage and transport is under O&S for all in Statoil Group.

3.4 Organisation at Mongstad

As mentioned above, there are four entities at Mongstad. In this section, we look at each entity and collaboration between them.

3.4.1 Statoil Mongstad (MRDA)

The oil refinery at Mongstad is ranked as the largest refinery in Norway, and medium-sized in Europe. It is owned 79 per cent by Statoil and 21 per cent by Shell. MRDA is a modern, highly upgraded facility with an annual capacity of 10 million tonnes. Almost all crude oil refined at the plant comes from the Norwegian continental shelf. The principal products are petrol, diesel oil, jet fuel and other light petroleum products. The heaviest oil components are used in part to produce petroleum coke, an important raw material for anode production in Norway's aluminium industry. Annual petrol production at Mongstad corresponds to 180 per cent of Norwegian consumption. Most of the refinery's output is exported, particularly to other European markets.

The oldest part of the refinery was built in the early 1970s. An expansion in 1989 increased annual refining capacity from 6.5 to 8 million tonnes of crude. A desulphurisation plant for diesel and gas oils began operation at Mongstad in March 1996, while a facility for reducing the benzene content in petrol came on line in the autumn of 1997. These ensure that products meet current European Union standards. A desulphurisation plant completed in the spring of 2003 allows Mongstad to supply petrol, which accords with the new EU specifications that came into force in 2005.

The Mongstad port is Norway's largest in tonnage terms. About 60 per cent of all products from the associated refinery are exported – and 98 per cent of its output is carried by ship, while road tankers account for only two per cent. As the emphasis of this thesis is on Statoil Mongstad, we present also its organisation chart.

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                          ┌─────────────────┐
                          │     Statoil     │
                          │                 │
                          │  Mongstad (SM)  │
                          └─────────────────┘
┌──────────────────────┐                      ┌──────────────────────┐
│ - Health, Env, Safety │                     │  - Public Relations   │
│  and Quality (HMS&K)  │                     │        (INF)          │
│                       │                     │                       │
│                       │                     │  - Human Resources    │
└──────────────────────┘                      └──────────────────────┘

        ┌──────────────────────┐   ┌──────────────────────┐
        │   Production Area Y   │   │   Techn. and Project  │
        │       (PRO Y)        │   │   Development (T&U)   │
        └──────────────────────┘   └──────────────────────┘

        ┌──────────────────────┐   ┌──────────────────────┐
        │   Production Area A   │   │  Planning and Develop.│
        │       (PROA)         │   │        (P&U)          │
        └──────────────────────┘   └──────────────────────┘

        ┌──────────────────────┐   ┌──────────────────────┐
        │  Production Support   │   │   Production Area B   │
        │        (PS)          │   │        (PROB)         │
        └──────────────────────┘   └──────────────────────┘
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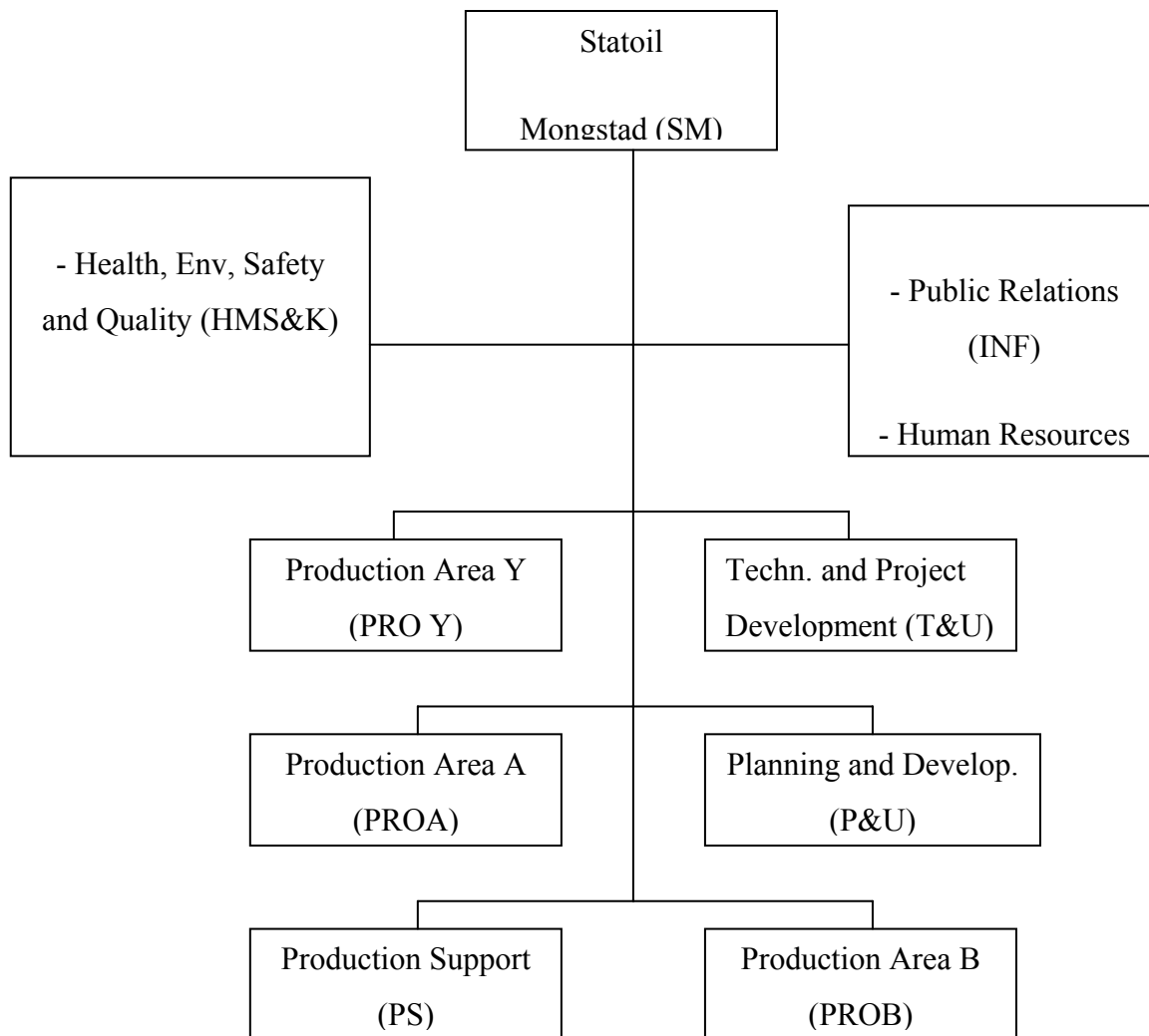
Figure 22 The old organization chart for F&M FOR SM. Source: Statoil
Mongstad internal web

F&M is the acronym for the manufacturing and marketing section of the Statoil ASA. (F&M – Foredling og markedsføring), FOR stands for Manufacturing department under the F&M section and SM is for Statoil Mongstad. The above organisation structure (figure 22) was in place up to the end of September 2005.

Production area A was the old facility that was build in the early 1970s, production area B was the new facility while production area Y is the outer facility used for shipping and storage of products. The economic planning and analysis section is responsible for the relations with Shell and the appliance of Balanced Scorecard.

At Mongstad, there are a canteen and an IT-service that do not appear on the above organization chart. This is due to the fact that these two services do not report directly to the local Mongstad Refinery authority. They report to or contract with (in case of external firm) the Statoil Corporate Services department. These firms are the same in the whole Statoil Corporate due to the standardization that is discussed below in this chapter. Mongstad Refinery does not for example decide an external firm that is to run the canteen. This is decided by the Statoil Corporate Services department.

The above organisation structure was modified, and a new organisation structure was put in place on the 3rd of October 2005. There are many reasons that have led to changing this organisation structure. According to Øystein Austrheim, the two main reasons are to reduce operating costs that have been higher than those of competitors (find more details on operating costs in chapter 6) and to create a common culture among production areas, as there were different cultures between production areas. The old organisation structure (figure 22) was designed based on the functional structure as related tasks were grouped under the same authority. According to the organisation structure theory discussed in the beginning of this chapter, one of the disadvantages of this functional structure is that it leads to a closed communication across different functions. According to this organisation theory, one can say that different cultures in production areas may have been possibly occurred due to a closed communication between these production areas.

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                        ┌─────────────────┐
                        │     Statoil     │
                        │  Mongstad (SM)  │
                        └─────────────────┘
                                 │
    ┌──────────────────┐         │         ┌──────────────────┐
    │ - Human Resources│─────────┼─────────│ - Public Relations│
    │      (PO)        │         │         │       (INF)       │
    └──────────────────┘         │         └──────────────────┘
                                 │
    ┌──────────────────┐         │         ┌──────────────────┐
    │ - Health, Env,   │─────────┼─────────│ - Econ. Planning &│
    │   Safety and     │         │         │   Analysis (ØPA)  │
    │   Quality (HMS&K)│         │         └──────────────────┘
    └──────────────────┘         │
```
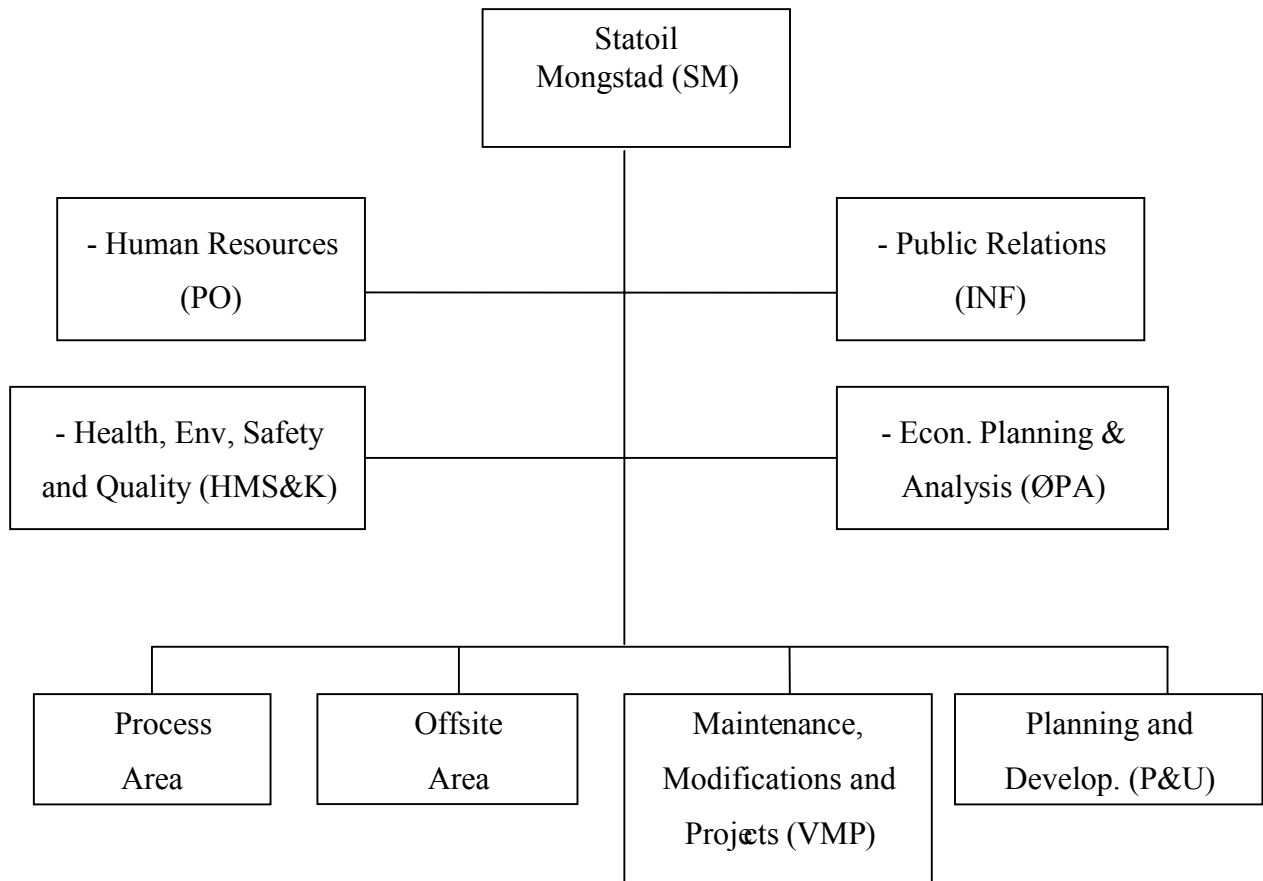
Figure 23 The new organisation for F&M FOR SM. *Source: SM DRIV rapport*

The new organisation (figure 23) is also designed on basis of different functions (functional structure). The main changes in the new organization are:

- Both Production Area A and Production Area B have been put together under the new department 'Process Area'.

- Production Support (PS) and Technology and Project Development (T&U) have been put together under the new department 'Maintenance, Modifications and Projects' (VMP)

- The new organisation promotes cross-functional teams. A cross-functional team is a group of employees from various functional areas of the organization who work as a team to improve coordination and innovation across divisions and resolve mutual problems.

These changes try to solve problems associated with functional structure such as time and resources consuming coordination, and closed communication across different functions. These changes are expected to strengthen the Statoil Mongstad's competitive position.

3.4.2   Mongstad – Crude oil terminal (MTDA)

Mongstad Crude oil terminal Partners are Statoil (65 per cent) and Petoro[2] (35 per cent). The terminal at Mongstad plays an important role in Norwegian crude oil exports. It provides intermediate storage for more than a third of all oil produced by the group off Norway, before these supplies are shipped to customers in North America, Europe and Asia. Oil is brought to the terminal in shuttle tankers, and through Troll Oil Pipeline I and II from the Troll B and C platforms respectively. Crude oil from such fields as Troll in the North Sea and Heidrun off mid-Norway are exported from the terminal. This facility also gives Statoil the option of holding back oil rather than shipping directly from the field to customers. Such flexibility is important as it eases the marketing of Norwegian crude outside north-western Europe.

The terminal has six rock cavern stores with a total capacity of 9.4 million barrels, two jetties able to handle crude oil carriers up to 380,000 deadweight tonnes, and one ship-to-ship jetty able to handle crude oil carriers up to 440,000 deadweight tonnes. It serves as the terminal for Troll Oil Pipeline I (about 250,000 barrels per day), Troll Oil Pipeline II (about 150,000 barrels per day) and Heidrun transhipment (about 240,000 barrels per day). Crude oil is also received for transhipment from Gullfaks, Norne and Åsgard.

3.4.3   Vestprosess (VPDA):

At Mongstad, there is a processing unit for natural gas liquids (NGL). The feedstock is converted in the Vestprosess plant to naphtha, propane and butane. Ethan is removed in the process, and is used for fuel. The plant includes two rock cavern stores for propane and one for butane, each measuring 60,000 cubic meters. A new jetty was also constructed, as a part

---

2 Petoro serves as the licensee for the state's direct financial interest (SDFI).

of the initial Vestprosess project. Due to the increased volumes, the Vestprosess capacity has been increased to 335 tonnes per hour, giving an annual production of 2.8 million tonnes.

Operations were started in October 1999. Initially, the feedstock was natural gas from Troll (Kollsnes) and Oseberg (Sture) and LPG (liquified petroleum gas) from the refinery at Mongstad. From December 2002, NGL from Tune was included to the feedstock from Sture and from October 2004 new volumes of NGL from Kvitebjørn, handled in a new processing unit at Kollsnes, boosted the feedstock to Vestprosess.

Vestprosess partners are:

> Petoro 41 per cent
>
> Norsk Hydro Produksjon a.s 17 per cent
>
> Statoil 17 per cent
>
> Mobil Exploration Norway Inc. 10 per cent
>
> A/S Norske Shell 8 per cent
>
> Total E&P Norge AS 5 per cent
>
> Norske ConocoPhillips AS 2 per cent

Vestprosess ties operations on the Norwegian Troll, Oseberg, Tune, Kvitebjørn, Visund and Fram fields in the North Sea together with the processing plants at Kollsnes, Sture and Mongstad. Vestprosess connects the Kollsnes gas treatment plant and the SCUP facilities (Sture Crude Upgrading Plant) at the Sture crude oil terminal to the Mongstad refinery with a 54-kilometre long pipeline.

Vestprosess and Kårstø are the most modern export terminals of LPG in Europe. This is because both terminals can boast large storage capacity for LPG and very efficient loading facilities. The LPG from Vestprosess is sold both in the European market and to distant markets worldwide. The main export markets are North- and South America, Turkey and the Far East. In most of these markets the volumes of LPG are used for heating and cooking.

3.4.4   Product Technology and Customer Service Centre (PKS)

The Product Technology and Customer Service Centre (PKS) at Mongstad is Statoil's centre of expertise for refined products, advanced analytical methods and petroleum coke

technology. Apart from continuous product development, important duties include adapting the refinery to market requirements and working on alternative products. It also deals with the technical characterisation and use of crude oils and other process inputs, and provides technical support for production as well as the marketing and sale of products in Scandinavia, Ireland, Poland and the Baltic states. PKS cooperates closely with the Mongstad refinery, where one of its principal duties is to ensure that all products have the correct user and environmental properties.

3.4.5   Collaboration between entities at Mongstad

Considering the production aspect, these entities complete each other. Crude oil that is sometimes bought from the terminal is processed in the refinery, and C5+ from the Vestprosess is also added in the overhead system of crude distillation. Results of analyses from PKS are used in collaboration with the refinery laboratory. Despite this cooperation in the production and the fact that these four entities are geographically placed at the same place, 'Mongstad', they report directly to different authorities in the Statoil concern as it is shown in the organisation charts of Statoil departments above in the text. This shows that Statoil Mongstad is not organized under a geographic structure because all entities at Mongstad are not under the same local authority. In this case of Mongstad, a functional structure is used. This means that all organisations that carry out the same function/work fall under the same authority though they might be placed in different places.

3.5 Administration and Performance measurement

In this section, we discuss administration and performance measurement tools used in organisational integration. Information presented in this section about Mongstad or Statoil is based on a presentation at Statoil Mongstad by Øyvind Arnesen and Signy Midtbø Riisnes, and from www.statoil.com.

3.5.1   Better and Faster Administration (BRA)

Before the coming of the BRA programme for better, faster administration, different entities in Statoil used different work processes. According to Statoil, this was not effective in time and economic perspectives. If there were a need for one employee of any given entity of Statoil to work for another institution, he/she would first have to start by learning the new work system. The payment of expenses used by employees (example tickets, lodge, etc.) took also a long time, as the process of approval was slow. This lead to high administration costs. The solution to these problems was to implement the BRA system.

The BRA programme for better and faster administration was initiated in 1996 and completed on 1 December 2000. Through this programme, Statoil has developed and adopted common work processes supported by the SAP R/3 computer platform. These work processes are implemented for accounting, finance, human resources, operation and maintenance, procurement and supply, sales and distribution, and project management for modifications and maintenance. Each entity has been responsible for adopting new work processes supported by SAP in its organisation, with the focus on the opportunities provided for gains.

According to Statoil, the BRA programme has yielded a considerable simplification and standardisation of administrative work. This system has been effective in reducing costs, especially administrative costs. These administration costs went down to the half. (www.statoil.com). The system reduces also adaptation or training costs because one employee in Statoil can work in any other entity in Statoil without more training, as the work system is the same. The programme has also laid a good basis for adopting new administrative solutions. However, this standardisation has also side effects. Organisations that operate onshore will have to work in the same system as the ones who operate offshore. Therefore, this programme does not respond to some specific situations of working for example offshore in order to maintain standardisation.

The BRA programme is based on the trust principle. Employees can fill in information on their expenses or their working time in the recording system and get paid before the expenses are approved. The approval can be made after the payment, and if in some cases,

there are deviations, adjustments are performed afterwards. This control system has been useful in terms of time effectiveness.

Although Mongstad is satisfied with this programme, it has to undergo some changes. These changes are orchestrated by the fact that Statoil is registered in the United States. All companies registered in the USA have to comply with a Sarbenes Oxley Act (SOX). The act is actually named after its main architects, Senator Paul Sarbanes and Representative Michael Oxley, and followed a series of very high profile scandals, such as Enron and WorldCom. The purpose of the act is to restore capital market's trust in corporate financial reporting. This act has different sections, but one of the most critical components of reliable corporate reporting is strong and effective internal control – Sarbenes Oxley Act Section 404. Statoil is mainly concerned with this SOX404 on internal control. SOX404 requires both US and non-US reporting companies to file with each annual report an internal control report prepared by the management and attested by the company's independent auditor. The internal control report must assess the effectiveness of the company's internal control over financial reporting based on management's evaluation as of the end of the fiscal year. The purpose of internal controls over financial reporting is to ensure that companies have processes designed to provide reasonable assurance that the company's transactions are properly initiated, authorized, recorded, processed, and reported. The internal controls also have to ensure that fraud is prevented or detected and that the company's assets are safeguarded against unauthorized or improper use.

The changes that are to be made due to SOX404 have different consequences on the BRA system. They affect the trust principle in that there will no longer be payments before expenses approval as it was originally suggested by the BRA system. Even though there is a return to the old culture that was there before the BRA system, Mongstad does not consider this as a drawback of the BRA system. But they explain this action as a result of the fact that they had taken so many steps ahead that they have to go back a little bit again. Statoil has to comply with SOX act by 2006; this is the same for all foreign companies that are registered in the USA.

3.5.2   Balanced Score Card (BSC)

The balanced scorecard theory

The balanced scorecard is one of performance measure tools used in Statoil. The BSC was developed in the early 1990s by Drs. Robert Kaplan and David Norton. The BSC development was motivated by a belief that the then existing performance measurement approaches, primarily relying on financial parameters, were becoming obsolete. It was a common belief that relying purely on financial accounting measurements was hindering companies' abilities to create future economic value, Anatharam (1999). Recognising some of the weaknesses and vagueness of previous management approaches, the balanced scorecard approach provides a clear prescription as to what companies should measure in order to "balance" the financial perspective.

Malina and Selto (2001) argue that BSC is not primarily an evaluation method, but it is a strategic planning and communication device to provide strategic guidance to divisional managers and to describe links among lagging and leading measures of financial and non-financial performance. Lagging indicators represent the consequences of actions previously taken, while leading indicators are the measures that lead to the results achieved in the lagging indicators. For example while sales are considered as lagging indicators, factors that drive sales such as hours spent with customers can be seen as leading factors. A BSC should measure both outcomes-lagging indicators and performance drivers- leading indicators. Outcome measures without performance drivers do neither communicate how the outcomes are to be achieved nor provide an early indication about whether the strategy is being implemented successfully.

Some indicators are maintained to measure an organization's progress toward achieving its vision; other indicators are maintained to measure the long-term drivers of success. Through the balanced scorecard, an organization monitors both its current performance (finance, customer satisfaction, and business process results) and its efforts to improve processes, motivate and educate employees, and enhance information systems – its ability to learn and improve.

The balanced scorecard is a conceptual framework for translating an organization's strategic objectives into a set of performance indicators distributed among four perspectives: financial, customer, internal business process, and learning and growth (see figure below). The four perspectives provide a useful framework for analysing and understanding how acquisition supports accomplishment of the organisation's mission. The four core areas – financial perspective; business process perspective; customer perspective; and learning and growth perspective – and their associated subset of metrics may vary to some degree from organisation to organisation.
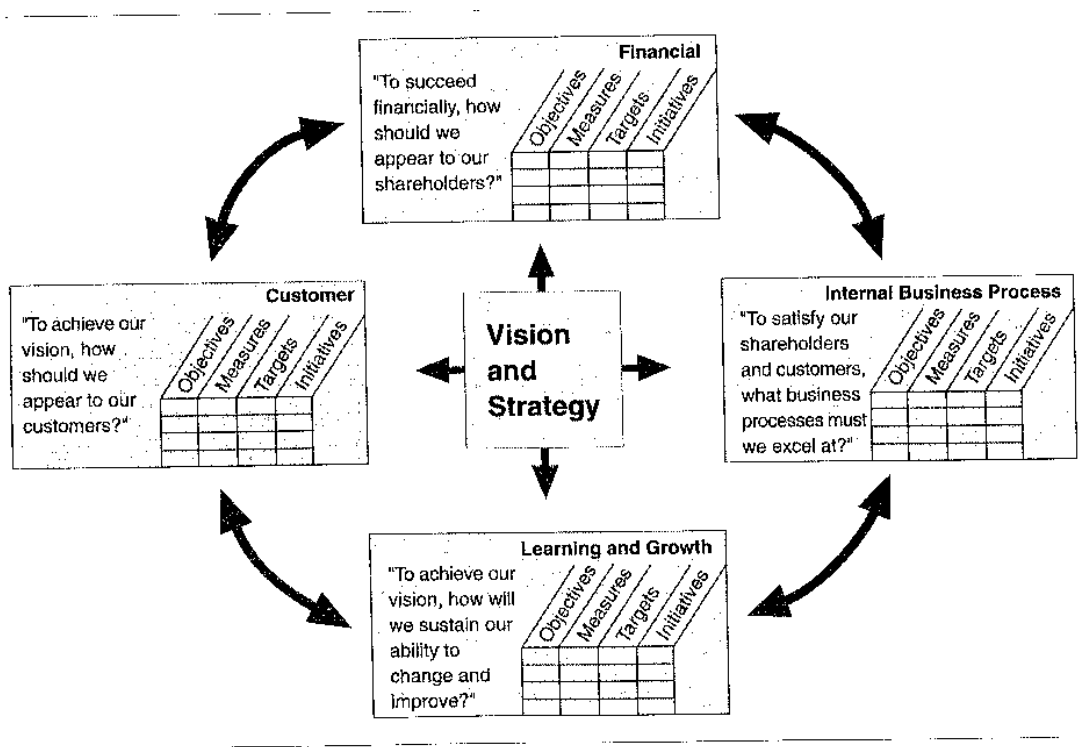

Figure 24 The Balanced Scorecard framework. Source: Kaplan and Norton (1996) p.9

The Financial Perspective

Financial measures are an important component of the Balanced Scorecard, especially for profit pursuing organizations. The financial measures are valuable in summarising the measurable economic consequences of actions already taken. Financial performance measures indicate whether a company's strategy, implementation, and execution are contributing to bottom-line results. The financial persepective includes indicators such as

profitability, revenue growth, and economic value added. Other additional financial-related data, such as risk assessment and cost-benefit data, are also included in this category.

The Customer Perspective

In the customer perspective, managers identify target customers and value proposition in serving them. This perspective typically includes several core or generic measures of the successful outcomes from a well-formulated and -implemented strategy. The core outcome measures include customer satisfaction, customer loyalty, market share, and customer acquisition. The drivers of core customer outcomes represent factors that are critical for customers to remain loyal to their suppliers. The customer perspective enables managers to articulate the customer and market-based strategy that will deliver superior future financial returns.

The Internal Business Process Perspective

In this perspective, managers identify the key internal processes the firm must excel at in order to continue adding value for customers and shareholders. The internal business process measures focus on the internal processes that will have the greatest impact on customer satisfaction and achieving an organization's financial objectives. Metrics based on this perspective allow the managers to know how well their business is running, and whether its products and services conform to customer requirements. Product development, production, manufacturing, delivery, and post-sale service may be represented in this perspective.

The Learning and Growth Perspective

This perspective includes employee training and corporate cultural attitudes related to both individual and corporate self-improvement. The financial, customer, and internal-business-process objectives on the BSC typically will reveal large gaps between the existing capabilities of people, systems and procedures and what will be required to achieve breakthrough performance. To close these gaps, businesses will have to invest in reskilling employees, enhancing information technology and systems, and aligning organizational procedures and routines. These objectives are articulated in the learning and growth perspective of the BSC. Employee-based measures include employee satisfaction, retention, training, etc. In the current climate of rapid technological change, it is becoming necessary for workers to be in a continuous learning mode.

Application of BSC in Statoil

The Balanced Scorecard is applied in Statoil. As we have seen above the BSC theory suggests four perspectives. However, Statoil has adjusted this theory to its organization and has ended up with five perspectives in its Balanced Scorecard application. This adjustment was made because the original BSC theory does not satisfy all the needs of the management in the business environment in which Statoil operates. Health, Security and Environment are so important in the oil industry in that they got their own perspective. The five perspectives or dimensions used are: a) Economy; b) Market; c) Health, Environment and Safety; d) Operation; and e) Organisation.

The economy perspective,

In this perspective, one gets information on financial activities. Measures, objectives, targets, achievements about economic activities are all specified in this perspective. This perspective can be compared to the financial perspective in the theory of the Balanced Scorecard.

Market,

This perspective deals with all external parties to Statoil. It includes customers, suppliers, competitors, stakeholders, shareholders, government, neighbours etc. This perspective can be seen as an extended customer perspective of the Balanced Scorecard theory because it deals not only with customers but also with all other external stakeholders that may have an influence on the business performance.

Health, Environment and Safety (HSE)

This perspective includes all activities related to health, environment and safety associated with every day activities. Regulations on emissions from the refinery are taken care of in this perspective. Statoil has a big obligation to achieve first-class results for health, safety and environmental protection (HSE) in all parts of its business. This includes responsibilities to employees, contractors and the natural environment (www.statoil.com 24.01.2006). This

may be one of the reasons that have led Statoil to create this specific perspective of the balanced scorecard.

Operation

This perspective is responsible for all operations and activities of everyday work that are not accounted for in the third perspective. There is no real clear-cut on the definition limit between the third and the fourth perspectives. Sometimes it may be difficult to know which activity is to be accounted for in the third perspective and not in the third perspective. One example is an every day operation that leads to emission in environment. In this case, the authority in charge tries to agree on the perspective that they think is best suitable to that operation.

Organisation

The organization perspective is for research and employees. Here, you find employees' learning, training, seminars, and all different research activities. This perspective deals with the employees' health, for example sick leaves are accounted in this perspective. The strategies on improvement are also part of this dimension.

Each of the five perspectives has different key performance indicators. Some key indicators are compulsory, and have to be filled in the BSC system on a regular basis. The obligatory indicators are normally collected and filled in automatically by the system in BSC. This information given by the compulsory performance indicators cannot be edited; but its access can however be denied to others if it becomes necessary. Other key performance indicators are filled in on a voluntary basis.

Due to the standardization of the work processes in Statoil, the BSC is the same in all organizations in Statoil, but in some organizations some perspectives are not used, as the organization sees no practical need of them. If there is a need to add a new key performance indicator, there is 'freedom' of adding it as long as the Statoil authority in charge approves it. The approval is needed to make sure that the KPI is new and different to other existing KPIs in order to ensure standardisation. Every KPI has a definition, measure and explanation, and a graph that compares the actual performance to the target performance. Some indicators may have initiatives and even targets in the future.

The most important key performance indicators at Mongstad are indicators that are used to measure Mongstad's competitive position. This position is measured through the Solomon benchmark that is discussed in the cost chapter. These indicators are also used in internal measurement model called the 'Diamant modell'. These indicators are:

- Personnel

- Safety and environment

- Capacity and capacity utilisation

- Operating costs

- Energy effectivity

- Net Manufacturing Margin (i.e. brutto margin minus operating costs, see more details in the cost chapter)

- Return on capital employed (ROCE)

- License to operate (LTO)

- Upstream integration (i.e. the coverage of attractive raw materials in manufacturing and the added value to the Statoil's upstream business section).

- Marketing or downstream integration (i.e. access to attractive markets for refined products and added value to the Statoil's downstream business section).
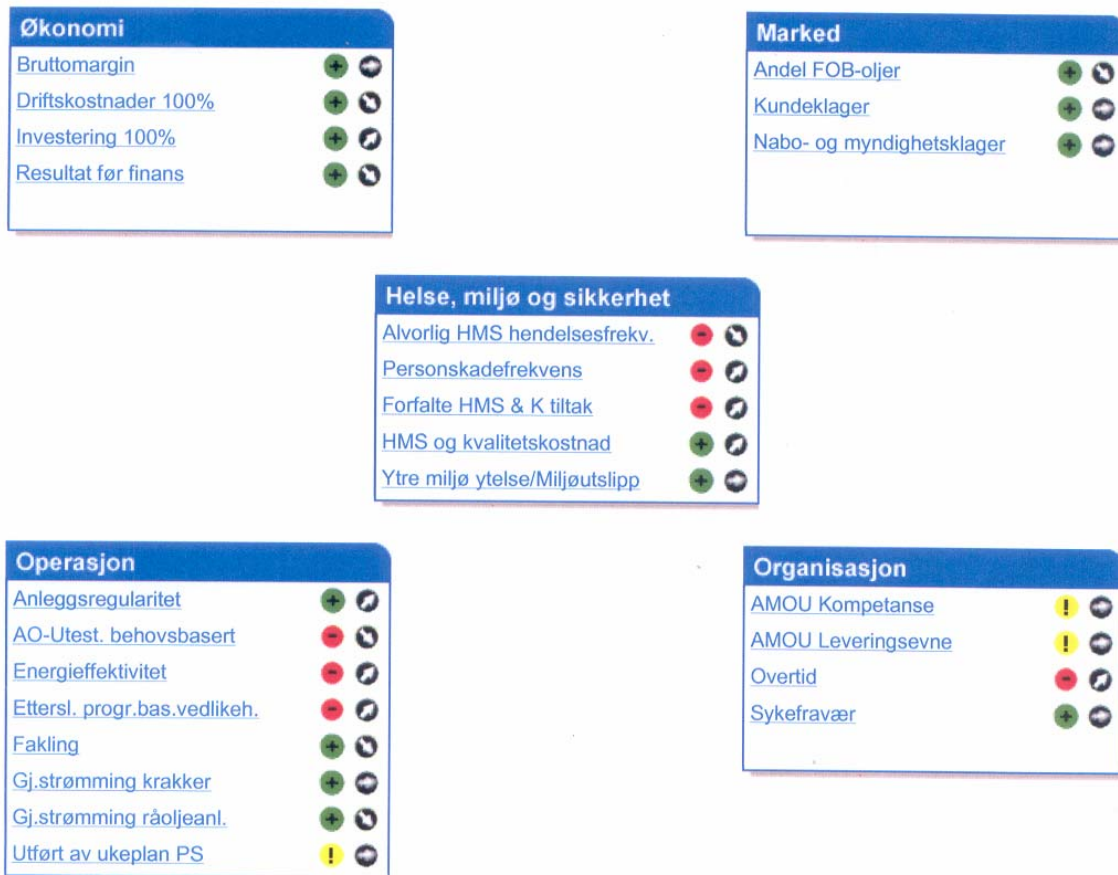
Figure 25 Balanced Scorecard as applied at Mongstad. Source: Statoil
Mongstad internal web

Figure 25 (in Norwegian) shows an example of how the BSC theory has been adapted and applied as a system within Statoil. The figure shows all the five perspectives. In each perspective one can read different key performance indicators.

The BSC is used to give information to the employees and some stakeholders who have access to the information. All employees at Mongstad have access to the BSC system. This BSC system at Mongstad is regulated using some signals like common traffic lights and signs. By logging into the system you can easily see all KPI that one has or does not have access to. There are also lights like green, which indicates that everything is going as planned. This means that the actual performance is as good or better than the target. However, a green colour does not always mean a good progress as projects that have not been started sometimes show this green colour. Red means that there is a deviation to the

negative side from the plan or the target. A red colour must be accompanied by a comment that explains what happened. There is a yellow colour that shows that activities are in progress. The economy, planning and analysis department is responsible for the disposal, the access to the information and the management of the BSC system. They can edit or erase most information except the obliged KPIs.

The BSC is used as a means of communication between leaders and employees and between employees. It helps the managers to communicate the targets and principles as employees can see the targets on their work and the progress of their work. Through the BSC program, they can also see how other fellow employees are doing compared to their targets. The system thus adds transparency, and works also as a type of motivation to employees as they do not want to show poor performance to the rest of the organisation.

3.5.3   The Budget

The budget is prepared by Statoil headquarters in collaboration with Mongstad. In this collaboration, Mongstad gives recommendations or suggestions to the head office. When the budget is agreed on between both parties, a copy of the budget is given to Shell. This is done to enable Shell to make comments and requirements on the budget. Normally, the influence of Shell in this budget progress is more theoretical than practical because the budget is submitted to Shell in its final stage when the other parties in Statoil have agreed on it. As Mongstad is a cost centre, the budget preparation is very important. When the final budget is agreed on, the only job remaining to Mongstad is to follow it closely. Mongstad cannot decide to take actions that may lead to the budget deviations; it can only give some recommendations that may be helpful in order to change the budget. These suggestions may be approved or not. At the end of the period, the deviations between actual and budget become a part of the deviation analysis. Further budget discussions are given in the cost structure part.

4. Production

The Mongstad refinery primarily converts crude oil into light products, with an annual production capacity of roughly ten million tonnes. Gasoline, jet fuel, diesel oil and gas oils are the principal products from this facility. In this chapter, we will discuss the main activities connected with the production at the refinery.

4.1 Input

At Mongstad, crude oil is the main input. It constitutes 80 per cent of all input as seen on figure 26 below. Other inputs include condensate used to make the feedstock lighter in favour of producing lighter components, and other components like MTBE as an octane-enhancer, and additives and catalysts.
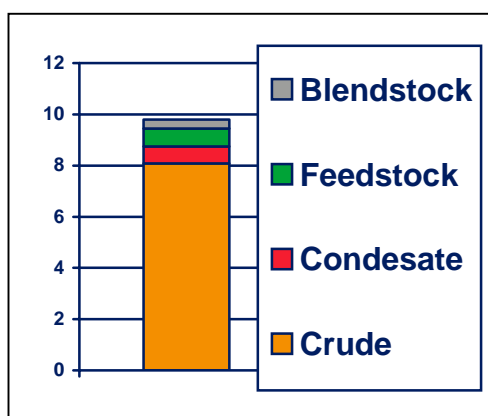

Figure 26 Production Input Mongstad, Source: Mongstad Refinery DA 2003

The main inputs used at Mongstad are:

- *Crude oil* with different API gravity and sweetness. The crude oil is being stored in different caverns and mixed up when entering the crude oil tower.

- *VP C$_5$+* is a mixed feedstock mostly made of naphtha but also butane and ethane. Mongstad buys this feedstock from Vestprosess DA.

- *Residuals LS/NS* with LS for low sulphur content and NS for high sulphur content.

- *MTBE/ISOMERAT* is mainly gasoline components. Isomerat is usually produced at Mongstad but sometimes it can be bought.

- *Catalysts*

- *Additives*.

4.2 Refining process

The refining processes presented in this section are based on Gary and Handwerk (2001), Abdel-Aal et al, (1992), Parkash (2003) and Favennec (2001).

Raw oil or unprocessed oil is not very useful in the form it comes in out of the ground. It needs to pass through an oil refinery where it is broken down into parts and refined before use. An oil refinery is normally a large industrial site where crude oil is processed. Sometimes refineries are located near oil wells, but usually the crude oil has to be delivered to the refinery by ship, barge, pipeline, or train. The refinery turns crude oil into a whole range of substances such as gasoline, jet fuel etc. It also determines the quality and the specifications of these useful substances.

The refining industry has a particular characteristic, which is that the products manufactured from the various crude oils are interdependent. It is not possible to manufacture just one product. Therefore, the refiner has no choice but to produce different products. Of course, the relative proportions of the resulting products depend on:

- The different input processed,

- The process units used,

- The unit operating conditions set.

This notion of the interdependence of the manufactured products has a direct consequence. It is not possible, mathematically, to calculate an actual manufacturing cost for a single product, without an arbitrary allocation of the raw material and operating costs among different products. This notion of cost will be more explained in the cost chapter.

The process of refining crude oil is depicted in the following figure that is explained in the following paragraphs.
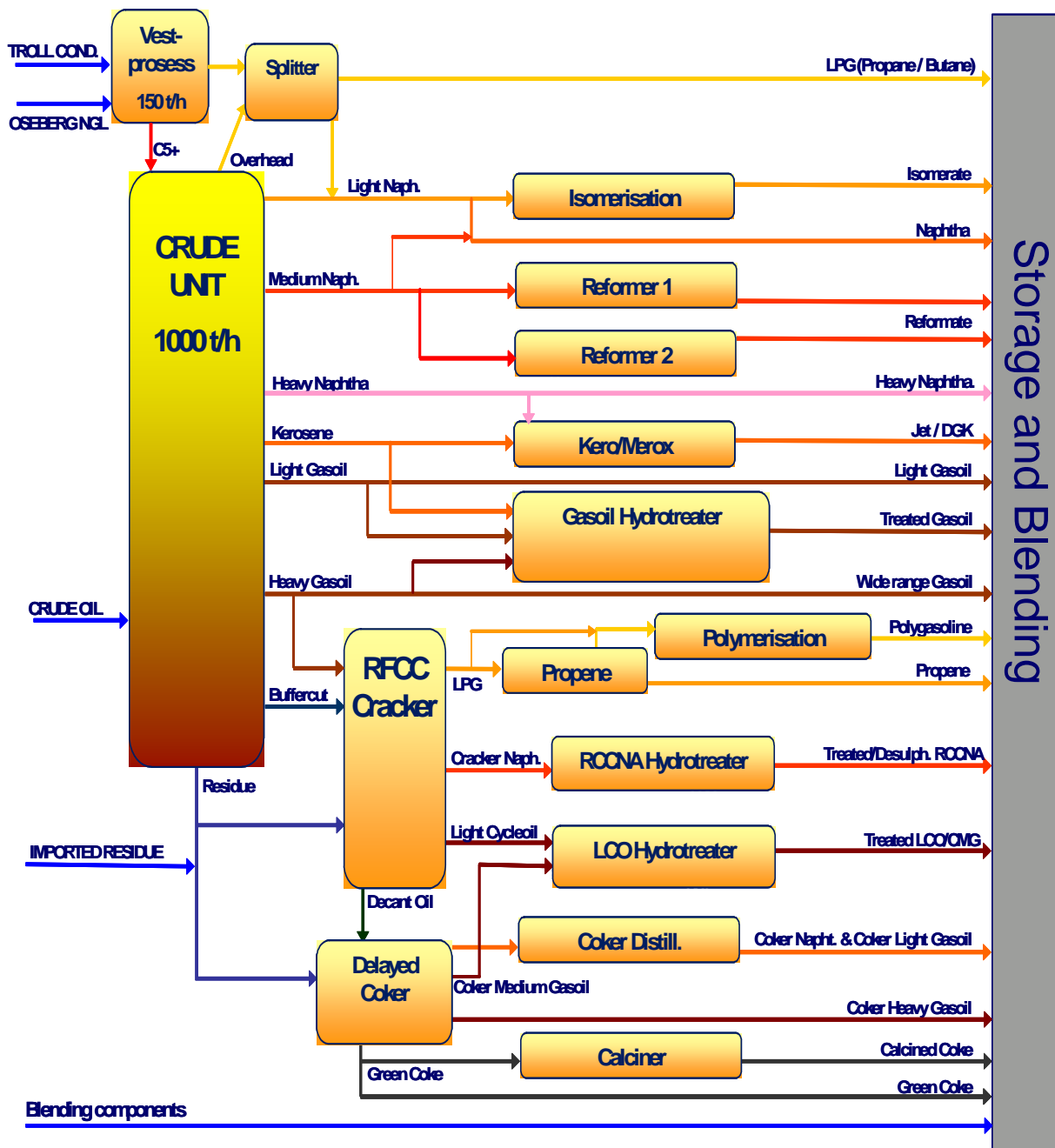

Figure 27 Statoil Mongstad Flow Chart. Source: Statoil Mongstad presentation 2005

On the top of figure 27, one finds Vestprosess that provides C5+ to crude unit and then output to the splitter that provides LPG that goes to both storage and light Naphtha under

Statoil Mongstad. Other refining processes in refineries and at Mongstad in particularly are discussed below.

4.2.1   Crude oil distillation

The various components of crude oil have different sizes, weights and boiling temperatures; so, the first step is to separate these components. Because they have different boiling temperatures, they can be separated easily by a process called crude oil distillation, or fractional distillation. On figure 27, this process is shown by the 'Crude Unit' that proceeds 1000 tonnes per hour. In this process, crude oil is heated to a high temperature. Heating is usually done with high-pressure steam. Crude oil boils and forms vapour (gases); most substances go into the vapour phase. The gases pass through a long distillation column that is filled with trays or plates. There is a temperature difference across the column. It is hot at the bottom and cool at the top. The vapour rises in the column. As the vapour rises through the trays in the column, it cools. When a substance in the vapour reaches a height where the temperature of the column is equal to that substance's boiling point, it will condense to form a liquid. The substance with the lowest boiling point will condense at the highest point in the column, and the substances with higher boiling points will condense lower in the column. The liquids are drawn off the distilling column at various heights and pass to condensers, which cool them further. The liquids may either go directly to storage tanks or to other areas for further chemical processing. At Mongstad, as it is seen on figure 27 the liquids from the distillation process that go directly to storage are light Naphtha, medium Naphtha, heavy Naphtha, light gas oil, and heavy Gasoil. These liquids do not go to storage in their entire production, but only a part of these products does so. Another part of the above mentioned liquids and other liquids such as part of Kerosene, Buffercut and Residue go for further processing. The overhead from the distillation goes to the splitter under Vestprosess.

There exist three methods of chemically processing one fraction into another:

- Breaking large hydrocarbons into smaller pieces. This process is called *cracking*

- Combining smaller pieces to make larger ones. Some call this process *unification* while others refer to it as *polymerisation*. Polymerisation is defined as a chemical reaction in which two or more small identical molecules or ions are chemically

joined to form a larger molecule or complex that contains repeating structural units of the original molecules.

- Rearranging various pieces to make desired hydrocarbons. This process is known as *alteration.*

4.2.2   Cracking

Cracking takes large hydrocarbons and breaks them into smaller ones. Cracking breaks large chains into smaller chains. There are several types of cracking: thermal cracking and catalytic cracking.

Thermal cracking

Large hydrocarbons are heated at high temperatures, sometimes-high pressures as well until they break apart. There are several types of thermal cracking.

- *Steam* – in this process, high temperature steam is used to break ethane, butane and naphtha into ethylene and benzene, which are used to manufacture chemicals.

- *Visbreaking* – this is the simplest cracking process. It is used for the conversion of a small proportion of either atmospheric or vacuum residue into components in the gas, naphtha and gas oil range. The residue is heated (482 degrees Celsius), cooled with gas oil and rapidly burned (flashed) in a distillation tower. The quality of these refined products is poor as they have a high olefins content and so are not very stable. This process reduces the viscosity of heavy weight oils and produces tar.

- *Coking* – coking units have more severe operating conditions, residual from the distillation tower is heated to temperatures above 482 degrees Celsius until it cracks into naphtha, gasoil, heavy oil and solids. When the process is done, a heavy or solid, almost pure carbon residue is left (petroleum coke); the coke is cleaned from the cokers and sold. **Delayed coking**, the process used at Mongstad (figure 27), yields coke of a quality suitable for use as electrodes in the manufacture of aluminium, providing the crude oil feed-stock is of the correct quality. Otherwise the coke can be used as a fuel in cement kilns or combined with coal for use in power stations. At

Mongstad, this process has residue and decant oil as input. Some of the residue used as input here is imported from other refineries.

Catalytic cracking

This process uses a catalyst to speed up the cracking reaction. A catalyst is defined as a chemical that selectively speeds up the process of a chemical reaction between other products. Catalysts include zeolite, aluminum hydrosilicate, bauxite and silica-alumina.

- *Fluid catalytic cracking* – in this process a hot, fluid catalyst (538 degrees Celsius) cracks heavy gas oil into diesel oils and gasoline. This is the process used at Mongstad (figure 27). Residue fluid catalytic cracker (RFCC) has heavy gasoil, buffercut and residue, as input and its output are LPG, cracker naphtha, light cycle oil, and decant oil.

- *Hydrocracking* – this process is similar to fluid catalytic cracking, but it uses a different catalyst, lower temperatures, higher pressure, and hydrogen gas. It takes heavy oil and cracks it into gasoline and kerosene (jet fuel).

After various hydrocarbons are cracked into smaller hydrocarbons, the products go through another fractional distillation column to separate them.

4.2.3   Unification

Sometimes, there is a need to combine smaller hydrocarbons to make larger ones. This is done through a process called *unification* or *polymerisation*. The major unification process is called *catalytic reforming* and uses a catalyst (platinum, platinum-rhenium mix) to combine low weight naphtha into aromatics, which are used in making chemicals and in blending gasoline. A significant by-product of this reaction is hydrogen gas, which is then either used for hydrocracking or sold. At Mongstad, there is a polymerisation unit as seen on figure 27 that has LPG from RFCC as input and Propan, Butan and Polygasoline as output.

Catalytic reforming of heavy naphtha is a key process in the production of gasoline. The major components of petroleum naphtha are paraffins, naphthenes, and aromatic hydrocarbons. The relative amount of these hydrocarbons depends on the origin of the crude

oil. The aim of catalytic reforming is to transform, as much as possible, hydrocarbons with low octane to hydrocarbons with high octane. The chemical reactions that lead to these changes are guided by a catalyst under well-defined operating conditions. At Mongstad, there are two reformers (See figure 27). Both Reformer 1 and Reformer 2 have medium Naphtha as input and reformate as output.

4.2.4   Alteration

Sometimes, the structures of molecules in one fraction are rearranged to produce another. Commonly, this is done using a process called *alkylation*. In alkylation, low molecular weight compounds, such as propylene and butylene, are mixed in the presence of a catalyst such as hydrofluoric acid or sulfuric acid (a by-product from removing impurities from many oil products). The products of alkylation are high-octane hydrocarbons, which are used in gasoline blends to reduce knocking.

Isomerisation is defined as a rearrangement of atoms and bonds within a molecule with no change of the molecular formula. Most gasoline formulations require inclusion of some light naphtha to meet the from-end distillation and octane specs. However, C_5/C_6 normal paraffins in this boiling range have low octane, which make them very difficult to include in the gasoline formulation. Branched chain C_5/C_6 hydrocarbons have higher octane, making them more suitable for inclusion in gasoline. The isomerisation process is designed for continuous catalytic isomerisation of pentanes, hexanes, and their mixtures. The process is conducted in an atmosphere of hydrogen over a fixed bed of catalyst and at operation conditions that promote isomerisation and minimize hydrocracking. At Mongstad, the isomerisation unit has light Naphtha from distillation unit and LPG from Vestprosess as input and isomerate as output (figure 27).

4.2.5   Common Refinery Chemicals

The following are the main chemicals used in production in refineries:

- **Leaded gasoline additives**: Tetraethyl lead (TEL) and tetramethyl lead (TML) are additives formerly used to improve gasoline octane ratings but are no longer in common use except in aviation gasoline.

- **Oxygenates**: Ethyl tertiary butyl ether (ETBE), methyl tertiary butyl ether (MTBE), tertiary amyl methyl ether (TAME), and other oxygenates improve gasoline octane ratings and reduce carbon monoxide emissions. MTBE is the main blending component at Mongstad.

- **Caustics** are added to desalting water to neutralize acids and reduce corrosion. They are also added to desalted crude in order to reduce the amount of corrosive chlorides in the tower overheads. They are used in some refinery treating processes to remove contaminants from hydrocarbon streams.

- **Sulfuric acid and hydrofluoric acid** are used primarily as catalysts in alkylation processes. Sulfuric acid is also used in some treatment processes.

4.2.6   Components treating

Distillated and chemically processed components are treated to remove impurities, such as organic compounds containing sulphur, nitrogen, oxygen, water, dissolved metals and inorganic salts. Treating is usually done by passing the fractions through the following:

- A column of sulphuric acid - removes unsaturated hydrocarbons (those with carbon-carbon double-bonds), nitrogen compounds, oxygen compounds and residual solids (tars, asphalt)

- An absorption column filled with drying agents to remove water

- Sulphur treatment and hydrogen-sulphide scrubbers to remove sulphur and sulphur compounds

Some of the treating processes used at Mongstad:

- *A calciner* is a treatment facility that uses heat and airflow to turn liquid high-level waste into a solid. It has green coke as input and calcined coke as output.

- *Kero Merox* is also a treating process that has lighter distillate components as input and Jet/DGK as output.

- *Hydrotreating:* Hydrotreating processes aim at the removal of impurities such as sulphur and nitrogen from products such as gasoline, naphtha, kerosene, diesel etc. Common major elements of a hydrotreater unit are a heater, a fixed-bed catalytic reactor and a hydrogen compressor. A hydrotreater uses hydrogen at elevated temperature and pressure in the presence of a catalyst. Hydrotreating has been extended in recent years to atmospheric resides to reduce the sulphur and metal content of resides for producing low-sulphur fuel oils. The operating conditions of treatment are a function of a type of product and the desulphurisation levels desired in the treated product. The principal impurities to be removed are sulphur, nitrogen, oxygen, olefins, and metals. At Mongstad, there are three hydrotreater units. Gasoil hydrotreater that has Kerosene, light gasoil, and heavy gasoil as input and treated Gasoil as output. Residue catalytic cracker Naphtha (RCCNA) hydrotreater that that has cracker Naphtha as input and treated/disulphuric Naphtha. Finally light cycle oil (LCO) hydrotreater that has coke medium Gasoil and light cycle oil as input and Treated LCO as output.

4.2.7   Refining Process Summary

Crude oil distillation is useful for separating a mixture of substances with narrow differences in boiling points, and is the most important step in the refining process. Very few of the components come out of the fractional distillation column ready for market. Many of them must be chemically processed further to make other fractions.

Cracking, unification or polymerisation and alteration processes are used in order to increase the yield of gasoline or other products from each barrel of crude oil rather than continually distilling large quantities of crude oil. Although products' yields are increased through these methods, products from different processes do not have same qualities, and consequently different prices. For example, LPG from crude oil distillation differs in quality from LPG from thermal cracking. The following graph summarizes the above processes and shows how different products' yields are increased from each barrel of crude oil. The products with lowest specific gravity are shown at the top of the figure 28, and as we move down on the figure, we meet products with medium and highest specific gravity at the bottom.
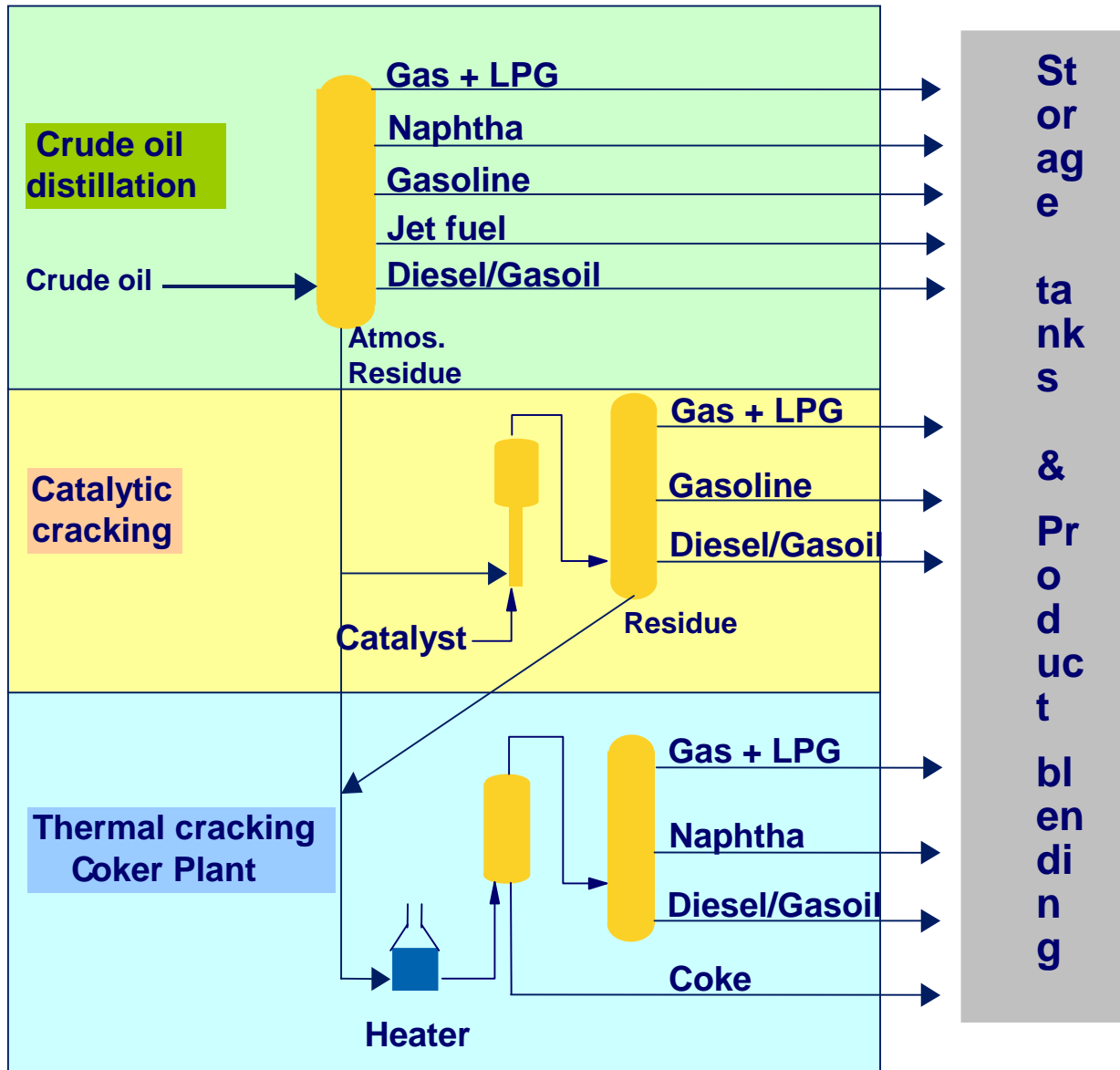
Figure 28 Statoil Mongstad Flow Chart summarised. Source: Statoil Mongstad presentation 2005

4.3 Blending and storage

After the components have been treated, they are cooled, blended and stored in tanks. The objective of product blending is to allocate the available blending components in such a way as to meet product demands and specifications at the least cost and to produce incremental products, which maximise overall profit. Most refineries use computer-controlled in-line blending for blending of main products.

At Mongstad, one imported component used in gasoline blendstock is methyl tertiary butyl ether (MTBE). MTBE is produced by the reaction of isobutene with methanol. Its main use is as a gasoline-blending component, due to its high-octane level. Any hydrocarbon stream containing isobutene can be used for the production of MTBE. In refineries with a catalytic cracker unit, C_4 cut from catalytic cracking is the principal source of isobutene for MTBE production. In petrochemical plants, C_4 cut from steam cracking after butadiene extraction can be used for MTBE manufacture. However, Mongstad refinery imports MTBE from other refineries.

4.4 Refined Products

Some of the refined products are gasoline, liquefied petroleum gas (LPG), naphtha, distillate fuels, vacuum gas oil, kerosene, residual fuel oil, coke and asphalt, solvents, petrochemicals, lubricants etc. Figure 29 shows refined products at Mongstad.
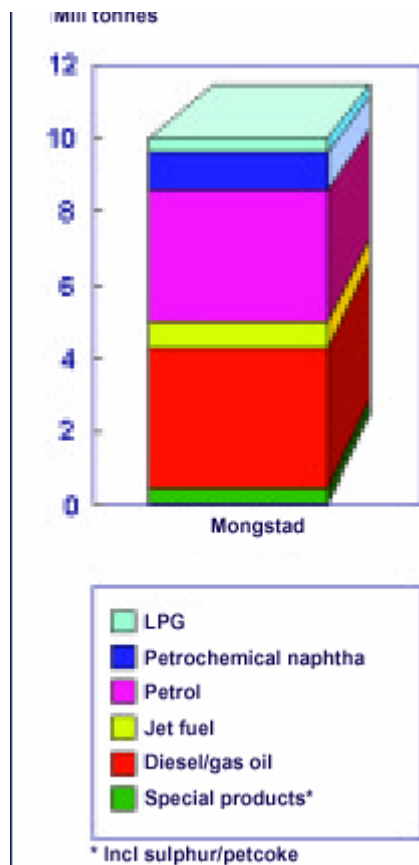
74

Figure 29 Refined products at Mongstad. Source: Mongstad presentation *2005*

Figure 29 shows an annual production of around 10 millions tonnes at Mongstad. The refined products at Mongstad are Petrol, Diesel/gas oil, petrochemical Naphtha, Jet Fuel, LPG and other special products. On figure 29, we can see that Petrol and Diesel oil, Naphtha, and Jet fuel are the main products at Mongstad, as they constitute approximately 80% of the whole production. More details on refined products are included in a technical presentation chapter.

4.5 Planning

4.5.1   Planning in oil refineries

Oil refinery faces an enormous number of options in its operations; it has to decide which type of crude oil to refine, what processing conditions to use, which products to sell and how to blend them from the intermediate components, etc. with limited resources.

Choosing the crude oil to use should be exercised with care. An oil refinery is primarily a continuous process. Crude oil is continuously pumped in to the crude oil distillation where it is heated and separated into different products. But although crude oil is fed continuously to the distillation tower, the quality of that crude oil changes over time. Refineries process a variety of crudes, depending on their availability and marginal economics (revenues and costs) (www.exodus.com). When the quality of the crude changes there are consequential changes in the quantities and qualities of the materials being produced from the crude oil distillation and downstream of it. These changes do not occur instantaneously; crude takes a number of hours to pass through a refinery. A change of crude may necessitate changes to the processing conditions and to the rates of operation of the crude distillation and the other process units. Refineries use optimisation in order to solve this problem of deciding which crude oil to buy or/and use.

An oil refinery has different processes it can use in refining. Different processes lead to different products with different specifications and qualities as described in the section above. Some products may be lucrative while others are not. Contribution margins are also considered in making decisions. A consideration of the market is needed in order to determine if products can be either sold directly to the market or processed further.

Production planning and optimisation in refineries is a complex task. To accomplish the task, refiners need a tool to guide their decisions. One of the common tools used in refineries is the monthly programme. According to Favennec (2001) this monthly programme determines the optimal operation of the refinery for the month ahead. He discusses that this programme is concerned with the choice of crude oils and feedstock for different process units. It gives average throughput levels for each unit and the associated operating conditions. It defines fractionation conditions (in other words cut-points), the use of

intermediate products, the manufacture of finished products, and imports and exports of products. It also provides information on marginal costs and on the costs of constraints.

The monthly plan allows refineries to take decisions or corrective actions concerning supply, refinery operations or commercial actions on the market in due time. Each refinery develops its own specific monthly process. An outline of the Mongstad monthly process is described later in this chapter. A number of refineries use LP based models or programmes to perform or make their monthly plan. As there are many different ways a refinery can use to conduct its operations, optimisation is used in decision-making.

Optimisation in refineries

Before the advent of linear programming, all optimisation in refineries were done by calculating several hand balances moving toward an optimal solution by trial and error; Parkash (2003). This was tedious and time consuming. In modern time, software solutions based on linear programming are used to address refineries planning and optimisation problems. Linear programming (LP) is a mathematical technique that has its origin in the 1940s; Sydsæter et al, (1995). It has now reached a very high level of advancement with the rise in computing power. LP is used when a linear function is to be maximized or minimized subject to linear inequality constraints. The problem arises here, as the nature of the refining processes is mainly non-linear whereas linear programming assumes that a linear combination of the provided options is valid. To resolve this problem, a technique called *successive linear programming* (SLP), also known as *recursion* is used to represent the refinery more directly.

This technique is widely used in modelling oil refineries; it addresses one of the main difficulties that arise with LP models: *pooling problem* (www.eudoxus.com). This problem occurs where one has a pool of product whose qualities depend on previous activities, for example the type of crude oil can determine much of the characteristics of the refined products. SLP works by finding the best solution within the neighbourhood of the existing solution. It can therefore be expected only to find a local optimum (www.eudoxus.com).

Mathematically, an LP model consists of a matrix of rows and columns. The values in the columns represent the unknowns or variables, and the rows or equations represent the relations between variables. In refineries, users use a set of data tables. Parkash (2003) says

that the refinery LP-model (SLP) has an automatic matrix generation that transforms tables in matrix. A typical refinery model represents an LP matrix with approximately 300-500 equations, and 800-1500 activities to optimise. The SLP software uses different optimisers to solve the matrix. The model has also a report writer that transforms a solution in preset format using the matrix data.

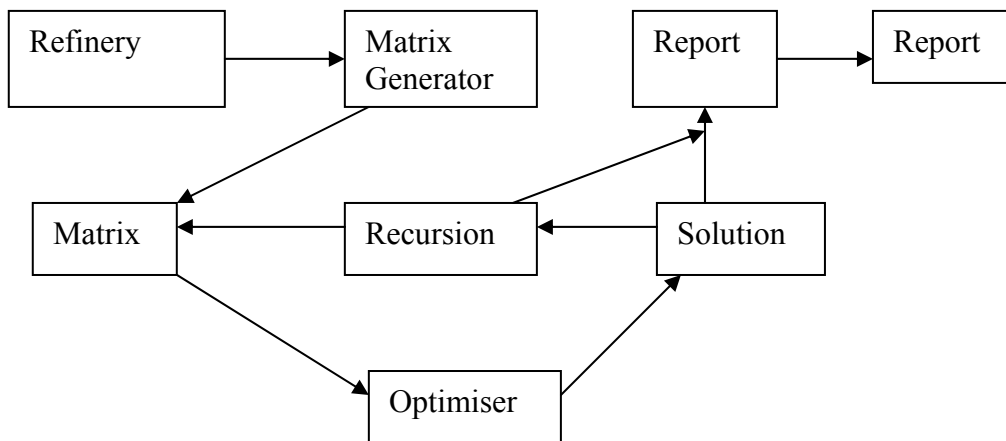The model can be presented as follows:

Figure 30 A refinery' s optimisation model. Source: Parkash (2003)

Sahdev et al (2004) discuss that though more rigorous non-linear programming softwares for use in refinery planning have been recently developed, planning and optimisation is mainly conducted using the successive linear programming (SLP) softwares like:
- RPMS – Refinery & Petrochemical Modelling System – developed by Honeywell Hi-Spec Solutions,
- PIMS – Process Industry Modelling System – developed by Aspen Technology

- GRTMPS – developed by Haverly Systems.

These models do not consider the elements of time and storage. They assume that all activities occur simultaneously and that all identified components are separately available for further processing or blending. They should not replace good and sound judgment. Mongstad refinery uses PIMS.

Refiners' objectives and constraints

A refiner has an objective of maximising its margins. In this case, a margin is defined as a difference between revenues from the products a refiner manufactures and costs such as purchase of crude oil and other inputs and operating costs: both fixed and variables. A gross margin does not include fixed costs while a net margin includes them. Fixed costs are considered in optimisation if they are reversible when considering future projects. A refiner optimises the balance between essential and by-products. This is in the form of the maximum or minimum target yields and the relative margins of each of the products that may result.

Sahdev et al (2004) discuss that a refiner may optimise refinery crude mix, fuel consumption, utilization of the assets, inventory management, capacity utilization and shutdown planning, unit operations maintaining highest standards of safety, catalyst life and activity, etc.

Parkash (2003) says that optimisation is used to determine:

- The quantities of raw materials and intermediate products used as feedstock for the process units.

- The quantities of intermediate products used in blending for the production of finished products

- The quantities of products used as refinery fuel

- The quantities of finished products or intermediates imported or exported

- The quantities of products manufactured according to predetermined formulations (ex: jet fuel.)

Refineries have also different constraints, Parkash (2003):

- Quality constraints: it should meet the specifications of manufactured products

- Supply and capacity restrictions: distillation capacity, reforming capacity, cracking capacity desulphurisation capacity, storage capacity, etc.

- Crude availabilities on markets and at the refinery

Input

Input data used in the model is normally provided by different departments or sections; Favennec (2001). These departments provide the latest information on:

- Forecast crude and product prices on the international markets

- Estimated arrival dates for crude oil cargoes already purchased for the month in consideration (month M)

- Monthly demand by product, forecast sales quantities and qualities

- Specialty requirements that can impact on the make-up in terms of quality and quantity of the crude slate

- Exchange or cross-purchase agreements with other oil companies, by quantity for each product with the location and timetable for deliveries and repayments. It is important to take such exchanges into account because they change the timing and the location of the net demand placed on the refinery.

- Opening crude and product stocks for the period considered

- Strategy to be followed for the stocks of crude and products to be held etc

- Refinery operations and analyses

- Maintenance activities (check-up, shut down, etc.)

- Assessments of operating costs and fixed refinery fuel requirements

- Research and development and quality specifications

Output and Analysis of results

The model gives a solution that optimises the margin. According to Favennec (2001) the solution shows:

- Optimal operation of the refinery for the month ahead

- Choice of crude oils (crude slate) and feedstock for different process units,

- Average throughput levels for each unit and the associated operating conditions,

- Manufacture of finished products

- Imports and exports of intermediate/finished products,

- Marginal costs and costs of constraints, etc.

The obtained solution is then analysed, Parkash (2003). This analysis consists of different aspects. It includes:

- Quantities, and quality of products

- Economic analyses: the analyses are based on the marginal costs of products or of activities, on the costs associated with the main variables in the economic function and on the penalties that result if a variable out of the base is forced to enter into the base (reduced costs), etc.

- Sensitivity analysis

    o The range option indicates a range over which each variable remains valid. It shows also which variables enter or leave the base once the limits of the validity ranges are reached.

    o Parameterisation provides for a systematic analysis of successive optima when right hand side values are changed. In this case we can mention the change in demand for a finished product.

It is very important to ensure that the LP models are updated as necessary at the beginning of the month. This ensures that the solutions obtained are truly optimal in the economic sense and remain valid up to the end of the month treated provided that no factors such as an unscheduled plant shutdown or a major change to the product price differentials has changed the assumptions. The scheduling techniques takes then over.

Selection of crude oil (Favennec 2001)

The monthly programme provides valuable indications, but it is not really an easy way of determining the choice of crude oils. This is due to the fact that by the time the official monthly plan is established, most crude oils (cargoes) for the following month (or the month considered in optimisation) have been already purchased. The monthly plan can be used to buy the crude oils that can be used at the end of the month. The crude oils already purchased are fixed in the LP-model that is used to select the remaining crudes assumed to be available on the market at estimated prices.

The choice of a suitable crude oil slate is one of the most difficult problems that refineries have to resolve. Different parameters are considered and optimised in order to decide the type of crude oils to be purchased:

- The price delivered to the refinery (CIF: cost, insurance and freight), more details are found in pricing structure chapter.

- Availability of refining tools: refineries take into consideration the optimum use of the refining tool available to change crude oil into finished products.

- Synergies between different crude oils: refineries analyse the results of processing different crudes together and processing every crude on a stand-alone basis. In this case a refiner considers complementary crudes.

- The standard yields of different crude oils in different seasons. An LP model with the description of a refinery is used to model processing a given quantity of crude oil X and the main product yields are noted down. The production of these products is optimised using a set of seasonal prices. This provides a set of yields obtained from each of the crudes modelled for different time seasons.

4.5.2   Planning at Mongstad

Production Planning at Mongstad has many common factors with other refineries' planning systems that are described above. This part is dedicated to a specific case of production planning at Mongstad.

Information presented in this section is collected through a presentation made by Eivind Blindheim at Mongstad and through a PIMS document at Mongstad.

At Mongstad, there are two main production plans. The first plan is a yearly plan and is known as production budget. Production budget is prepared or divided in two main plans: a winter budget and a summer budget. The production budget is used in monthly planning and in preparing the refinery's budget. It is also used for investments and new markets. The second production plan is the monthly plan that optimises a monthly production. In making these plans, Mongstad uses the successive linear programming software 'PIMS'. The remaining part of this section will concentrate on the monthly plan.

Data from different departments are entered and optimised in PIMS model in order to make a production plan. The following graph summarizes the application of PIMS at Mongstad.
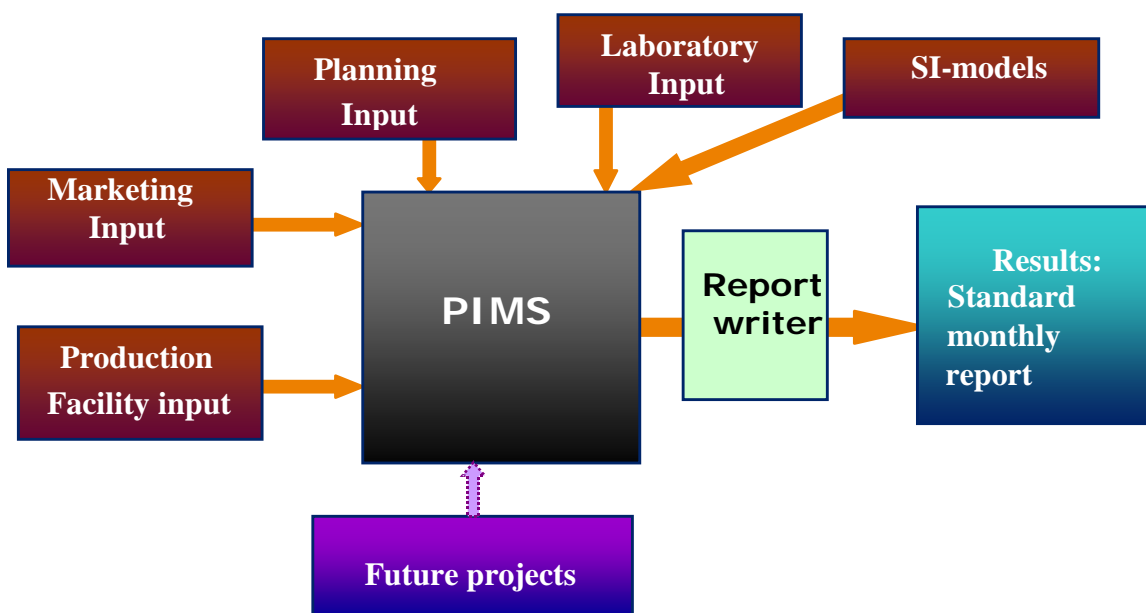

Figure 31 PIMS model at Mongstad. *Source: Statoil Mongstad PIMS presentation, 2005.*

Different data are entered in the PIMS model. The data are normally provided by different departments in charge:

- Data from oil sales, trading and supply department (marketing input or O&S input) is normally the crude oil assays; expected prices of crude oil, MTBE and other

components to be purchased, quality and quantities of products to be sold, blended components, condensate, data on different contracts or agreements with other oil companies, data on agreements with different customers, forecasts prices on international markets, data on import or exports of different components, etc.

- The input data from the production facility at Mongstad (PRO input) includes the production facility's capacity and regularity (percentage of capacity to be used), set-up and shutdown, data on requirements, qualities, and characteristics of products, etc.

- The data from the production planning section (planning input or PPL input) are the blending matrices, blending margins, grounds of these blending margins, opinions on the O&S input, optimal crude oil slate and condensate quantities.

- The input data from the Mongstad laboratory (or LAB input) are normally the products specifications, calibrated data and results of other different analyses made.

- The future projects input include production budget, data on different projects, economic opinions on different alternatives (change of catalysts, etc.), and other economic data. These future projects are used for business development purpose.

- Different models used in refineries in different facilities are also entered (SI-models).

Most of these data are entered in the model in the form of tables, which the model will transform into matrixes.

The PIMS model optimises the input data and gives a solution (a maximized margin). At Mongstad, this margin is the difference between revenues and variables costs. Revenues are given by the prices of overall products produced at Mongstad. Variable costs are given by the price of crude oil, other purchased components, and other variable costs at Mongstad. The maximised margin is the margin of the whole refinery.

From the definition of a gross margin (difference between revenues and variable costs), one can see that after crude oil and other input have been purchased, the gross margin can be increased/reduced by an increase/decrease in the products' prices. During the production process, the product prices' fluctuations play a very important role in increasing, reducing or maintaining the refinery's margin. The product prices are frequently updated throughout the

planning process and once every week (Wednesday) after the final plan has been made. If a price of one product increases, the production of that product can be increased on the expense of another product (with lower price) in order to increase the margin. However, this decision is made with the help of the LP-model (PIMS).

Fixed costs of operating a refinery are not included in the LP-model. These costs include wages and other fixed costs in the short run. The reason of not including fixed costs is that little or nothing can be done about these costs in a period of one month. Therefore, fixed costs, which are referred to as operating costs, are not used in calculating the refinery's margin. However, they are accounted for in financial statements of the refinery.

Inventory data, which can be for example opening crude and product stocks for the period considered, is not considered in the LP-model. The economic management of inventory is performed by the O&S department while its physical development is managed by the scheduling section at Mongstad.

When all data are entered and optimised, PIMS model gives a solution. The solution, through a report writer, is presented in a preset form of a report that contains different information on:

- Purchase of crude oil, residue and components.

- Selling products

- Facilities' regularity (capacity percentage to be used)

- Details per facilities

- Characteristics of finished products

- Blending matrices

- Characteristics of blending components

- Crude oil evaluating that includes swap-value (technical value) and actual value of crude oil.

The authority in charge will analyse the report (the plan), and use it in decisions making such as buying crude oil. The PIMS model is usually repeated several times in different occasions to reach the final plan, as it is detailed below.

4.5.3   Planning process at Mongstad.

The monthly plan proves itself very important in production process at Mongstad. The figure below summarizes the planning process at Mongstad.
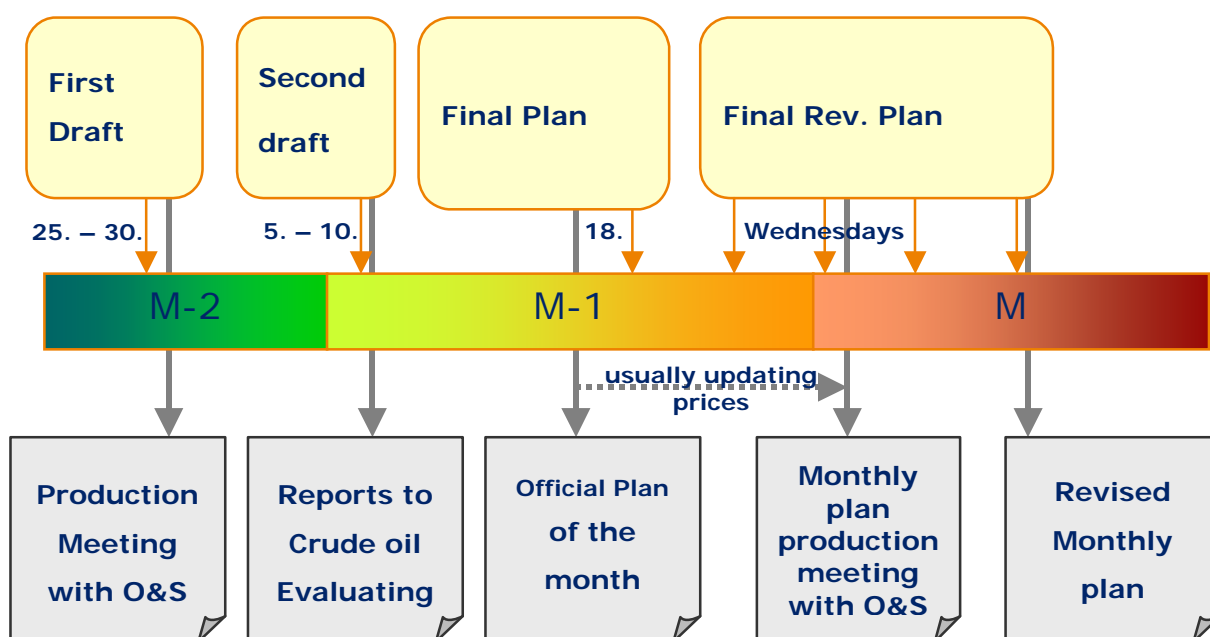

Figure 32 Planning process at Mongstad. *Source: Statoil Mongstad PIMS presentation, 2005.*

Three months are taken into consideration: M, M-1, M-2 months. The M month plan is started between 25th and 30th of the M-2 month. During this period, the first draft of the M month plan is prepared using PIMS model. At this level, many entries are subject to change as the time range is still large with uncertain information such as forecasted prices on international market and finished product demand. After the first draft, there is a meeting between Mongstad and O&S. In this meeting that takes place between the 2nd and the 6th of the M-1 month, they have a short discussion on possibilities for the M month. The updated information or/and changes are entered in the PIMS model as they come in. The second draft

is performed between 5[th] and 10[th] of the M-1 month. The second report (draft) is used in the assessment process on crude oil possibilities. This assessment takes into account optimal crude oil mix or crude oil slate, and swap[3]-analyses. The evaluation report is made, and crude oil for the M month is ordered on 11[th] of the M-1 month. As the time range becomes narrow, more updates on prices, crude oil differentials, facilities information, and condensate quantities etc. come in. The model is run with the updates, and the final M month plan is reached on the 18[th] of M-1 month.

After this, there is normally a telephone meeting between Mongstad and O&S to discuss on this official M month plan and make adjustments if necessary. The plan is given to Shell and other parties in Statoil on the 22[nd] of the M-1 month. Thereafter, every Wednesday, the model is run with the updated data especially new prices reached. Between 2[nd] and 6[th] of the M month, there is a production meeting between O&S and Mongstad team at Mongstad on different updates or/and changes in facilities conditions, etc. As time goes on, there can be events that may cause the plan to be revised. If a big change in the plan is made, a new plan is submitted to Shell and others in Statoil. The PIMS model can also be run whenever it is needed to do so. The planning process reveals to us that the planning section at Mongstad works on three paralleled months plans that are on different time scales, we can for example mention that in the M-2 month, the planning section works on the M-2, M-1, and M month plans that are on different stages of planning processes.

4.6 Production Scheduling

4.6.1 Scheduling in oil refineries (Favennec 2001)

The monthly plan provides the framework of what the refinery is to do and then the scheduling activity takes over. Scheduling activity establishes the sequence of operations that satisfies the constraints, and achieves the optimal programme computed by the LP model. It has to ensure that operational departments produce the volumes of products needed for the requirements of the sales and marketing departments.

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[3] A swap is an agreement or a contract between two campanies to exchange cash flows/products in the future.   Hull (2003)

The scheduling applications need a substantial quantity of data such as tank levels at any particular moment, unit operating conditions, product qualities, component qualities, the availabilities of the main equipment, marketing requirements, forecast deliveries from outside the refinery, forecast lifting[4] requirements. As we move to shorter time horizons, the degree of precision increases, the refiner knows precisely which crudes it has, which crude to run; how long to do so, the process conditions to use on the various units, and many more. One of the main concerns, at this level, is having sufficient quantities of products available to meet the delivery schedule determined by the supply and marketing department. Therefore, the refiner is concerned with stocks and how they vary through time.

The production process follows, if possible, the recommendations from the LP- model. The operating sequence is given by the sequence of the crude runs and the crude blending rules, unit operating conditions, allocation of tanks, the sequence of product movements, and blend formulations for finished products. These sequences give details of volumes, throughputs, characteristics and origins of the inputs, together with quantities of the essential products required, how they have to be blended to meet the required specifications, the timetable for the requirements and where to be stored, and shipped finally to their destinations. However as the LP-model does not take into account time effects, actual outcome would be different from the outcome suggested by the LP model. The actual stock varies, and it is not easy to predict it before production has started. It can be lower or higher than expected or suggested by the model.

Other factors can also disrupt the scheduling programme; for example changes in crude oil quality, late crude oil arrivals, non-availability of essential equipment, unscheduled unit shutdowns, non-availability of the loading facilities, and changes in the finished product lifting programme due perhaps to short term demand change or to inclement weather affecting shipping. This can make delivery or storage of products difficult. In this case, some measures are taken to ensure on time delivery

The scheduling objective is to minimise the difference between the planning and actual operation despite unforeseen events, and constraints not taken into account in the LP model such as time effects and storage.

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[4] Lifting program is described under section 4.6.2.

4.6.2   Scheduling at Mongstad:

Information presented in this section is collected from different meetings with Eivind Blindheim, Frode Bakke, and Jan Helge Svedhaug.

The scheduling section has the responsibility to ensure that the refiner's supply meets demand. Schedulers follow closely production and stocks movements, customers' orders, etc. in order to reach a planned delivery of products. To perform this task, the following programmes are used: Lifting program, Sport program and FEF-SKED program.

Lifting program

The monthly plan derived from LP-model (PIMS) is prepared by considering the whole month's process capacity, the whole month supply of crude oil and the whole month expected demand. In brief, this monthly plan does not take into consideration time and storage effects as it takes a whole month production as a single production. This is not possible in practice because a whole month production cannot be produced at once due to different factors such as production and storage capacity. To adjust this monthly plan to the practical reality, a 'Lifting program' is used for that purpose. The Lifting program divides the monthly plan into small plans of normally 10 days. Therefore, there are 3 lifting programs for the M month divided as follows:

- From 0 to 10^{th}

- From 10^{th} to 20^{th} and

- From 20^{th} to the 30^{th}.

Lifting program combines information from the monthly plan and a Sport program (Sport program is explained below in this section). The monthly plan provides to the Lifting program the following data: products specifications and products quantities. The sum of the products quantities from the three Lifting programs is equal to the products quantities given by the monthly plan. Other output data of the Lifting programs are date and time when products are to be delivered, cargo types, Sport identification (it is an identification from the Sport program that is discussed later), the time range of deliverance (this range indicates a period in which a boat or a cargo has to arrive at Mongstad in order to be loaded, this range

is normally 3 days at Mongstad. If a boat arrives before this range it can wait there until its agreed time range in order to be loaded, but if there is an available jetty (port) capacity and enough stock, it can be loaded before its appointed time range). The Lifting program is updated once a week. This update can be for example a change in time range of a given cargo.

Sport program:

There are two types of Sport Program: Sport RAF and Sport BRIO. Sport RAF is used by Mongstad while Sport BRIO is used by Stavanger. The O&S department in Stavanger enters data in both programs Sport RAF and Sport BRIO. The common part between these two programs is that both programs are a sort of database for information on customers, cargoes, products demanded, and so on. In brief, they have information on demand data. The difference between these two databases is that Sport BRIO has more detailed information on demand. Whereas Sport RAF has information on demand that is only necessary to be used at Mongstad during production planning and scheduling, and shipping of products. The Sport BRIO represents all commitments made by the O&S, and it is updated as new information comes in or new commitments are made. Some of the data in the Sport RAF are estimated time of arrival of cargo at Mongstad, estimated time of boating, the time range, products to be loaded, product specifications, cargo or vessel name, shipment number, type of movements: export or import of products, flag, inspectors (independent inspectors for boat checking), etc.

REF-SKED program

REF-SKED stands for refinery scheduling. The following graph summarizes the process around the REF-SKED program:
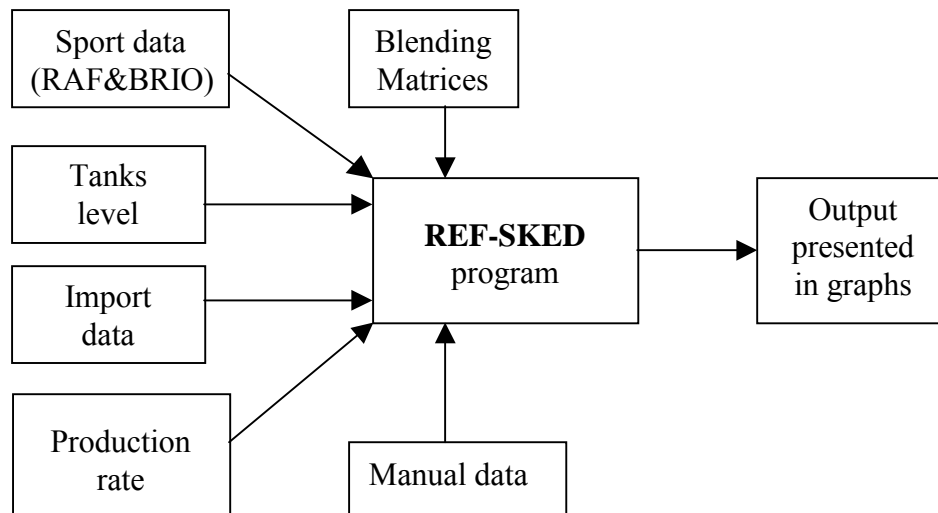
Figure 33 REF-SKED program at Mongstad.

This program is different from the other two programs described above as it has both supply data and demand data as input. Supply is entered in the REF-SKED program in a form of tanks level and production rate while demand is entered as data from the Sport program. REF-SKED uses both data from both Sport RAF and BRIO since both programs cover the commitments made by the marketing department (O&S). In some rare cases, there can be import of products; these imports data are also entered in the program. The different tanks levels are automatically read by the controlling system and entered automatically into the REF-SKED' program. Different blending matrices for products are also entered in the program. Production rates represent the forecasted production development and they are updated every week. Manual data are data that are entered manually. Manual data can be some commitments that are not in the Sport system, for example a small amount of products to be delivered.

Output of the REF-SKED program is presented in graphs. It shows an expected evolution of different product stocks if everything goes as planned. The program has a freedom to show a negative stock as well as a stock that is greater than the maximum stock level. As it is not possible to have a stock that is more than the stockage capacity or a negative stock, it is a scheduler's job to avoid these situations to happen.

4.6.3 Scheduling process at Mongstad

At Mongstad, the scheduling task is not centralized. It is divided in three main groups. The first group is responsible for light products. The second group takes charge of medium and heavy products while the third group has the responsibility of scheduling boat shipping. Each group can have only one person that performs the task.

The shipping scheduler has the responsibility of planning the loading sequence. He determines which jetty a ship or a cargo will use in order to be loaded. There are different product jetties and crude oil jetties. All jetties are not used for all products. Some jetties have been built with the possibility of shipping different products while some products may have a given jetty they can be loaded from. When determining the jetty to use, a scheduler takes into consideration the jetty's capacity and different products a ship will carry (some ships can be loaded with different products). To perform this task, the shipping scheduler uses data from Sport RAF. As described above, these data are entered in Sport RAF by the O&S department in Stavanger. Once data are entered in the Sport RAF, the O&S has access to make change on these data. However, a shipping scheduler at Mongstad can deny O&S access to the Sport RAF data access on if the time range becomes narrow (around two days before delivery). This is done in order to make a plan to run smoothly without interference of O&S. If O&S finds it necessary to make a change in this case, it has no other choice but to call Mongstad to perform that change. This measure is taken to avoid some changes that may come in late, pass unnoticed and cause problems in shipping exercise.

The other two scheduling groups, the one for light products and the other for medium and heavy products, perform the same type of task, have a same scheduling process and use same programs. The only difference between their jobs is which products they consider and some other specific problems or advantages associated with these products. So we will describe their scheduling task together without putting emphasis on products specifications.

The products schedulers have a responsibility of following closely movements of production and stocks in order to ensure that deliveries happen smoothly as planned. They use the REF-SKED program to perform their task. As described above, this program use different input data. O&S, which is responsible for contracting with customers, provides data on demand to

the scheduling groups through the Sport program. These data are for example delivery schedule, products to be sold, their characteristics, quantities and qualities. Products schedulers use both Sport programs with different identification in order to differentiate them because both programs together represent the aggregate demand. Data from the Sport RAF are confirmed data while data from the Sport BRIO may have some additional requirements that need to be met. The O&S enters all data concerning M month by latest on the 20[th] of M-1 month. Some of these data are imprecise by the time they come in the Sport program. They may have missing information like cargoes, delivery time, etc. Their range time usually have an interval of five to ten days when they are entered in the Sport program. As time horizon becomes narrow, the interval or time range is tightened and specifications on days (dates) and hours are given. The normal range is three days. Tank levels and production rate are also input of the REF-SKED program. Production rates are given by a production panel, which meets once a week to make prognosis on production development (rate) and products lifting.

With the help of the REF-SKED program, a scheduler has to assess if the deliveries will happen as planned. If the output of the REF-SKED shows a negative stock or a stock exceeding the maximum stock level, a scheduler has to take measures in order to avoid these situations. There are different measures that can be taken to prevent such situations and some of them are discussed here. One of the measures can be for example changing a blending matrix. This means using a blending matrix that is not recommended by the LP-model. Doing so, however, a scheduler takes into consideration the critical limitations suggested by the LP-model. Three times a week production schedulers and production runners meet in order to put the production plan in process. Another measure can be that a scheduler asks O&S to negotiate with a customer in order to change some delivery time ranges.

There are many factors that the scheduler has to deal with in assessing if the production will meet demand. Most scheduling problems are connected to unforeseen events around logistics, storage capacity, availability of crude oil, intermediate products and finished products, changes in plan as for example unplanned shutdown. On the one hand, delivery can happen as planned without problems; but on the other hand, there can come up unexpected situations that cause the delivery process not to run smoothly. A problem arises if it seems impossible to meet lead-time. Sometimes the product yield differs from expected

or suggested by LP-model. In some cases, the stock can be so low that the refiner cannot meet demand. If a boat arrives before it could be loaded, the refiner can be charged for the waiting time. This is so expensive that the refiner tries all its best to avoid it. Other alternatives or measures are normally considered. The refiner can either try to negotiate with the customers before they arrive at Mongstad or try to meet the demand by buying the same products from other refineries. These alternatives are less costly than waiting to get enough stock from the production.

The worst case happens if tanks of some components are full and ships to be loaded have not yet arrived. This causes problems as components have their usually specified tanks to be stored in. In this case, Mongstad prefers to use other components' tanks to stock products. This is a very crucial situation. It has a number of consequences in around three following (or consecutive) weeks. The refiner has to change programs used in order to avoid the components blending. Tanks should be cleaned properly before they are used for this purpose and afterward so as to make them ready again for their usual components storage. Though this is hard and expensive, it is still an alternative that is much better than stopping production. This situation occurs normally in the winter when ships have problems of keeping time. If ships arrive late at Mongstad, they can be loaded if possible or they can wait to be loaded when it will be possible without Statoil paying their waiting time.

It is hard to follow the LP-model as this gives the overall monthly-targeted production. By following specifications, the outcome is not necessary the same as the model report has suggested. Every month, the actual production is compared to the planned production. The deviations are analysed and the report is given to the leaders who will take necessary measures. Sometimes the deviations analysis can be performed after a short period if there is a tremendous difference between the actual and planned production in order to take appropriate measures before it is too late.

4.7 Production Control

4.7.1   Production Control in refineries

The control is performed using an *advanced technology*. This technology is not explained here as it is beyond the scope of this study. However, the main tools used as described by Favennec(2000) are:

- Sensors and actuators: sensors provide basic information like discrete signals , temperature, flow rates, pressure,etc. Actuatorsare essentially pumps, motor-operated block and control valves.

- On-line analysers: are used to control process in real time, and to check that the rules and procedures aplicable to the activities are being properly applied.

- Communication networks: they are mainly used to link different computers or distributed control systems so that data could be shared.

- Programmable logical controllers (PLC)

- Surveillance robots

- Digital control systems (DCS)

- Data processing hardware

- Softwares

According to Favennec(2001) the control activity is important as it gives information on the progress of the production. One of the objectives of this control is to ensure that everything is running as planned or intended. This information is critical because it allows the refiner to follow the process closely, and it can reveal when it is necessarily to change or take more measures. The control activity is performed at all stages of production. It includes control of crude oil, control of unit operating conditions, product control, control of integrity of equipment etc. In refineries, there are usually meetings on a regular basis between all parties involved in the control activities.

Each refinery process has normally its own specific function, but it is possible to vary unit-operating conditions around their normal position. The control is exercised to maximise the suitability of the feedstock for the quantities and qualities the market requires. The control tools are used to identify process at each activity level. Reports are taken and analysed at each level or stage of production. This ensures a smooth control of production and an early intervention if it becomes necessary. In this case, we can mention for example if an actual product quantity is very low compare to what is needed later in production, some measures maybe taken such as changing product specifications.

Plant and equipment are also controlled. The inspection of plant and equipment has the responsibility of the daily maintenance operations, long-term strategic maintenance, and defining the scope of major turnaround shutdowns for periodic maintenance plans. This has a big influence on total maintenance costs.

Products are also controlled against specifications. This control covers two distinct areas. The first is the control of intermediate products to achieve on-line or deferred (intermediate tankage) optimisation of manufacturing unit operating or blending conditions. The second area is the control to ensure that finished products for shipment outside the refinery are on-specifications, given that any failure to meet specification requirements could lead to heavy commercial, or even judicial penalties.

4.7.2   Production Control at Mongstad

Information presented in this section is collected from a presentation made by Frode Bakke and Signy Midtbø Riisnes.

At Mongstad, products are controlled to ensure that they have all the required specifications. On most products, there is an automatic sample taker, but in some cases, it can be done manually. The sample is usually taken while blending or shipping (packing). The sample can be taken many times in one ship if the automatic sampler has not been working properly. This is usually done in big ships. The sample is analysed in the laboratory, and all the deviations that occur become subject of the deviations analysis. After the sample analysis, the specifications of delivered products are written on a certificate that is given to the ship.

The product specifications can be grouped in two parts. The first part is the government requirements. Each country has its own requirements on products specifications. The second part consists of customer specific requirements. On top of the government requirements, a customer can require other specifications on products.

In some cases, products do not meet the required specifications. The reaction to this problem depends on the type of deviations. If the deviations are only on certain particular specifications wanted by a customer, the authority in charge (O&S in Stavanger) respond by negotiating with the customer. In this case, Mongstad has no authority to take the end decision. This problem is normally solved through negotiations between a customer and the O&S; some discounts, or more quantities etc. may be granted to the customer.

However, if products do not fill government requirements on products, there is no way out, the products can be pumped back to the tanks. These products are blended again in order to meet the requirements. This decision is made at Mongstad, as it does not need the approval of the O&S section. If it seems impossible to fill the government required specifications, a number of factors are considered. The blending matrix may be revised; Statoil can sell the products on the spot market, or sell them to markets with less stringent specifications.

5. Price Structure

5.1 Introduction

The petroleum industry is heavily dependent on the price of oil. This is easily seen on the stock market where, for instance, the price of Statoil shares is closely related to the crude oil prices. When the crude oil prices rise, the Statoil shares rise too since an increase in crude oil prices will increase the expected revenue of an oil company. Being a part of Statoil's value chain, Mongstad Refinery is required to continuously improve its contribution margin between its buy price of primary oil products (crude oil, NGL, additives etc.) and its sales price on secondary oil products (refined products). As we will begin to analyse the price emergence of primary oil and its refined products, it will be evident for the reader that this contribution margin is often not a lucrative one and thereby being a threat rather than an opportunity.

By naming this section Price Structure, we are mainly interested in the price emergence of direct inputs (primary oils) and direct outputs (refined products). One would argue that direct input like crude oil is a cost and thus should not be included in a pricing chapter. However, by price structure we want to focus on how Mongstad must adapt to price changes on its inputs and outputs. Hence, we are interested in the gross margin[5] structure rather than the price that Mongstad can charge its buyers. Main focus would therefore be on the opportunities and threats on gross margins. The *Cost Structure* section will be focused on the cost of operating a refinery (OPEX[6]) and cost of investments (CAPEX[7]). These costs are something that Mongstad can affect. The price of outputs and inputs cannot be affected by Mongstad since the O&S (Oil and Supply) at Stavanger is responsible for this. However, Mongstad can affect the decision costs in the choice of crude oil type in their production system as well as which product to produce.

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[5] Gross margin = Price on outputs-Price on inputs

[6] Operating expenditures

[7] Capital expenditures

To understand the price structure of Mongstad, we should first try to understand the industry it plays in. Let us unravel the story of the refining industry.

5.2 The Industry

5.2.1.   Supply and Demand in the Petroleum Industry

As any other prices on commodities, the prices of primary oils and end-products are created by the market. The market is created by supply and demand of a given product or a group of products. Market delineation will later be given for each oil-product that requires it, since it will prove us useful when we want to investigate the price creation in detail. For now, we will try to get a general overview of the refinery business and thereby understanding the underlying market structure.

Below you see diagram of world demand and supply of petroleum, presented in quarterly terms from 1991 up to end of 2004. We see that the demand has high variations around a trend where there are demand peaks at least once a year and demand lows also at least once a year. This variation is maybe caused by different consumption patterns during summer and winter. In cold winters, more energy is required to keep the same level of work and heat as in summer times. Therefore, the demand of petroleum should be higher during winter times (usually first and fourth quarters) than summer times. We see that the world demand trend has been going upwards since 1993. Many analysts explain the general increase in demand due to the expansion of the Chinese and Indian economies during the last ten years, Geman (2005). We will be discussing this in-depth later.

The supply is correlated in some way with the demand but at a much lower level of variations. Since demand often is uncertain, variations in demand is difficult to follow by suppliers thereby requiring market players to hold some buffer inventories to secure supplies. In addition, the commodity market has been a somewhat uncertainty risk absorber since contracts of future deliveries give some predictions of future demand. We end this part by observing that the supply curve and demand curve follow each other closely. This is not unexpected since one has limited possibilities to store products.
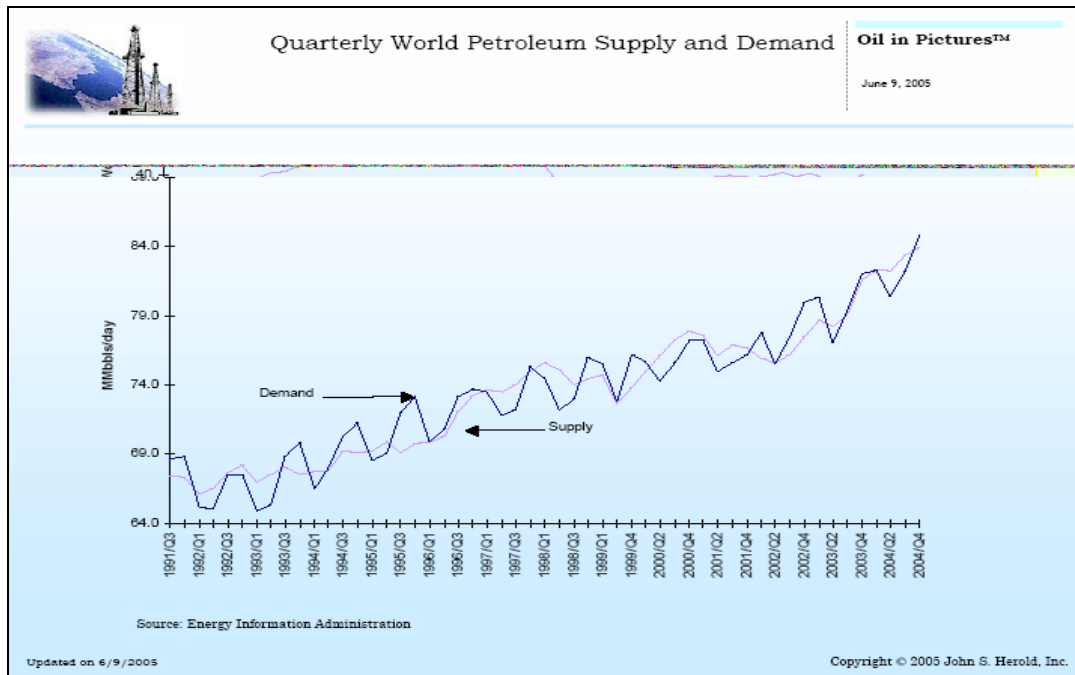
Figure 34 A Quarterly Overview of Supply and Demand of Petroleum in the World from '91 to '04. *Source: Energy Information Administration*

5.2.2. Product Life Cycle (Nagel & Holden 2002)

A life of a product may be sectioned into four phases: introduction, growth, maturity and decline. Each phase has its own distinctions that affect the sales and profits of a company. The *introduction* of a product is the beginning of a market in development. Demand is relatively inelastic (a relative price increase will be larger than a relative sales quantity increase) since the customers lack the knowledge of the product benefits. However, the production costs are high so that the potential profits will more likely appear as a loss. Fortunately, there are few competitors that can pose a threat to the company since the product is not well-established in the market.

As the *market grows*, consumers become more aware of the product's attributes due to personal experience, or information from other users. Thus the customers become more price sensitive along with the increase of number of suppliers. This gives an increase of price competition in the market. Still, this phase will generally generate both high sales (due to high price and quantity) and high profits (due to cost reductions because of higher utility of capacity and lower manufacturing costs).

When the *market matures,* the consumers frequently purchase the product and the price sensitivity reaches an all-time high. As a result of intense competition between many suppliers, there is a pressure to lower prices since market capturing is the only way for a company to grow in a matured industry. In addition, the many players in the market give none the opportunity to set the price as they please. Hence the price is mostly given in the market but probably with a downward price trend due to intense rivalry. In such situation, most suppliers are forced to become more cost-effective both in their production and supply chains. Those who do not keep up with cost reductions in the industry are more likely to be eliminated by the market play.

The *market decline* (also called *stagnation*) marks the beginning of the end for a product. This phase is easily recognised by reduced demand (temporary or permanently) and overcapacity in the industry. The price competition gets even tougher since suppliers try to capture shares in a declining market. Here the cost structure of the industry plays a vital role. If costs are largely variable or capital may be reallocated elsewhere without significant extra costs, even a small fall in prices will encourage sellers to cut capacity or move out from the market entirely. This opportunity is limited when costs are largely fixed and sunk. As a result of reduced utilisation of capacity, the average cost will increase[8] when there are low exit-possibilities from existing capital resources, or lack of alternate use. Often this leads to tough competition to the bitter end since suppliers will try to reduce prices to increase capacity utilisation. However, this is an industry in decline so the relative price reduction is more likely to be larger than the relative quantity increase, thereby making the competition even fiercer due to loss in net sales.

Suppliers have then mainly three options: retrenchment, harvesting or consolidation. Nagel & Holden (2002) give an example from the tire-industry in the 1970s where the characteristics were a fall in demand due to competition from substitutes and overcapacity in the industry. Three tire-companies faced this challenge by choosing their own distinct strategy. Goodrich chose a harvesting strategy where they used skimming pricing to harvest the already existing market share and giving up low-performing segments. The goal was to have a controlled exit of the market. To make harvesting a successful strategy, it must begin

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[8] In literature this increase in costs are mentioned as an increase of capacity costs. We will further investigate these costs in the chapter for *cost structure.*

before the competitors realise that the market is in decline, or else how will the company be able to sell off its assets? Firestone chose also to give up low-performing segments but decided to retrench in the high-performing segments. Firestone sold seven of its factories and used the new available capital to improve efficiency and become a low-cost producer. Retrenchment requires that the company decide which segments it wants to let off, a decision that can be quite hard. Goodyear, however, chose a consolidation strategy to strengthen its position by reinvesting, modernise and take-overs. This requires a financial strength that few companies have. Consolidation is somewhat a more long-term strategy than the other strategies and requires a prediction of what segments that will have the longest life.

The point of working out a new strategy in a market in decline is the possibility to turn-around a bad financial company into a new healthy business. To be successful in a market in decline, timing, foresight and creativity are crucial. The model below summarises the theory of Product Life Cycle:
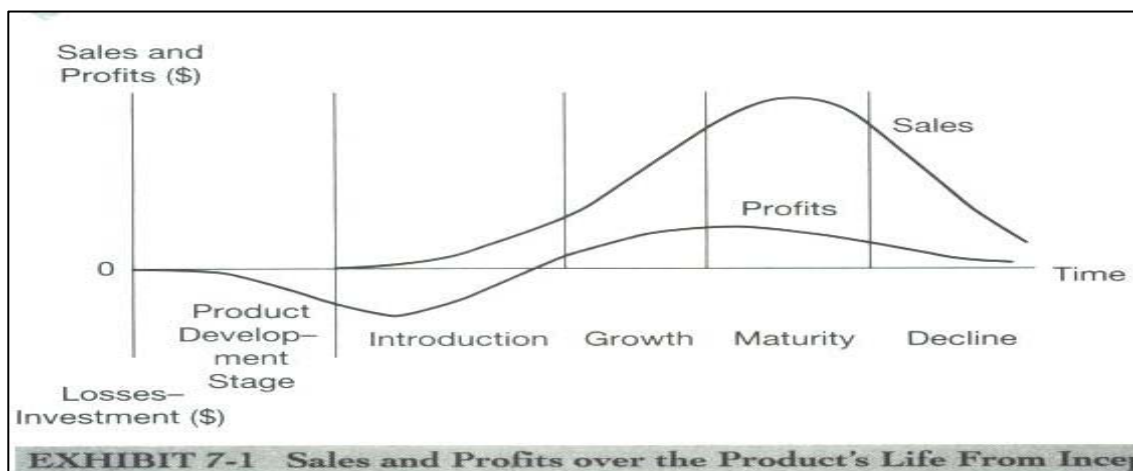
Figure 35 Product Life Cycle, Nagel&Holden (2002)

5.2.3.   Product Life Theory applied on the Refinery Industry

Petroleum as a commodity has only been important for our society from the 20th century to today. In fact, it was after the 2nd World War that the use of petroleum had an incredible push toward world domination. For instance, petroleum as a source of energy has in many cases replaced coal. This has led petroleum to become our new engine in the modern society. Its vital role in the world economy has given an incredible development in oil related activities like refining.

Simplified, we may define petroleum refining as a product. Primary oils (crude oil etc) are the input of a refinery system and the output are the refined products, ready for shipment to end-users. Hence the product value creation lies primarily in the refining process.

Both capacity and numbers of refiners have increased remarkably after the 2nd World War in a phase of *growth*. The refining industry has become the most high-volume and low-margin industry in the world. The result of the tough competition due to *maturity* is a consolidation where the major energy companies control the refining complexes to secure their supplies of petroleum products to the market. In addition, the capital costs on investing and sustaining a refinery plant are so high that the large amount of funding needed is difficult to raise due to high risk, caused by high complexity of building a refinery and low/no-alternative refinery use. Often, those amounts are at an unreachable level for most independent refineries. Many of the small independent refineries had to give up the market by choosing a harvesting strategy or often failing in a retrenchment strategy. Even large multi-national energy companies try to share both costs and risk by establishing different types of partnerships and joint ventures. According to Bruce Burke of Chem Systems, from 1997 to 2002 almost 45 per cent of the refining capacity in the U.S. has changed ownership due to a market in maturity. The figure below shows how the general pressure on oil companies has forced consolidations to major integrated oil companies.
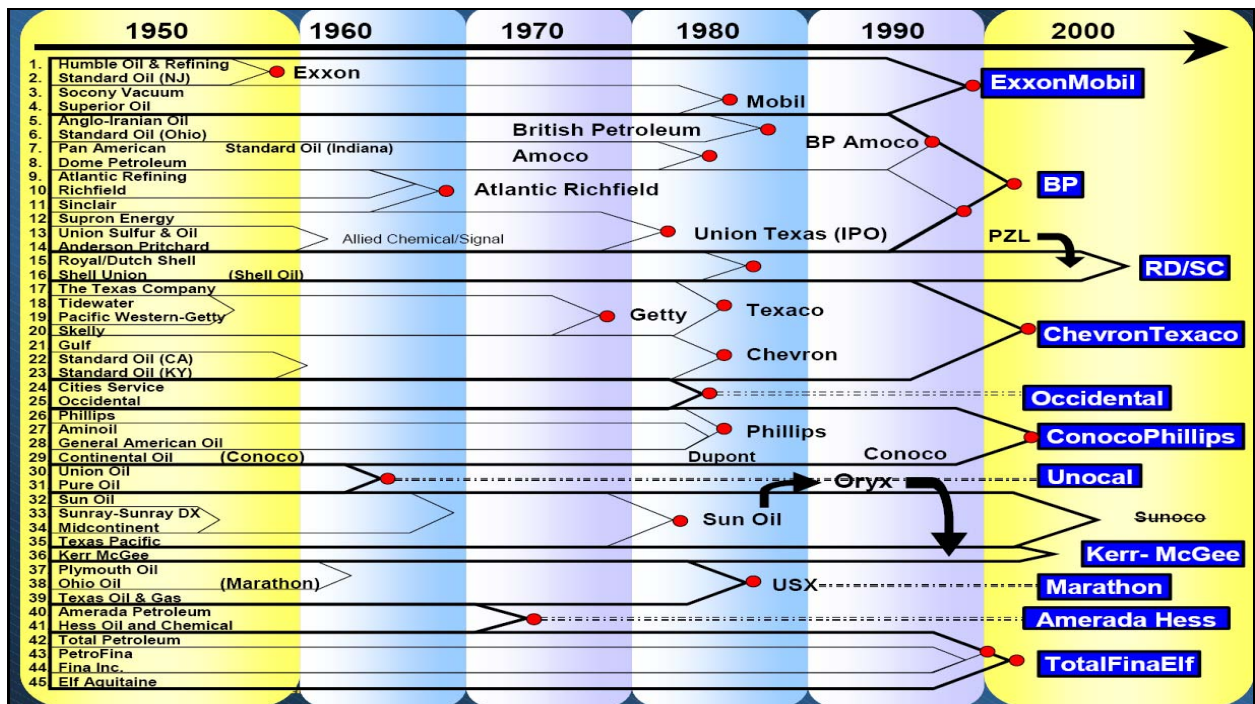
Figure 36 Structural Changes in the Oil and Gas Business, John S. Harold Inc, Arthur L Smith, Chairman and CEO, Oil&Gas Conference 2002

Experts predict that those refineries, which cannot form alliances by mergers or equity partnerships, will exit the market. Mongstad Refinery DA is an example of partnership where Statoil ASA owns 78 per cent and Shell owns the rest of it. How this affects the processes and organisation at Mongstad refinery will be discussed at a later stage. Maybe the supply side in the refinery industry is most likely only economical viable for tough market players with financial power due to an industry in *maturity* and even in *decline*.

While the supply side seems to be over-matured and characterised by tough competition and consolidation, the demand side remains high and even increasing as shown in an earlier figure. Developing countries like China and India have an increased need of petroleum products due to increase in energy consumption generated by higher standards of living, Geman (2005).

Number of Refineries

World Total	
Asia & Oceania	
Africa	
Middle East	
Eastern Europe & Former U.S.S.R.	
Western Europe	
Central & South America	
North America	

0   100   200   300   400   500   600   700   800
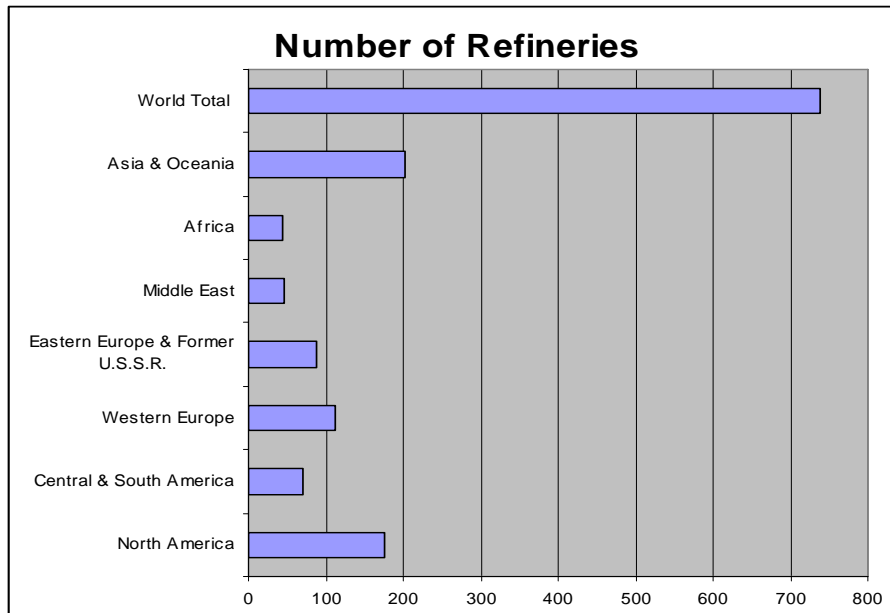
Figure 37:
Distribution of the World's Refineries, Source: Energy Information Administration, 2004

China alone has been having a 15 per cent year-on-year increase in oil demand. In absolute terms, this implies an increase of 0.8Mb/d while, as an illustration, the spare production capacity in the Middle East is only 1.6Mb/d (Geman 2005). In other words, the supply side has limited possibilities to increase its production on a short term. In addition, petroleum products like gasoline, diesel etc., have few or none real competing substitutes today. For instance, the hydro-fuel car as a competitor to the petrol-fuel car is unrealistic in the near future. This is due to the fact that hydrogen does not appear naturally alone in nature and thereby being a bearer of energy rather than a source of energy. With today's technology, hydrogen may be separated from hydrocarbon molecules but the question is how we are going to store the large amount of carbon residuals. Thus, hydrogen remains a vision in the future and not a real-threat. A close discussion will be given later. Summarising the key element of this part; both the supply side and the demand side is relatively high compared to earlier, and the demand side is even increasing substantial.

The world is dependent on secure supply of petroleum-refined products. Prices increase and are highly volatile when uncertainty appears. This gives a highly inelastic demand. Hence, there are signs that the petroleum refining industry is in a maturity phase and not in a declining phase. A couple of years ago, many experts said that refining was a declining industry due to overcapacity. This prediction must be modified slightly after the recent trend. As mentioned earlier, no other energy source has yet proved to be a real threat to petroleum, and the increase in demand from China and India will certainly increase the need of

petroleum-refined products. However, the structure of the refining industry has given it a large disadvantage in keeping up with the required product flow from primary oils to refined products to match demand. The reserves of highly desired light crude oil are under strain, forcing refineries to purchase less-wanted heavier oil with more undesirable sulphur content. Refineries without conversion capacity are not able to convert heavy oil to lighter components, implying that the refiners are sitting with "useless" residuals. The increase in heavier oil types and amount of residuals, have pressured the existing refining complexes with spare transformer capacity. In addition, crude oil with more of the lighter hydrocarbons increases in price. This is somewhat a good situation for refineries with capacity of converting heavy oil components to lighter oil components, for instance, by cracking. In fact, the refinery can widely use imported residuals to utilise its cracker-capacity since it is more often profitable than working only with light crude oils. The trend in the refining industry is that large refining companies and integrated oil-companies invest in transformer capacity. The bottleneck in the supply of refined products is thus mainly the lack of refining capacity.

¼ of the refining capacity in Western Europe is cracking or reforming capacity, shown in the figure below. Only North America has a considerable cracker and reforming capacity, while the other geographical areas are heavily dependent on light crude oils. There are several new upgrades of refineries in progress so that even more heavy primary oils may be processed.

World Refining Capacity '03
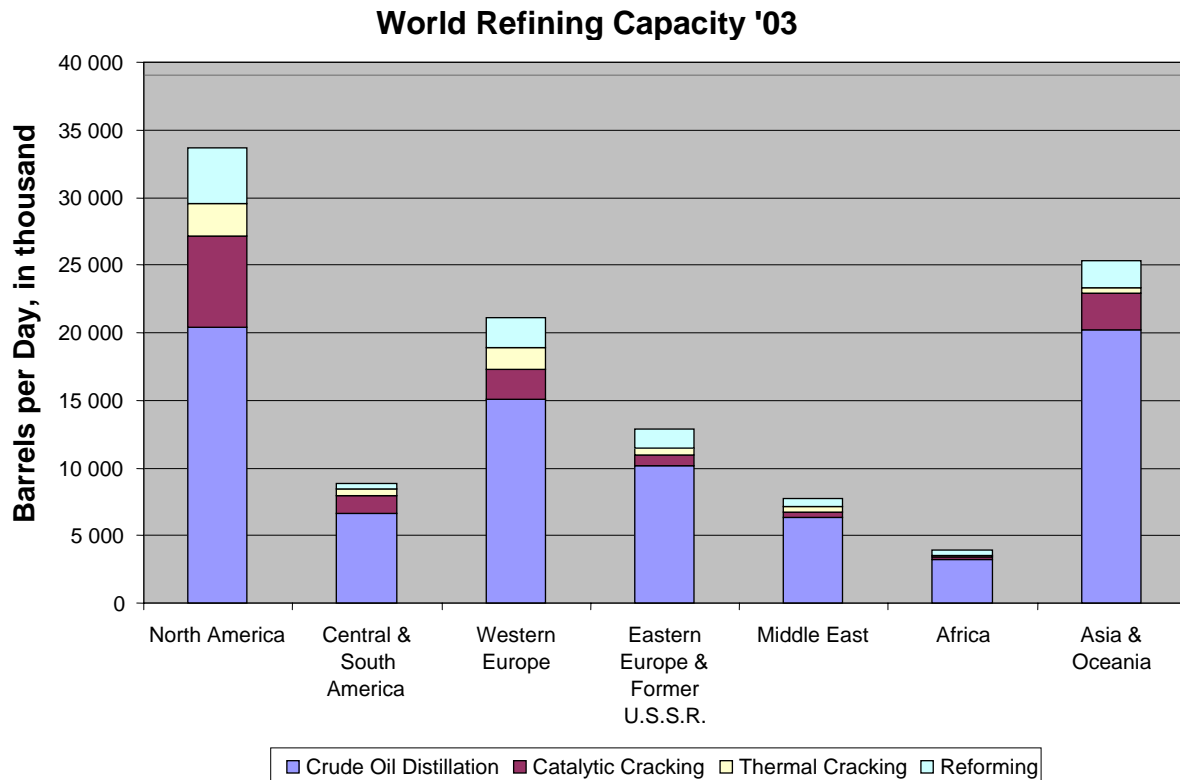
Figure 38 Energy Information Administration, International Energy Annual 2004

With no near threats from product substitutes and an opportunity in what seems to be an "ever-increasing" demand, the revitalisation of the refining industry appears to be a possibility. However, the refiner should not be too optimistic. China and India may probably install extra refining capacity to secure their own supply of refined products, although this might take some time. China has already been building up large oil inventories and constructing new refineries. Time will also be needed before we see results of the large upgrading investments in conversion capacity in the rest of the World. Some experts believe that the demand is unusually high and probably will not sustain over the long term due to more fuel efficient engines, like the hybrid car that runs on both gasoline and electricity, and other environmental focus on efficient energy use. A worst-case scenario for the industry could be that the high demand fails and the large investments results in excess capacity. This will return the refining industry where it was in the late 1990s, an industry in *over-maturity and decline.*

However, the consolidation of the industry in 1970s has made it healthier and has given it a financial backbone. Historically, most refining plants have been using a large part of their capacity, usually above 80 per cent utilisation.

A serious obstacle for many refineries is the increasing regulatory requirements in many countries. Requirements like maximum sulphur content in end-products, removing pollutants during refining, and emission control of dioxides, have forced many refineries to commit to expensive investments in equipments. Some governments have environmental taxes on pollution emissions, while other uses tradable emission quotas as an incentive to invest in new equipment. The stringent environmental regulations and the low margins have made many refineries aware of the possibilities to make money from secondary activities like energy supply to local areas from refinery wastewater. The Statoil refinery in Kalundborg is a good example of a refinery living in symbiosis with nearby commercials and residential. In Denmark it is illegal to let large amount of hot wastewater go unused from industry.

5.2.4.   Margins in the Refining Industry

As mentioned earlier, the refineries have often been exposed to low-profitability due to the nature of the processes being homogenous and the easy accessible worldwide excess capacity. Hence, there are few possibilities for the refineries to differentiate their products and to price discriminate, with the exception of the swing producers that can change production process and customise it to the buyer's requirements. By being a high-volume and low-margin industry, financial strength is required for any refinery. Financial strength gives the refinery the possibility to invest in new equipment to adapt to new environmental requirements (regulation imposed reduction in sulphur content as an instance) and to hedge on the commodity market. Hedging protects the refiner against the adverse effects from undesired price movements. By financial securing a fixed price for the refinery input and the refinery output, the refiner can operate with fixed gross margins[9] for a period. This gives the refinery operation much less uncertainty and it helps ensuring profitability.

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[9] Price of outputs – Price of inputs

However, operating a refinery is quite difficult and hedging does not always ensure profitability as the diagram below of gross benchmark margins in three different regions of the refinery industry indicates. The three different margins are calculated from income per barrel given by the product yield[10] and the end-product prices, and subtracting it with the crude oil price of the given region[11]. NWE Brent Cracking gives the refinery margin of North-Europe by using Brent Blend as crude oil and Rotterdam as a refinery centre. We observe from the curves that refinery margins have been quite low during the 90s (0-4per cent). However, the last two years the refining margins have been increasing in the last two years (4-9 per cent). This is mostly due to the higher refinery utilisation and the need of lacking residual oil processing infrastructure due to heavier crude oil. The US refinery utilisation has increased in the last ten years from 70 per cent to 95 per cent, indicating an increased utility of earlier excess capacity. In fact, the lack of residual oil processing capacity has made the refinery industry the bottleneck of the world petroleum product supply.

As the US is installing more hydrocarbon-converter capacity and Asia is increasing its refining capacity, it might be possible that the trend of 90s with low economic yield in refinery business will return.
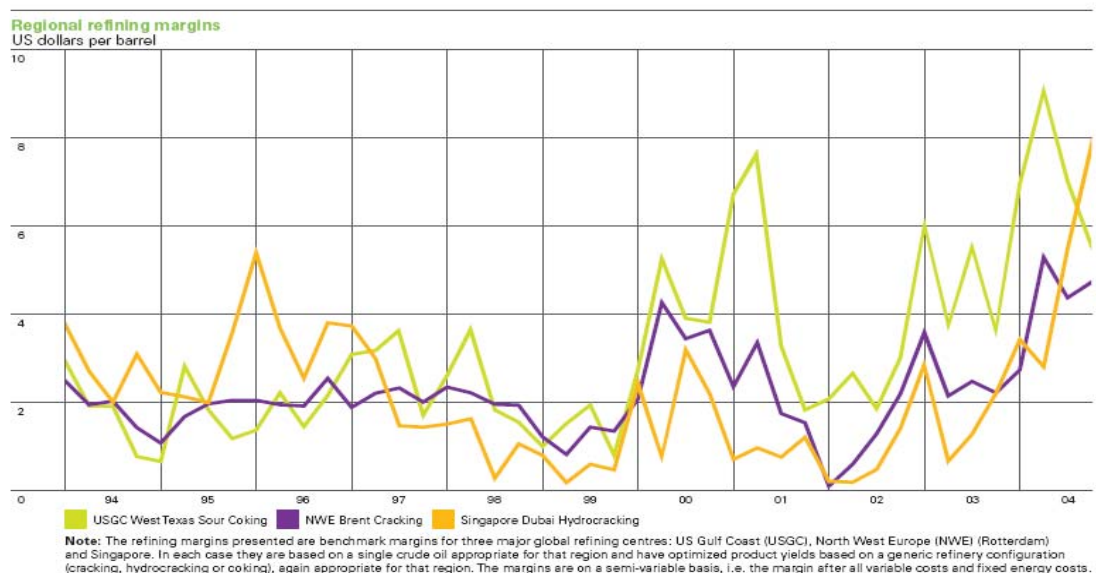
Figure 39 Refining Margins, BP Statistical Review of World Energy 2005

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[10] The product yield is optimised by the generic refinery conFigureation in that region.

[11] Brent Blend in Europe, WTI in America and Dubai in Asia.

Regardless of trends, a good refiner must find out which crude essay blending will give the best product yield regarding to optimisation of the gross margin. This is a difficult task where many variables have to be taken account of. Ordinary product calculations are hard to use due to joint cost problem, the dynamics in prices and the simultaneity in stochastic variables. Linear programming and successive approximation has thus been the key factor in any production decision depending on prices of inputs and outputs, and are discussed in detail in the production chapter.

5.3 External factors

5.3.1.   OPEC

OPEC[12] was formed by some oil-exporting countries (mainly oil-rich Arab countries) in desire of pushing oil prices up by reducing the quantity of oil in the market. The idea is to capture larger share of the consumer surplus by increasing the product price. When the cartel cuts its production, the existing consumers must fight more intensely for the reduced supply. Since the suppliers are interested in selling their product at a premium price, only the consumers who are willing to pay a higher price will be included. In other words, prices increase when quantity reduces due to market power of the cartel. In these days, OPEC controls about 40 per cent of the world's crude oil output (Hanesson 2003). With a 60 per cent share of world trade and 80 per cent share of proven reserves, it is clear that OPEC will still play a vital role in crude oil prices. For instance, US import of oil has gone up from 30 per cent in 1985 to 61 per cent in 2003. It is evident that the US, the main engine in world economy, is becoming more and more dependent on OPEC due to economic growth that cannot be met by domestic oil supply. The diagram below where market share of Non-OPEC countries is steadily falling illustrates this.

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[12] Organisation of Petroleum Exporting Countries
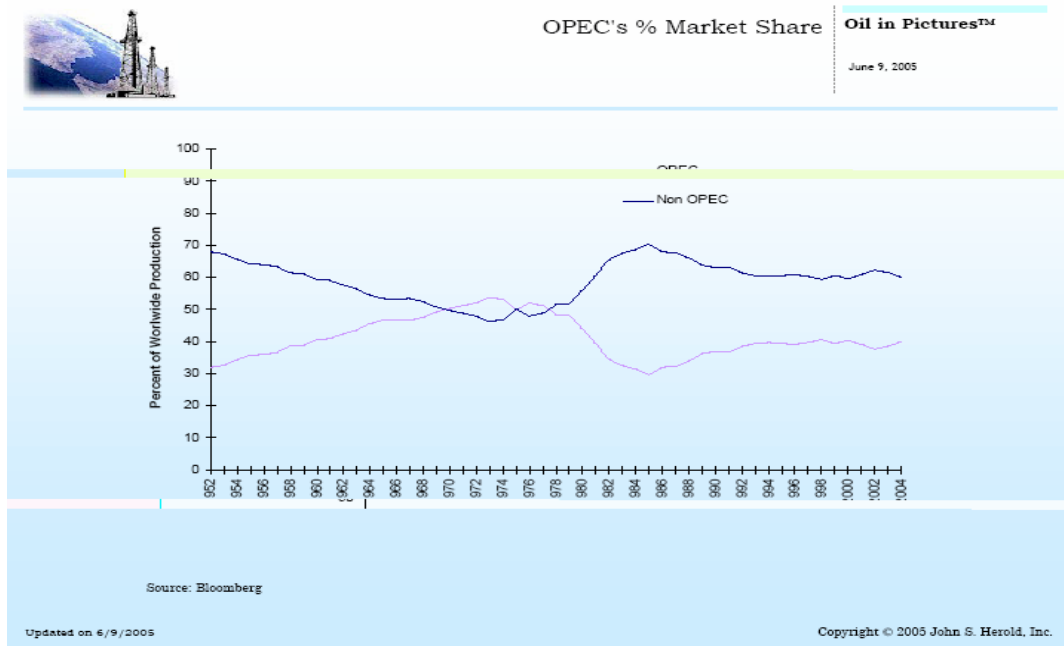
Figure 40 Market Share, OPEC vs. NON-OPEC, *Source: Bloomberg*

A particular feature of the behavioural pattern of OPEC is its attempts to control production according to ever-changing demand so that oil prices are kept high and stable. Non-OPEC countries like Norway usually keep their production level independent from production changes by OPEC. Regardless of OPEC's efforts to match demand and supply, inventories are necessary to meet mismatches. However, level of stocks has been falling steadily due to more wide use of "Just-in-Time" inventory policy in the oil industry. For companies in the OECD[13] the average holding inventory[14] measured in days was a total of 53 days (Geman 2005) for the whole supply chain, where 21 days for crude oil and 32 days for refined products (we will discuss the difference in numbers in the supply chain chapter). When we get to know that the average delivery time of crude oil to the refinery market is about 30 days (Geman 2005), it is easy to understand that the refinery production would be highly vulnerable without a monthly production and inventory planning due to the long lead time. In fact, the prices of primary oils are highly volatile during this transportation lead-time. For

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[13] Organisation for Economic Cooperation and Development.

[14] It is more like an end-of-period average inventory rather than average holding inventory. In financial terms, this is called *the forward cover* and is calculated by dividing stocks at the end of a given period by consumption in following period.

instance in a downward oil market, an integrated oil-company could purchase its crude oil for 40$/b but sell with a gross loss by selling the refined crude oil for less than 40$/b! This volatility in oil prices is a threat for refineries. OPEC would, in theory, reduce this volatility since its trying to adjust production according to demand. However, when a market uncertainty appears, for instance a change in head of OPEC, the cartel will probably add to the uncertainty by giving prices higher volatility. And, OPEC's efforts to stabilise prices have maybe been somewhat inefficient due to the cartel member's difficulties to agree on a joint production plan.

It is in place to mention that OPEC did try to actively control world prices with varying its production. OPEC has its own reference price, the so-called OPEC-basket price. It is an arithmetic average of seven crude oils15 and is used to monitor the market conditions since 1987. In 2000 the organisation decided that it would try to keep the OPEC-price within a price band.
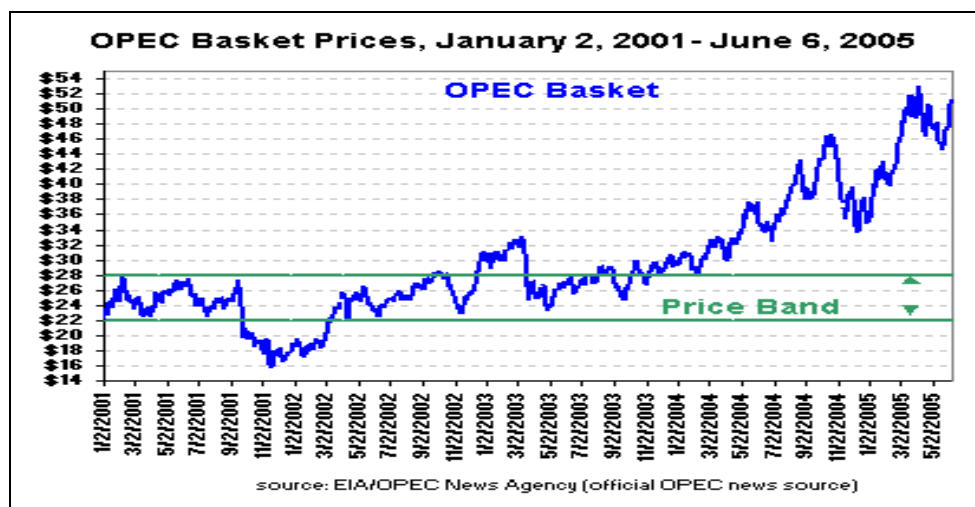
Figure 41 The OPEC Basket Price

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[15] Algeria's Saharan Blend, Indonesia Minas, Nigeria Bonny Light, Saudi Arabia Arab Light, Dubai Fateh, Venezuela Tia Juana and Mexico Isthmus non-OPEC oil).

If the price of crude oil was above \$28 per barrel in twenty consecutive days or below \$22 per barrel in ten consecutive days, the production would be adjusted to make the price return to the price band interval. This mechanism has only been used in October 2000 when OPEC decided to reduce production by 500,000 barrels per day. However, since the end of 2003 the prices of crude oil has been above \$28 without actions and OPEC decided in the beginning of 2005 to end the price band practice due to rendered market condition. It concludes that OPEC only has limited market power to affect price of crude oil to its desires. However, the limited price power does add uncertainty to the prices of crude oils. Middle-East countries are the backbone of OPEC and they are sitting with most of the world proved reserves (see diagram). As the oil reserves of the Non-OPEC countries fall, the world will be more dependent on OPEC and making demand more inelastic.

Figure 42 The World's Proven Oil Reserves, BP Statistical Review

5.3.2.   Taxes and Politics

Oil prices are highly volatile with political uncertainty, especially for refined products. Not only the political play within OPEC affects the prices but also the internal affairs in different countries. The US is a good example where oil-companies pressure politicians to ease taxes, fees and other restrictions on oil operations, while environmental-concerned organisations

try to push politicians towards more taxes and fees to divert production to more environmental friendly energy sources. The US oil politic has usually been friendly towards end-consumers and oil-companies. American consumers often drive fuel-intensive cars and the US politics on keeping the taxes and fees on gasoline low have been a public demand. The figures in the table below given by IAE, show that the US has significant lower retail prices than other countries on transportation fuels like unleaded gasoline and automotive diesel. The price of unleaded gasoline in Norway (1.366$/litre) is approximately threefold of what it is in the US (0.443$/litre)

	Heavy Fuel Oil for Industry[b] (tonne)	Light Fuel Oil for Households (1000 litres)	Automotive Diesel Oil[c] (litre)	Unleaded Premium[d] (litre)
Australia	..	..	..	0.696
Austria	219.36	526.50	0.773	1.106
Belgium	208.53	399.89	0.856	1.357
Canada	219.80	454.48	0.539	0.581
Chinese Taipei	236.27 L	x	0.428 L	0.583 L
Czech Republic	180.37	425.22 L	0.733	0.964
Denmark	313.81	950.50	0.923	1.395
Finland	272.73	474.97	0.806	1.354
France	214.90	488.86	0.848	1.263
Germany	203.88	432.46	0.944	1.356
Greece	267.75	396.30	0.700	0.972
Hungary	213.66	x	0.810	1.128
India	285.79 L	284.02 L	0.535 L	0.767 L
Ireland	308.76	551.29	0.849	1.121
Italy	268.81	1054.39	0.914	1.330
Japan	320.69	432.78	0.615	0.979
Korea	336.30	598.84	0.713	1.138
Luxembourg	194.96	383.00	0.686	1.065
Mexico	145.13	..	0.602	0.553
Netherlands	245.23	751.04	0.862	1.493
New Zealand	407.96	..	0.382	0.741
Norway	..	732.83	0.939	1.366
Poland	144.11	436.23	0.627	0.920
Portugal	312.73	x	0.826	1.206
South Africa	184.01 L	..	0.426 L	0.492 L
Slovak Republic	209.81	362.82 L	0.819	1.029
Spain	257.61	468.71	0.744	1.014
Sweden	c	992.55	0.867	1.297
Switzerland	229.59 L	344.06	0.922	1.044
Turkey	336.80	953.96	1.031	1.327
United Kingdom	258.44	338.49	1.215	1.408
United States	210.82	398.44	0.420	0.443

(a) Prices are for 1st Quarter 2004, or latest available (L). (b) High sulphur fuel oil for Canada, India, Ireland, Mexico, New Zealand, Poland, Turkey and the United States; low sulphur fuel oil for all other countries. (c) For commercial purposes. (d) Unleaded premium gasoline (95 RON); unleaded regular for Australia, Canada, Japan, Korea, Mexico, New Zealand

Table I: Petroleum Refined Product Prices Worldwide, International Agency, Key World Energy Statistics, 2004

However, the price difference on fuel oil for industry and households is not significant. This is maybe generally due to the lack of political willingness in most countries to impose extra costs for competition-exposed industry.

Cheap energy supply is often crucial in most industries. The EU and Norway have recently being using emission quotas that are tradable. Those industrial companies that invest in cleaning systems could reduce its emissions and sell its quotas. In fact, tradable quotas have emerged in the financial market and traded as other any financial goods. However, the US has traditionally regarded emission quotas and other governmental intervention of the market play to be a threat to American jobs. While European companies become more environmental focused, some Americans believe that this might make US companies less technology competitive and more vulnerable to potential environmental regulations in the future (Miller et Al. 2003).

Getting back to the low gasoline prices in the US, it is worth while noticing that a low gasoline price where taxes relatively consist of a lower part of the total gasoline price is more sensitive to changes in primary oil prices. Let us exemplify this: If the gasoline price to end-consumers is 1.4 $/litre in Norway and 0.5 $/litre in the US, a crude oil price increase of 0.1 $/litre gasoline will give an increase of 20 per cent (0.1$/0.5$) in US gasoline price but only about 7 per cent (0.1$/1.4$) in Norway. The US consumer would therefore be harder hit of a crude oil price increase. One should not under-estimate this political pressure that lies in US consumers as voters. George Bush, the President of the US, has earlier approved to release emergency crude oil inventory to the American market to reduce upwards price pressure on refined products. This may affect the worldwide crude oil prices and shows that the crude oil market and the refined market maybe is one integrated market as whole. We will be later discussing this relationship later.

For refineries like Mongstad, the main political uncertainty lies in the regulations in different countries on the physical content of refined products. Countries have different quality standards and requirements for fuel depending on how far they are in their environmental concerns. When Mongstad delivers its gasoline to the US, its content may be different from the gasoline served to the EU market. In fact, 20 states in the US have limits on the use of

MTBE[16] due to danger of groundwater decontamination (EIA 2005). MTBE was used to replace lead as an octane enhancer because of the many health-risks connected, but it seems that the replacement itself is under the threat of being replaced. Mongstad uses MTBE to increase octane levels in their gasoline. This must be reconsidered if MTBE-limits are made federal since Mongstad delivers to the US market. Ethanol has proven to be a substitute for MTBE and is mostly a renewable source since it is made of corn or cellulose. The benefits of using Ethanol instead of MTBE are also made political by exempting it from taxes by 51 cents per gallon through 2010 (EIA 2005). The reason is that the ethanol production is mainly domestic based in the US due to its vast amounts of corn and thereby creating jobs[17].

It is clear that political and environmental issues are often made economical. They often affect the production decisions at Mongstad. As a refinery supplying petroleum products to Europe and the US, flexibility is required to match each order's recipe that follow with each contract. Both giving away too much quality[18] and not fulfilling the stringent requirements of each order may harm the refinery margin severely, in particular in the latter case in form of fines, contract cancellation due to contract violation, or economic compensation. Rigid quality systems and flexibility in production like blending components direct to harbouring ships and control the product to ensure that the purchaser receives the product of agreement. However, the potential economic sanctions connected to product shortcomings do have a larger economic value in form of lost future sales and fines. That is why Mongstad can have buffers in the requirements in favour of the purchasers to avoid lawsuits or other sanctions.

5.3.3.   Technological Uncertainty

Technological uncertainty can play on the oil prices if it changes the energy consumption pattern or/and the supply pattern. Future scenarios from experts often replace oil with more environmental friendly and energy efficient sources. The electric car like the Ford's *Think,* was a part of such a scenario. However, to make an energy source replaceable, in this case

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[16] MTBE is an important additive to extend gasoline volume, enhance octane levels so that the fuel motor runs better, and as an oxygenate to reduce carbon monoxide emissions during cold winters.

[17] The American Jobs Creation Act of 2004

[18] Called *give-away* in refinery language.

the gasoline car, the alternative technology must be more energy efficient and/or economical cheaper in both design and use. Any way, Ford phased out the Think car due to little success among car purchasers, most likely because of its limited travelling range[19]. Instead hybrid cars running on both gasoline and electric have been a real option. This, and more efficient car engines, will probably reduce fuel consumption. However, as long as gasoline is cheap, especially regarding to the prices in the US, there are less incentives to consumers to change to more energy efficient cars. In addition, the developing countries have yet to match up the living standards of the developed countries. The fastest and cheapest way is to use filthy energy sources that are cheap.

Odell (2004) argues in his book that oil will be an important energy source well into 21st century. Although the supply of conventional oil is well in its product life, the supply of unconventional oil, for instance, from sand in Canada and Venezuela has barely begun. Investing in infrastructure to extract more oil, producing, refining and transporting will only amount to $3 per barrel[20]. In other words, production costs of oil will still be at a low level.

5.4 The Mongstad Refinery in the Market

We have up to now discussed the characteristics of the refining industry, its profitability and associated uncertainties. Now we will try to limit our description and analysis to Mongstad and its geographical and product market. By delineating a market we will be able to make a deeper market analysis of Mongstad. In the appendix of this chapter, a presentation of econometric delineation will be done to analyse the market.

5.4.1. Market Delineation

To perform a market analysis we are required to do market delineation. Although market delineation has been mainly used in antitrust cases to ensure competition, the use of it has spread out to other fields. To be able to form a pricing strategy, one must know the

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[19] The Think car was practically thought to be a city car due to its limited range.

[20] In p.103, Odell estimates the costs to be $3100 billion with today's technology to extract 140 Gtoe of crude oil.

competitors and other market forces mentioned in Porter's Five Forces Model (Porter 1980). The forces exerting on Mongstad will vary with what is defined as the market. Is the defined market Europe or the World? Should changes in the European market or World market be accounted for when price and purchase strategies are formed? Without a well-defined market achievability of a clear strategy will be reduced.

Theory on Geographical Market of Relevance

A worldwide market may consist of many smaller markets. For instance the crude oil market may be divided into an Asian market, a North American market, and a European market, based on the reference prices in these different regions.
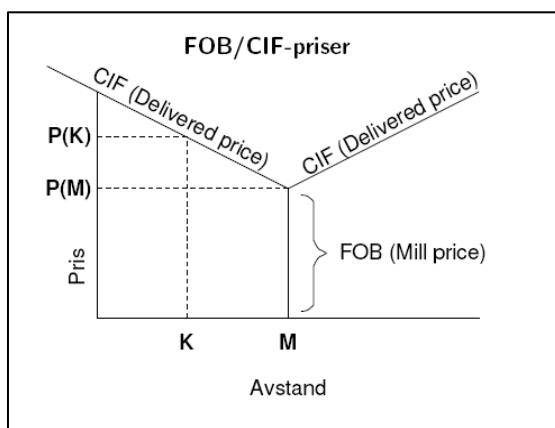
Figure 43 Model on Geographical Different Prices, Source: Roger Bivand, Department of Economics NHH

One of the main characteristics of one common geographical market is that prices of homogenous products will move together. That is, crude oil price at the NYMEX will correlate with the crude oil price at the IPE if Europe and North America is a common market.

Let us build a model that illustrates this point. We will use figure 43 above where the x-axis notes the distance (*avstand)* and the y-axis notes the price (*pris*). Let M on the x-axis mark the spatial location, for instance, of a mill in Bergen. The FOB (*free-on-board*) is the sales condition when the mill product is delivered to the customer from the mill plant. Sale price is then given by P(M). However, a customer at spatial location K may want to purchase the products of the mill at location M. Customer at location K must then pay a delivered price, P (K), under the sales condition CIF (cost, insurance and freight). Note that P(K) will increase when the distance from M to K increases due to higher freight costs (and maybe also higher

insurance costs). Thus, we have two graphs from point [M, P(M)] that note the price of the mill product as the distance from M increases. However, the customers have a limit to how much they are willing to pay.

If we say that the price an average customer is willing to pay is P(L) marked in figure 44 below, the customer base of the mill will be limited to distance +/- L. Thus, the circle drawn below the diagram is the geographical market of the mill.
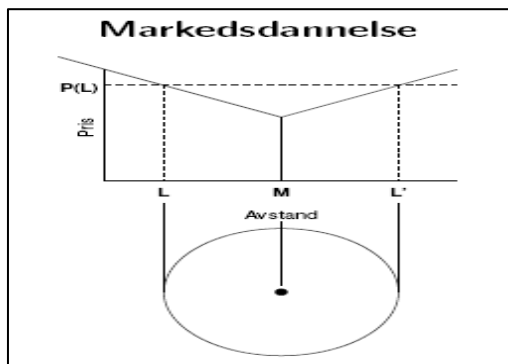
Figure 44 Emergence of a Geographical Market, Source: Roger Bivand, Department of Economics NHH

Mongstad refinery can choose between several crude oils from different regions so the case above with only one seller is not realistic. Tord Palander, a Swedish economist, has tried to model how the market share of two seller of a homogenous product will be affected by the spatial element. Let us imagine, in figure below, that M marks the land based oil production in Texas and M' is the offshore oil production at the Brent Group.
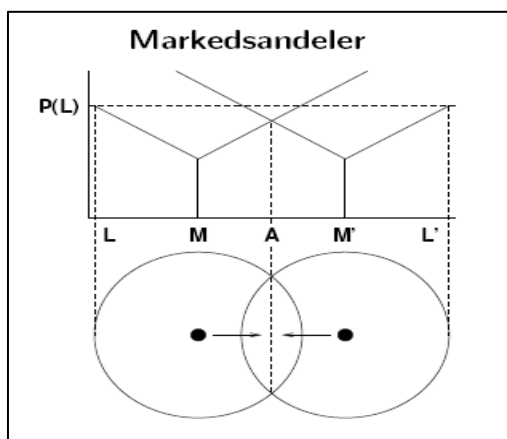
Figure 45 Share in a Geographical Market , Source: Roger Bivand, Department of Economics NHH

Then point A will mark the location where the customer is indifferent to the two oil producers due to equal price. The market will be split at point A where M takes all the customers to the left of A, and M' takes all the customers to the right of A. Thus, the market for Texas oil is [L,A] and for Brent oil is [A,L'].

Mongstad and its Crude Oil Inputs

Located in Norway, Mongstad is geographical closer to crude oils measured against Brent Blend than the Western Texas oil. It is not surprisingly that the most of the input crude oil comes from the Norwegian Continental Shelf (NCS). The price of crude oil should be cheaper when it comes from NCS than other parts of the world due to transportation cost advantage, given everything else are equal. If we look at figure below, you will find that most of Mongstad's crude oil is from NCS. According to Eivind Blindheim of Statoil Mongstad refinery, there are periods where crude oil from Russia or other regions are being used in the production process. However, this is not a common practice at Mongstad. The crude oil input comes from several different suppliers, not only Statoil's upstream infrastructures but also Hydro, Shell and other operators on the NCS. Although Mongstad is a heavy user of some types of crude oil, the composition may change from month to month.

Figure below shows that there is a heavy preference for Troll Blend crude oil the given year
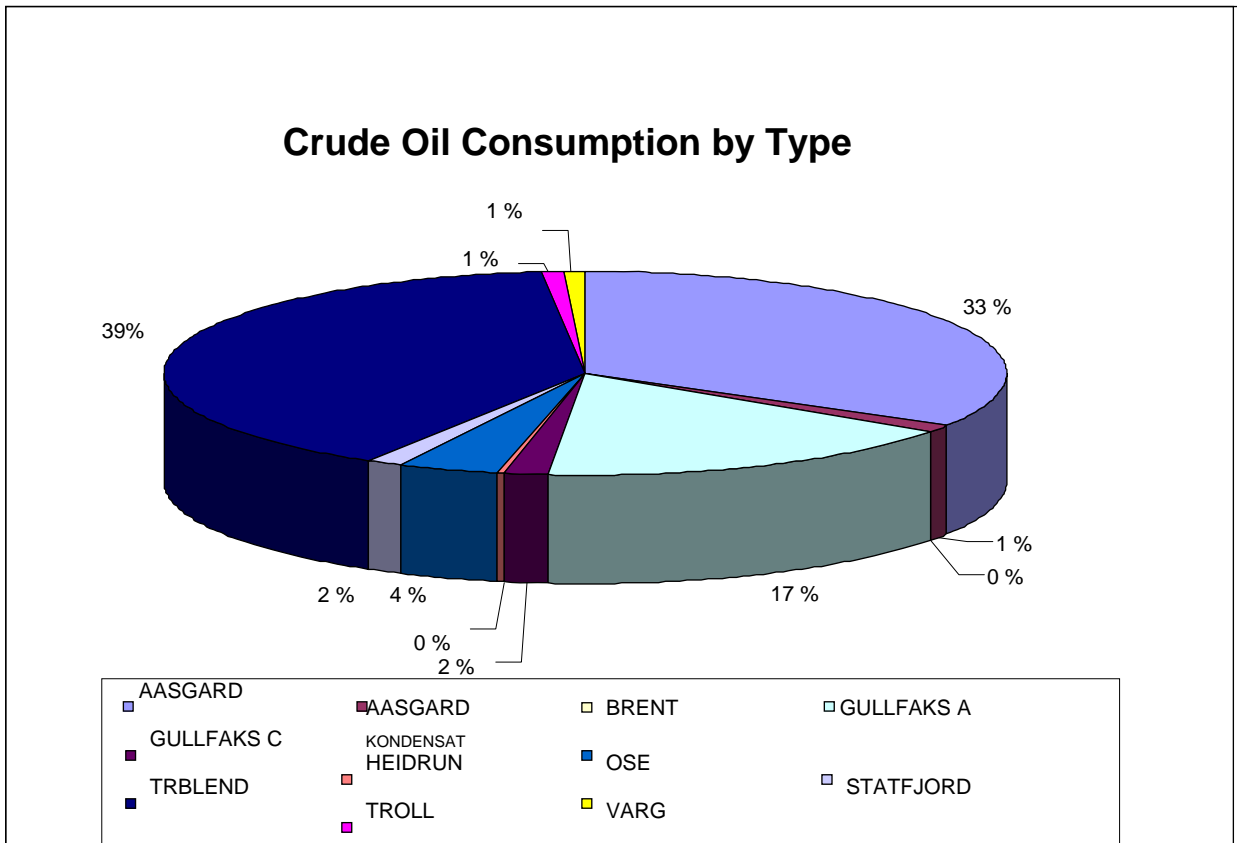
Figure 46 Crude Oil Consumption by Type, Year X, Source: Mongstad
Refinery DA

Change of consumption pattern can be due to several reasons or even a coincidence:

- This can be due to a certain crude oil assay in the production of the demanded refined products will be more efficient due to perhaps less cracker use etc. In practice at Mongstad, the conversion units are in operations continuously and therefore it is usually economical to use those units anyway.

- The price of the certain crude is favourable.

- While the input products from Troll-field arrive in pipes so that the supply is fairly stable, the input products from Oseberg come from ships, giving a more bulky supply.
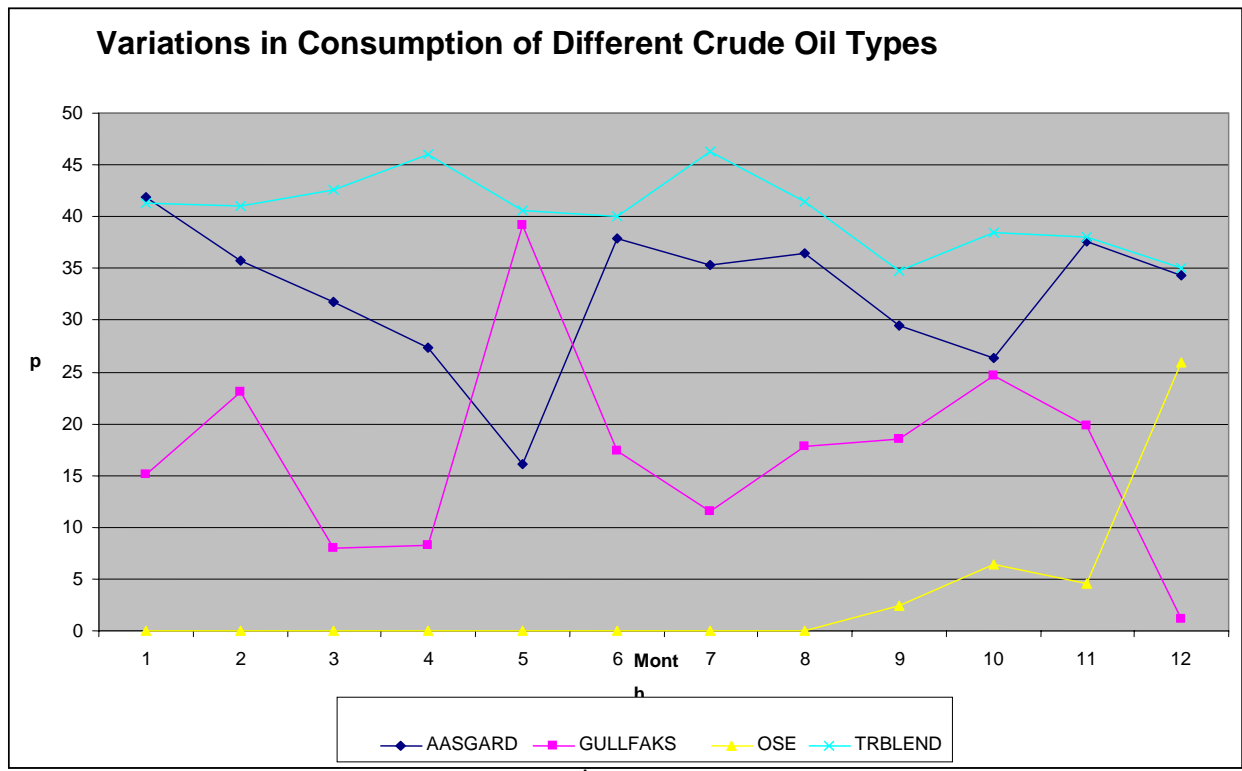
Figure 47 Variations in Consumption Patterns, Year X, Source: Mongstad Refinery DA

Intuitive reasoning and rules of thumb by decision makers and some spreadsheet quantitative tools often make the choices of input materials. We will look into this later in this section and in the production section.

We recommend you to read the part on reference prices later in this chapter to get an overview of the different geographical markets. Afterwards you can read the presented econometrical framework of a market delineation presented in the appendix of this chapter.

5.4.2. The Relationship between Crude Oil and Refined Products

Studying price relationships can give us important information about the market like the market delineation of Mongstad's crude oil market shown in the appendix section of this chapter. Price relationships can also help us to define the relationship between different types of product. A high price relationship between crude oil and refined product prices may tell us that the entire petroleum market is an integrated market, as predicted earlier. This can simplify the analysis somewhat by trying to find out if the prices are supply-driven or

demand-driven. Thus, we want to investigate if it is the crude oil price that drives the refined product prices (supply-driven), or the other way around (demand-driven). This helps us predicting the prices better.

Stiegler's (1969) definition of one product market is given by:*" The area within which the price of a commodity tends to uniformity, allowance being made for transportation costs."* In general, *uniformity* will say that the price movements of different petroleum products are very much alike (high price relationship). As earlier, this can be tested by econometrics. This has already been done by Asche et al (2000). We will discuss their findings.

The authors have used the Johansen test, a multivariate co integration test, to uncover price relationships. We refer to p.291-292 for a formal presentation of the test. The monthly data is represented from January 1992 to November 2000 and focuses on crude oil, kerosene, heavy fuel oil, naphtha and gas oil. The authors have not explained why gasoline prices are not included in the analysis. The refined prices are from the Rotterdam market and the crude price is the Brent Blend spot prices. They have used spot prices since they think that spot contracts are often connected to a physical delivery, and hence they reduce the speculative aspect of trading commodities.

The authors are interested in finding out the long-term relationship between crude oil and refined products and whether the price spread is constant. They argue that if long-term price relationship exists then it is a sign of an integrated market. It could be an example of supply driven market integration where refiners adjust there product mix by the relative prices. In addition, they want to find out if there are any price leaders.

Their findings are that long-term relationships do exist between crude oil and gas oil, kerosene and naphtha in northern Europe but not for heavy oil. They did also uncover long-term relationship between gas oil, kerosene and naphtha. This could mean that prices of these products may affect the optimal mix of them. If price on gas oil rises relatively more than kerosene then it would be likely that the product mix would be changed in favor of gas oil. Also, when we look at the refining process of crude oil, these three products often come from the same part of the crude oil so that a trade-off must be done. The authors did also find a weak long-run exogeneity for oil price indicating that crude oil might be a price leader. However, they did not find that refined products being price leaders to be true in the long-run. In short-run, refined product prices may affect crude oil prices. Thus, it seems like that

the oil market is slightly supply-driven. Although only kerosene and gas oil had constant spreads with crude oil prices while naphtha did not.
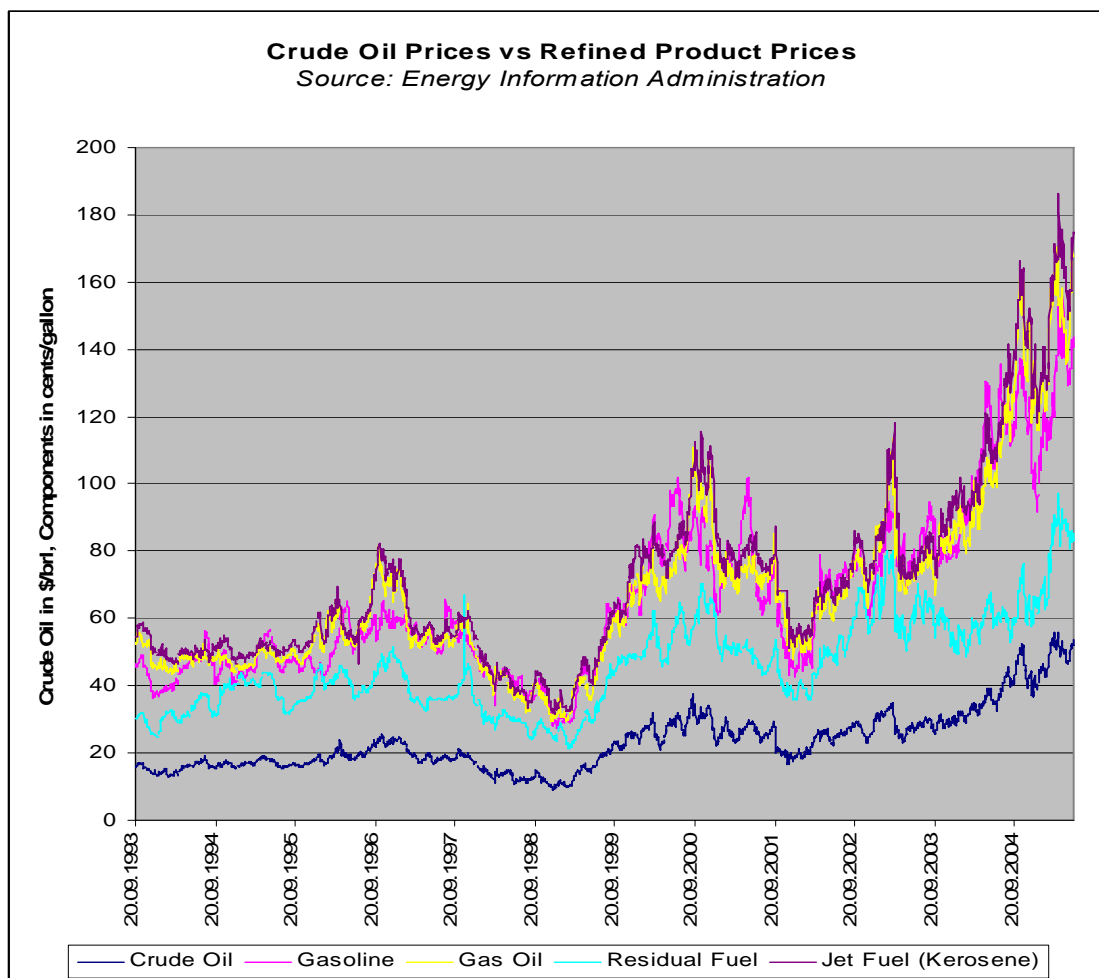
Figure 48: Crude Oil Prices vs. Refined Product Prices, Source: Energy Information Administration

The diagram above shows the price movements of the different petroleum products including gasoline. Notice that crude oil prices are noted in $/brl while the refined products are in cents/gallon. However, we are solely interested in the price movements. We see that kerosene and gas oil prices follow each other closely as the authors concluded. Also, gasoline has the same trend as the other two refined products but has a larger variation around the trend than them. Reasons for the larger fluctuations in gasoline prices are difficult to say but it is well known that gasoline is a more seasonal product where, for instance, the demand is higher during the American driving season. Residual fuel has a price movement that differs from both crude oil and the other refined products. Not all refining complexes are

able to process residual fuel. However, the refining industry is now building up conversion capacity, something that will possibly increase the price of residual oil due to higher demand by refiners.

Nowadays the capacity utilisation is much higher for refineries, especially those with cracker and reforming capacity due to heavier crude oil on the market. Since the demand is highly inelastic and the industry is without large spare capacity, external shocks like a refinery production stop, for instance due to a required process revision, at Mongstad refinery might induce an increase in refined product prices because of reduced supply, and a fall in crude oil prices due to reduced absorption of the supply of crude oil by the refineries. However, these price movements will be within an upper and a lower limit in a limited geographical area (here: Europe). For instance, if the price fall of crude oil is large enough, it might be more lucrative to transport it to America, dependent on the cost of transport and time (will be discussed later). Note that the prices of refined products are more sensitive than primary oils due to difficulties of transporting it from one region to another. While crude oil can be transported in large bulks in tankers, products like LNG (liquefied natural gas) must be transported in special ships with small bulks. Another fact that reduces the volatility in prices is the high liquidity in crude oil. The financial market helps moving commodities where capacity is available

5.4.3. Export Market of Refined Products

We will primarily discuss the export market of refined products when we enter the chapter of

value chain analysis. However, it is appropriate to illustrate the market for Mongstad export by the pie chart below. As earlier mentioned, Mongstad processes roughly half of Norway's need of refined products. We see that mostly of the processed products go to Norway and the EU but also 6 per cent of it goes to the US. The export to US consists mainly of gasoline.
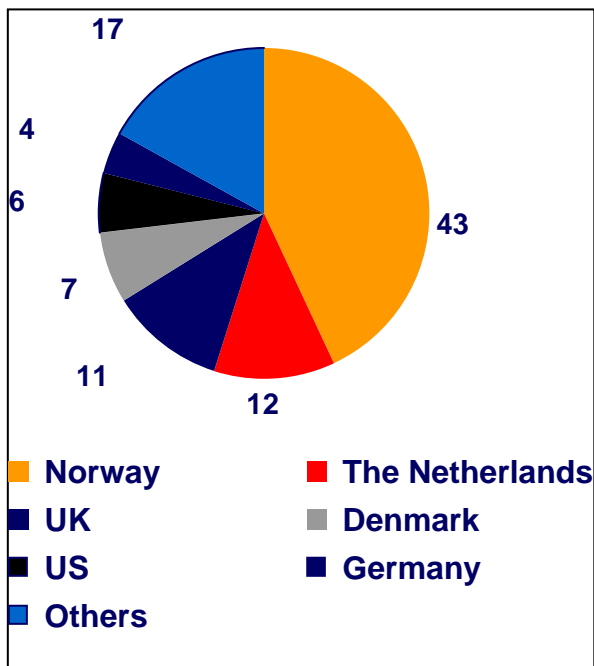
Figure 49 Mongstad Refined Product Deliveries 2003, in per cent *Source: Mongstad Refinery DA*

On average, Statoil sells 250,000 barrels (Aftenposten 2005) of gasoline weekly to the US; most of it is processed trough Mongstad. Einar Strømsvåg, CEO Manufacturing and Marketing in Statoil, comments that gasoline from Mongstad stands strong in the American market (without mentioning why). Also, the latest refinery upgrades have resulted in 90 per cent (Aftenposten 2005) of produced gasoline meets the stringent environment requirements in the EU.

5.4.4. Products Supplied to and by Statoil Mongstad

Not only crude oil are used as input but also condensate to make the feedstock lighter in favour of producing lighter components, and other components like MTBE as a octane-enhancer, and additives and catalysts. However, crude oil constitutes 80 per cent of input quantity (figure 26).

We see that (figure 50) both gasoline (used in transportation) and gas oil (heating) are high on sales quantity. Diesel (mainly transportation) and naphtha (important in polymers industry) are also important sales product.
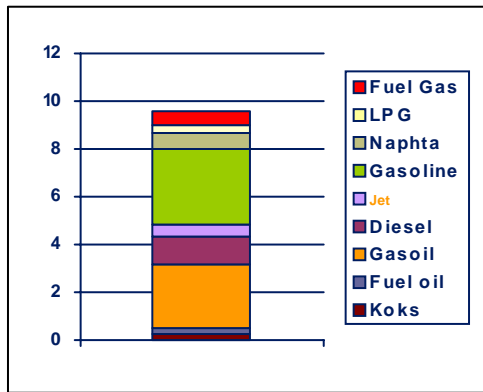
Figure 50 Production Output, Source: Mongstad Refinery DA 2003

Although jet fuel amounts for a small part of total production, it is a vital refined product for the airliner industry. More stringent process control is needed for processing jet fuel to match requirements since a small deviation may give fatal consequences. Mongstad get premium price for its jet fuel but also the quality control costs are high to avoid large specification deviation. Coke is a low-value product (compared to many other petroleum products) that Mongstad delivers to the aluminium industry for a low-price. The price of coke is fairly stable since it is more independent of crude oil price changes.

Claus Hvid (2005) of the Oil & Trading unit at Stavanger says that Mongstad do not have a large market power. However, if the refinery must unexpected close down then there could be some price movements in the refined product market.

5.5 The Petroleum Commodity Market

The petroleum commodity market consists of trading in both primary oils and secondary oil. The market of commodities like crude oil is almost global (like the NYMEX and IPE) while the market of commodities like naphtha is more local (like the Rotterdam APA) maybe since naphtha products are transported in smaller bulks and have by such higher transportation unit costs. Another reason of crude oil being more global than the refined products is basically due to crude oil production centres are global suppliers, while the supply of refined products are more connected to the local markets.

We will in this part focus mostly on crude oil trading. This is because it is more of interesting nature due to its size (rather global than local), liquidity, and the many different contract types. Although this is not a thesis on financial markets, it is quite fundamental to understand how Mongstad acquires its input materials and sell its output.

In the figure below, we see the historical aspect of trading oil commodities. From using long-term contracts with fixed prices and volumes, the market has become quite flexible with both adjustable prices and volumes. The contracts may also be at hand of third parties with little or no direct play in the physical value chain. In addition, the contracts do not always have a physical delivery linked with it.

The figure below illustrates the evolution of supply contracts in the oil business:
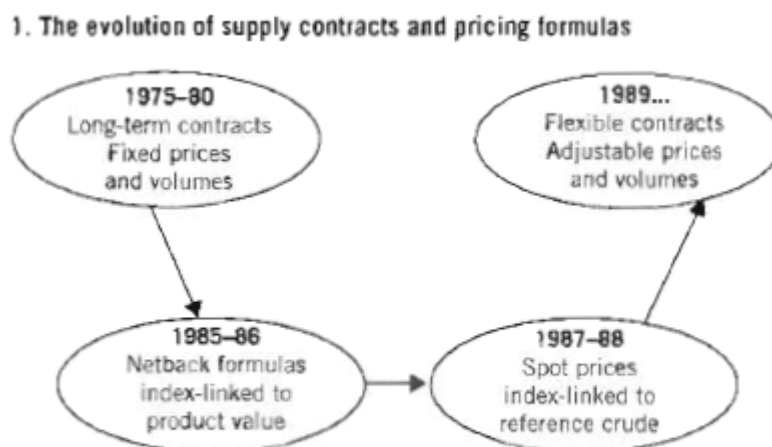
Figure 51 A Historical Perspective of Supply Contracts, *Source: Jaques Gabillon.*

5.5.1   Where to buy what – Reference Prices

There are three different benchmarks, or reference qualities, that play a major role in the physical and financial market of crude oil:

- The WTI (West Texas Intermediate) reference crude oil in the US which is primarily traded at the commodity market NYMEX. The WTI has an API of 38-40* and a sulphur content of 0.3 per cent. This makes the reference crude both light and sweet.

- The Brent blend reference crude oil for Europe. The Brent blend is reference oil that is a mix of crude from the old Brent field and the Oseberg field. It has a product specification that is quite similar to the WTI. It has an API of 38* and a sulphur content of 0.3 per cent.

- The Dubai reference crude oil for Asia and is both heavier and sourer than its counterparts. With an API of 32* and a sulphur content of 3 per cent, this reference crude is cheaper to buy but more expensive to refine. The Dubai reference crude comes from four offshore local fields (Fateh, SW Fateh, Falah and Rashid).

The crude references are used as a standard crude oil product which different grades can be compared against. Although all crude oil traded is paid in US dollars, the floating prices of the traded crude are based on which geographical area it is bound to. For instance, crude oil produced from wells at Gullfaks field will be noted against the Brent Blend. This somewhat geographical segmentation can give some interesting aspects. Indeed, when there is a supply uncertainty in the Middle East, like the Gulf Crisis in 1991, the price of oil will increase and producers like Saudi Arabia will try to produce more oil to a higher price (Gabillon 1994). However, the crude specification of Arabian oil has a sourer and heavier profile. This type of oil is more expensive to transform in a refining system[21] than the Brent blend or WTI so that you get an increase in supplies of less-desirable crude. This would push the price of the Arabian oil downwards, making the difference in price between the Brent Blend and Dubai larger. Another example is the difference between the WTI and the Brent Blend. The WTI is primarily an onshore oil that is traded in the US and the price of it somewhat reflects the expectations of oil imports. Since the Brent blend and the WTI have the approximately the same product essay, the difference between those two on the US market primarily should reflect the shipping costs of moving oil supplies from Europe to the US. The strikes at the PDVSA, a Venezuelan national oil company, in February 2003, stopped almost 2 millions

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[21] An upgraded refinery is necessary to transform heavy components to lighter components.

barrels a day to the US and Caribbean markets (Geman 2005). The price differential adjusted then to the fact that oil supplies had to be transported farther away.

5.5.2   The Financial Instruments

There are mainly three types of oil commodity markets (Hanesson 2005):

- The spot market for immediate delivery.

- The forward market for future delivery at a predetermined price.

- The futures market for standardised contracts about future delivery.

A purchaser may want to buy future deliveries to reduce the risk of price changes (hedging) or profit by speculation. Hedging can be done by, for instance, a buyback alternative. The refiner of crude oil buys futures in October 2005 that are due to fall in February 2006. The futures are bought for $40 per brl while the spot price is $43. Then in January 2006 the producer sells his futures for $x and then buys oil spot for $y. If $x \approx y$ then the realised price would be around $40 plus transaction costs. The cash flow for the refiner is then (simplified): -$40 +x − y. It is also possible to hedge in a different product, for instance, gasoline for naphtha.

The crude oil term structure is presented in figure below. We see that the first figure illustrates a lower barrel prices for future contracts with constant (fixed) prices for increasing maturities, while the nominal prices (maturities nominated to a variable price, affected by the current spot price) have an increase prices when maturities increase. The nominal term was in contango (explained later) and the constant term went into backwardation (explained later) few years later. This means that the price could be locked in 10 years later at a lower futures price than the prevailing spot price.

6. Crude oil term structure of nominal and constant (black line) futures prices
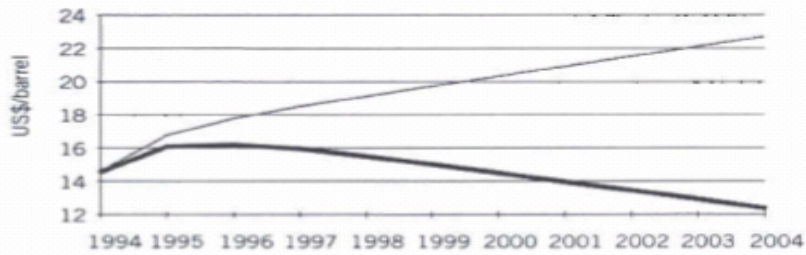
Figure 52 Crude Oil Term Structure, Nominal and Constant Futures Prices*, Gabillon '94*

When exchange rates are taken into account, the term structures changes a bit. This is illustrated by figure below.

7. Crude oil term structure of futures
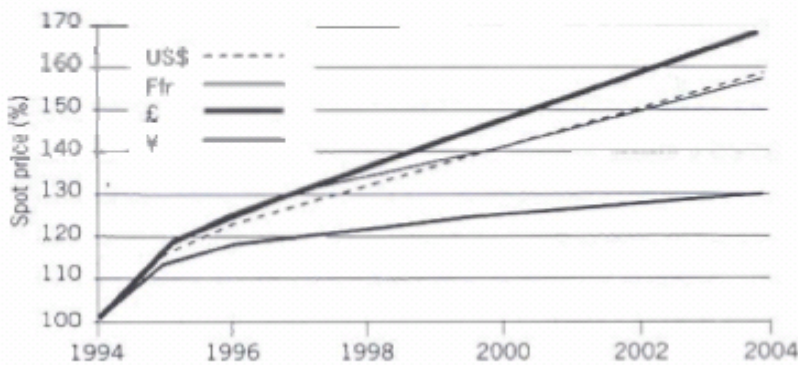
Figure 53 Crude Oil Term Structure for different Currencies*, Gabillon '94*

There is a convergence of spot prices and futures prices, and their movements are somewhat parallel. If the market thinks $40 per barrel is a "correct" price and the price has been stabile at that price for a long time then the futures price would be pretty much the same as the spot price. The spot price usually varies around the futures price depending on the physical position of the commodity. If the inventory levels are lower than first predicted then the spot price would get higher than the futures price since buyers would want to secure its crude supplies. The relationship between spot prices and futures prices can be expressed by the

futures price being dependent on the current price of the asset and cost of carry, given in the following simplified equation from Hanesson (2005):

$F < S (1+r) + c$ where F = futures price

S = spot price

c = storage cost

r = risk less interest rate

Formula II The Relationship between Spot Price and Futures Price*, Source: Hanesson 2005*

Note that this equation does not include "the time of maturity"-element that may affect the futures price. If this equation should not hold then it would be cheaper to hedge by purchasing physical crude oil and store it rather than buying it at futures price. By presenting the convenience yield as the difference between the right hand side of the equation from the left hand side, we get following equation:

$\Omega = S (1+r) + c - F$

Formula III The Convenience Yield, Hanesson 2005

The convenience yield has been defined by Brennan (1989) as "the flow of services which accrues to the owner of a physical inventory but not to the owner of a contract for future delivery". When S < F then the convenience yield is small and the market is in *contago*. While the market is in backwardation when S > F since the convenience yield is large. Since the interest rate is strictly positive and there is a cost of carry (c), F should be larger than S. However, the market is not always in contago. Backwardation happens when it is preferable to hold inventory for strategic reasons although it seems unprofitable in the short term. The physical nature of oil and its political/strategic importance give the commodity a distinct

structural preference. Oil cannot be produced and distributed to cover sudden demand but with a time lag. In addition, processing centres and refineries are often distant from consumers, making the lead time longer. This makes the elasticity of demand for refined products inelastic, putting an upward pressure on physical prices.

On figure below you see how backwardation explodes during the given winter since there is a high expectance of higher future prices.
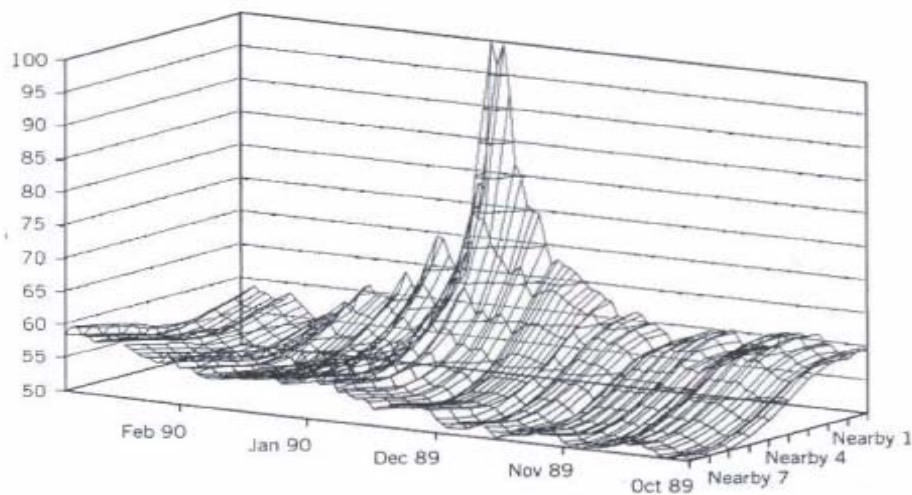
Figure 54 The Backwardation Effect due to Winter Season*, Gabillion '94*

The figure illustrates how the term structure is for a market in contago. The "cash-and-carry" arbitrage increases with the time length.
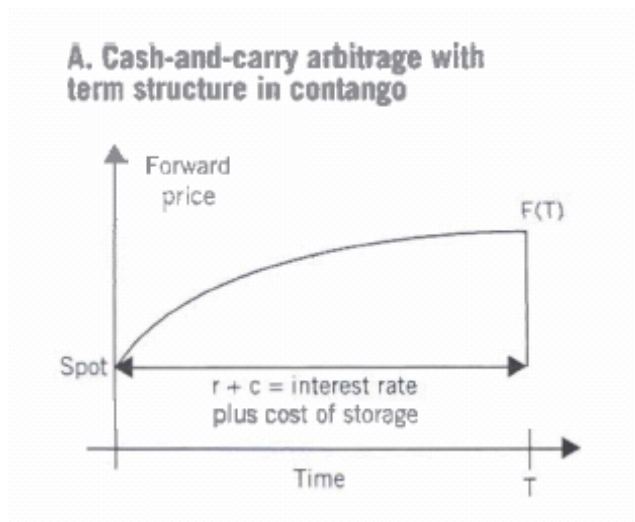
Figure 55 The Term Structure of Forward Price when Market in Contago*, Gabillion '94*

Crude oil producers hold reserves and they might be exposed to drop in prices. They are then "short hedgers" to cover the short-term exposures from their sale contracts and inventories. This will give a downward pressure on the future prices due to increase in number of sellers going short since producers want the highest price. However, when there is a perception that prices are already at a historical low then the producers are reluctant to cover their exposure since there is a high probability of an increase in prices. For the refiner the situation is slightly different since it involves both crude oil and refined products. When there is a large risk of prices of crude oil and refined products to fall in price to a bottom low then the refiner wants to go long on crude oil (buy position to profit from higher crude oil prices later) and short on refined products (sell position to profit from higher prices now), and thereby hedging their refining margin. As a result, refiners transfer financial risk between the two forward curves, crude oil and refined products, thereby securing a refinery margin.

5.5.3   How Financial Activities affect Refinery Activities

As we earlier discussed in the section for refinery margin and showed the historical refinery margin in the industry in figure 39, securing a satisfying refinery margin is essential for the refiner. Many variables and many equations must be optimised to produce high performing results. One way is to fix the refinery margin for a time. Remember that the refiner is

rationally short on crude and long on refined products. Refining margin swaps are used to lock-in profitability. The refined products are sold and crude oil is bought for equivalent forward times. The refinery margin swap is thus the difference between the weighted sum of refined products and the reference crude (simplified). The refiner sells a refinery margin swap that is an index of products to a fixed price, based on refinery yields. The refiner then buys it back at a floating price (an average value of the index) over a certain period.

The key is to "cash-and-refine" when the fixed margin is larger than the cost of refining crude oil including transactional costs. When a yearly hedging position is considered, yields can be adjusted to summer and winter seasons. Also, the refiner can also optimise product deliveries by selecting the best suitable delivery dates.

Refinery hedging is a multi variable problem since each refined product has its own price term structure. They have their own price term structure due to the time dimension of storage and refining and therefore different restrictions must be satisfied to optimise. Often the refiner locks its spread[22] for a certain product in addition to the margin as whole. This strategy is an advantage, especially when there is a particular product that has a large contribution. A simple contribution ranking of each product over a one-month period is done regularly to find which product to hedge. Sometimes it would be more lucrative to refine naphtha instead gas oil. This calculation is also made at Mongstad on an Excel spreadsheet discussed in the cost structure chapter.

Figure below shows how same product can have different yield at different time. We see that the ranking differs at different time. Note that these spreads are from 1992. The spread profile for different products nowadays could be completely different.

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[22] The price difference between a certain refined product and crude oil.

B. Contributions to margin relative to average (losses excluded)
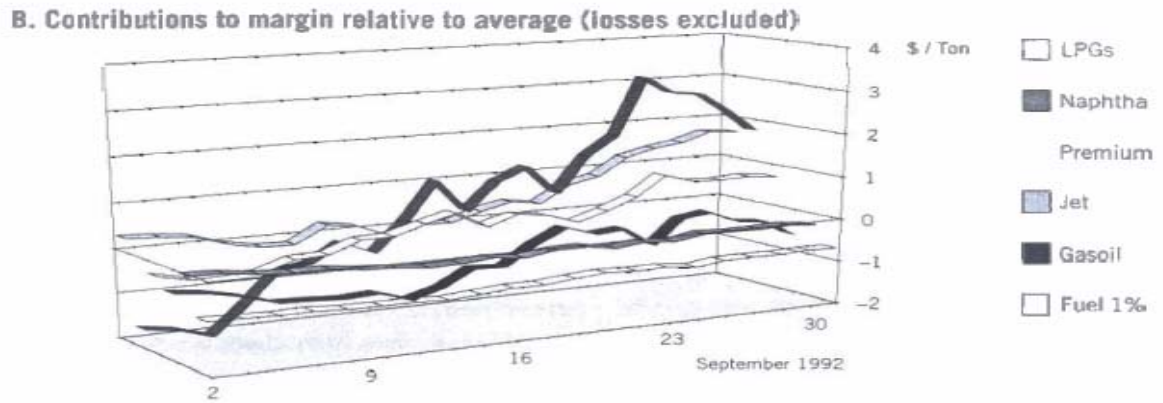
Figure 56 Contribution Margins (Crack Spreads) for different Refined Products, monthly*, Gabillon '94*

Figure below shows that the overall refinery margin consist of spreads for the different refined products, or one might say, it consist of the margin spread between choosing different
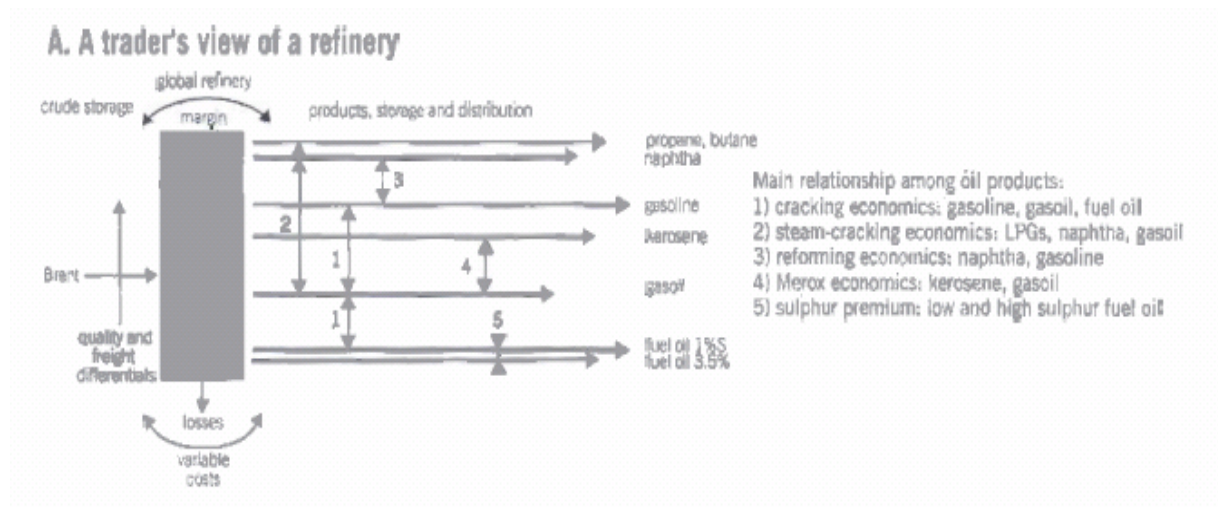
Figure 57 A Trader's View on Refinery Margin*, Gabillon '94*

products. If the refiner chooses to produce naphtha instead of gasoline[23] he will get margin 3. By choosing gasoline instead of naphtha then the refiner loses margin 3. On the right hand side of the figure, you will find a list of different product trade-offs for different choices

Also options are possible to use to reduce risk. For instance, by selling an option on gasoline spread a satisfying premium could be gained, if the market conditions are appropriate. The premium gained could then be used to finance part of the processing cost. If it is a trader that issues the option, premium can be used to finance part of the processing fee. Options can also be used to add flexibility in production so that the utilisation rate of the can be increased if desired. We will not go any further into options since our focus is primarily on the pricing structure.

5.5.4 Does Futures Price give a good Prediction of the Spot Price?

To compare the futures price and spot price one has to look at the spot price appearing at maturity. Like previous mentioned, if the market is in backwardation the expected future value of the spot price at maturity will be lower than the current spot price. So the market players would expect the spot price to go down. The reverse is true for a market in contago.

Gabillon (1995) points out the contago during June 1990 when the Iraq-crisis became apparent. The market players expected that the spot prices would rise sharply. October later that year, the spot price was at $40 per barrel and the market had a strong backwardation indicating an anticipation of lower spot prices. However, he continues to warn the reader that one should not be misled by the forecasting power in the futures prices. He argues that empirical studies of the oil price show that it often moves in a random walk. He exemplifies that when the futures price is $17 per barrel and the spot price at that time is $15, then a good prediction of future spot price at maturity could be both $15 and $17. He underlines that the situation is different when studying the price differentials, also called crack spreads for different products. By charting the differentials for spot prices and the futures prices there was found a matching anticipation value in the term structure. This is illustrated in the

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[23] This is a frequent choice that a refiner has to make since gasoline and naphtha come from the same part of crude oil.

two charts below where we see that the term prices anticipate the direction of the spot prices fairly well.
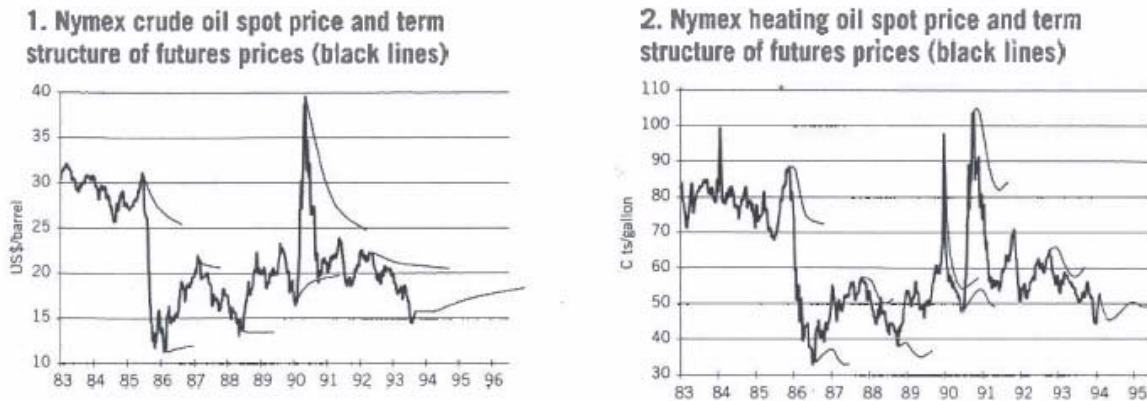

1. Nymex crude oil spot price and term structure of futures prices (black lines)

2. Nymex heating oil spot price and term structure of futures prices (black lines)

Figure 58: How futures prices anticipate the spot prices, Source: Gabillion '94

5.6 Pricing the Products

5.6.1. Pricing Crude Oil

Generic Model for Pricing Different Crude Oil to Mongstad

Crude oil processed at Mongstad differs in many ways. First, different crude oils have different qualities like sulphur content, API profile etc (discussed in the technical chapter). Lighter crude oil tending to be more expensive due to lower processing cost of producing heavily wanted gasoline, while higher sulphur content tends to be cheaper due to extra costs of reducing the sulphur amount. Second, different locations of crude oil production will generate different transportation costs. Crude oil from Venezuela will have a higher share of transportation costs than Brent Blend from the North Sea. In other words, same price will seldom occur due to different quality and spatial patterns in crude oils. We may express our problem with simple algebra:

Cost of crude oil = Price of reference crude oil + Difference in quality + Transportation costs + Transaction costs + μ

Formula IV The Crude Oil Price Decomposed

Notice that we do not take into account of future expectations (time dimension) in the price decomposition model above. We are assuming that the needed crude oils are purchased on the spot market with no additional expectations. When the crude oil is purchased on the spot market, the trader will start on a reference price (presented earlier in this chapter) of a similar crude oil type traded on the commodity markets. One will then adjust the reference price to the quality of the given crude oil to be purchased. If the given crude oil were lighter than the reference crude oil, one would be forced to add a certain amount to the reference price. However, if the given crude oil contains more sulphur than the reference oil, one will down-adjust the reference price. Depending on where the crude oil must be shipped from, the trader could demand a discount for transportation costs. This is possible due to the fact that nearby crude oil sources would be cheaper than long distant due to lower transportation costs, given everything else equal. Hence, there is a possibility that a poorer quality crude oil far away may appear more expensive than a better product nearby. This logic calls for a warning. Although, from an economic perspective, it may seem that a refinery should always pick the crude oil that gives the best price, this is not necessarily the best solution. A refinery must always consider which crude oil types suit the refinery system best at any given time. Different crude oils require different system setup regarding to temperature, pressure and time. If there would be a period of higher demand of light oil products than usual, say, gasoline, it may be more preferable to buy a more expensive crude oil since this would require less cracking (crushing large hydrocarbon molecules into smaller ones). Thus, in this case, the incremental setup costs may be larger than price gain of choosing a crude oil of poorer quality. It is therefore essential that a refinery explicitly tells the finance unit their crude oils of desire.

Transportation costs occur when the produced oil from a production field has to be transported to a refinery system. On the NCS, the transportation is done by pipeline systems or by ships. However, most often pipelines are build to transport natural gas while crude oil is transported by both small and large ships. There are lots of economics in connection with the transportation and we will discuss this later in the supply chain section. Transportation of crude oil to ships on the NCS is often sold at FOB-prices. FOB stands for free-onboard and is the point where the seller hands over the judicial responsibility to buyer. In general, this

means that the seller provides the crude oil at an installation and the buyer takes the responsibility of shipping and insurance costs. The purchased crude oils are most often bought at FOB-prices but sometimes also at CIF-prices. When CIF-prices are used the selling price includes costs of shipping and insurance to a named destination. However, the buyer himself must pay for the charges to bring the cargo to the warehouse (in this case: crude oil tanks).

The location of Mongstad gives it an advantage in freight costs compared to refineries in central Europe. The short route from the NCS to Mongstad gives short lead-time, less transportation costs and less uncertainty in deliveries. Most often Mongstad itself do not stand for the transportation but independent traders that makes a profit on the freight market. Also, the insurance cost should be somewhat less since transporting cargo in Northern Europe is looked as a low-risk transporting area compared to transporting through the unstable Middle East. Finally, the cost of transport is often covered by other integrated oil companies that wishes to use the refinery at Mongstad. Conclusively, the location of Mongstad is a clear advantage to be the refinery of choice for production on the NCS.

Transaction costs must also be included in the final crude oil price. Any transaction induces some costs for both the seller and the buyer. The cost of facilitating a transaction could be different financial fees to complete transactions, keeping a trading department etc. Trading in large bulks will give lower transaction unit costs but often this gives the inventory holder greater inventory costs.

Notice in the decomposition equation that we have added a residual. The residual is used to adjust to the final spot price acquired. The final price is often pending on negotiations skills. The residual element could also include an economy of scale in transporting large bulks rather than small bulks. The transportation costs per unit decreases and the possibility of quantity discounts when large bulks are used. Also, special prices are often achieved if there is a ship that wants to sell away its cargo fast.

5.6.2. Pricing Refined Products from Mongstad

The refined product market is a bit different from the crude market. The refined market is more local and differentiated. These are features of the crude oil supply chain where the

geographical area for a certain supply chain shrinks as you move vertically farther down the chain. The market for a production field could be global, while the market for a refinery as a seller could be restricted to a part of a continent, and the national distribution centres deliver to smaller local distribution centres which in turn supply to the pumping stations. Especially the transition point from a global market to a national market for petroleum products imply in more differentiated products. While the US has its own regulatory standards for gasoline, the UK may have stricter requirements. The result is that there are limited possibilities to sell a certain gasoline standard. With new stringent regulations from, for instance, the European Commission on product specification, especially on gasoline, many ordinary refineries strive to match the requirements.

As we earlier showed, when we looked at the Mongstad market for refined product we discovered that half of it was actually distributed to the Norwegian market. In contrast to the more global crude oil market, the refined products to outside Europe, except the US, stand for a very small part of the Mongstad export. Mongstad refinery has solved the problem of the different product requirements of different countries by allowing a more customised refinery production. The refinery acts like a decoupling point where different parts of a crude oil and other inputs are stored in separate tanks. When a ship to France arrives to Mongstad a mixture of the different inputs is made to match the necessary product specification. Upgraded refineries like Mongstad have also the ability to satisfy the latest requirements of different countries. In addition to the up to date equipment, the supply of cleaner (less sulphur and other environmental hazards) and lighter crude oil nearby from the NCS makes the production environment very economical favourable. Gasoline of premium quality can be sold at a premium price instead of letting a third party do the final work. In this way, much of the gross margins can be kept at Mongstad.

The market conditions of the different products vary. Sometimes there are more sellers than buyers and vice versa. Any particular features of the different market are difficult to deduct. Most of the markets for refined products are local (except of gasoline), that will say within Northern Europe. However, when the difference in prices gets large enough there are some movements between continents. When it comes to sales liquidity of the different products, Claus Hvid (2005) of the Oil & Trading unit says that the liquidity of oil components and final products are good at the right price, however, since each country has its own specifications this reduces the liquidity. A large and liquid market will create a commodity.

One such example is IPE gas oil futures which are a financial contract with physical delivery connected.

While some refined products are sold at flexible prices and volumes, others are based on fixed contracts with little flexibility in prices. Coke, being mainly supplied to specific companies in Norway, is traded on primarily fixed terms. Gasoline is on the other hand supplied worldwide and the prices are flexible. Prices for gasoline, naphtha and jet fuel is being sold against ARA[24]-prices. The ARA-prices reflects the market prices in Europe since the area around Rotterdam is Europe's largest refinery area.

Mongstad has tried to earn money on every part of crude oil regardless of its liquidity. Even the low-value added coke is sold to the industry for electrolyses for a small amount of money. Also, residuals from all over the world are being imported to increase the utilisation grade of the refinery. As a refinery with a conversion capacity, Mongstad is not dependent on light crude oil to use most of it since heavy oil can be transformed to lighter form.

Seasonal variations in different products do occur, according to Claus Hvid (2005). While the winter is a season that pushes the prices on heating oil due to increased demand, the summer is "driving season" in the US that drives the demand up and results in higher prices. Also the inventory figures, for instance, from the US has its effect on prices of the refined products. The figures for commercial inventories are given every Wednesday.

The tax consists of the largest part of the gasoline price. As a simplified example, the gasoline end-price in Norway can be decomposed in following manner:

Gasoline price = International price + Gross margin + Gasoline tax + CO2 tax + Value added tax

Formula V **The Gasoline Price Decomposed***, Source: NP/Esso*

The international price is the reference price for the gasoline price here in Norway. Then an additional margin is retrieved for the oil companies and distributors. However, before the

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[24] Amsterdam-Rotterdam-Antwerp.

gasoline can be sold to the consumers the price of gasoline is taxed with a separate gasoline tax reasoned with the cost in using the roads, taxed for CO2 emission due to environmental harm, and a value added tax of 25 %. Note that a price increase in gasoline will be amplified by the VAT since an increase of 1 per cent will in reality mean an increase of 1.25 per cent. In total, the taxes consist of 64 per cent (*Norsk Petroleumsinstitutt, NP)* of the gasoline price to the consumer. The diagram below illustrates the cost components of gasoline.
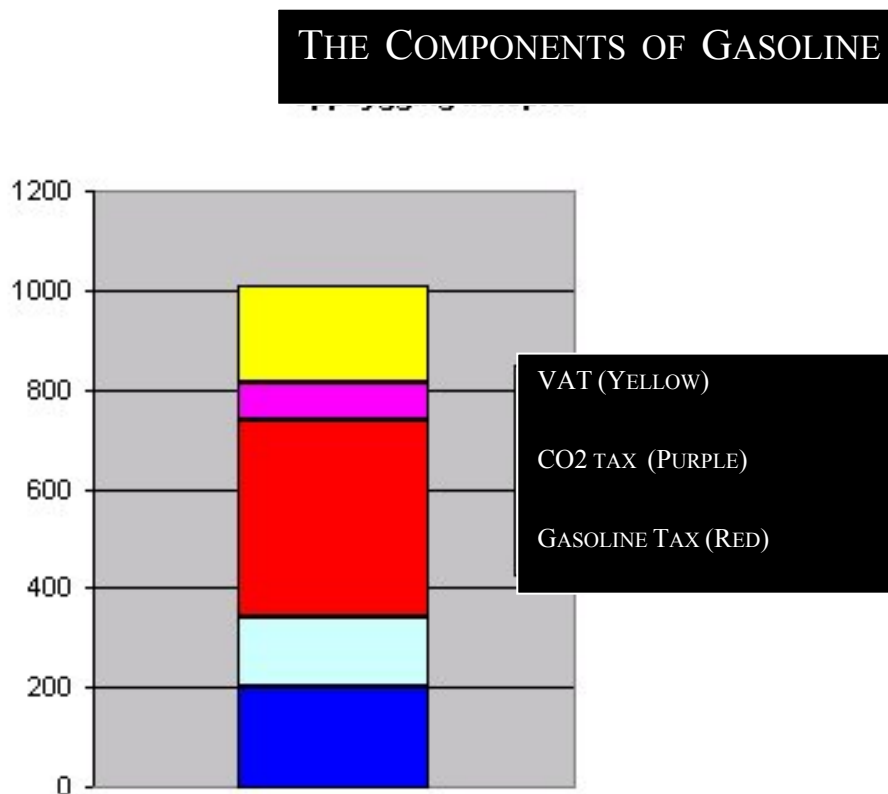
Figure 59 The Components of the Gasoline Price. *Source: NP/Esso*

5.6.3. Pricing Natural Gas

The liberalisation and integration of the European gas market has made the Norwegian gas market more flexible. However, the market of gas still lacks competition due to limitations that lies with costly infrastructure from specific gas field installations. The pipeline systems have been handed over to third-parties to avoid the producer of gas owning both the gas and the transport system after regulatory actions from the EU. Furthermore, the competition in

the gas markets lies with the competition from substitutes in the market for end users. Consumers often alternate between energy carriers and such the price of gas often follow these, particular fuel oils since the area of use is quite similar. However, according to Ole Gunnar Austvik (2003), operational costs and negotiation strengths when trading gas decide the margins of the distribution companies and not the prices in the end-market. So the margins of the distribution companies are more or less independent of the prices in the end market. With fixed contracts, this could mean that the price to the producer will change according to the end-market. For instance, when any company wants its gas from Troll and onshore to Norway through the pipeline system they usually have to pay a fixed transporting cost that has been negotiated. Also a certain tariff is being charged when the gas is processed.

Mongstad refinery gets most of its lighter hydrocarbon components from the Vestprosess pipeline system. By using gas as an energy source and blending component to make the crude oil lighter, it has become a large part of the Mongstad operation. It is mainly the processing facilities at Sture and Kollsnes that delivers gas in the Vestprosess pipelines to Mongstad. The products from the Vestprosess are mixed butane, propane and C5+ (parts of crude oil). All C5+ is sold to the refinery on fixed terms. However, propane and mixed butane is shipped out to the various Vestprosess partner at different terms. Some of the terms are fixed while others are flexible and sold to spot market.

The price of C5+ is difficult to decompose due to the high complexity. The price function of C5+ is based on the price of naphtha, heavy naphtha, kerosene and Oseberg crude oil.

Mongstad refinery is required to pay tariffs for the transportation through the Vestprosess pipeline system. There are three different tariff-zones that Mongstad have to pay:

- Zone 1 for the use of Vestprosess pipeline system.

- Zone 2 for handling naphtha.

- Zone 3 for handling LPG (Liquid Petroleum Gas) like propane and butane.

5.6.4. Pricing with the Sales Department in Stavanger

Decision makers at Mongstad Refinery have regularly contact with the sales department at Stavanger to plan out a production strategy with the given market conditions at the certain time. Information flow to Stavanger consists of plans on production, port traffic and inventory levels so that the two units can together optimise the refinery operations. However, the final decision on every sales agreement lies at the Stavanger unit, from price to volume variables.

In the decision process, the main focus is the price between crude oil and the refined products, the so-called differentials or gross margin. The indirect costs for each product are not the main focus when optimising the production plan. However, the LP-model used by Mongstad tries to some extent incorporate these product specific costs. Where this is not possible, manually adjustments, if needed, are done by the Stavanger unit and Mongstad unit in co-operation. When all is said, the Stavanger unit pays little attention to the cost structure of the refinery. Inputs from the market, like price and demand, are delivered by the Stavanger unit to the production plan at Mongstad. The inputs are based on the contracts at hand and the future market perspective of the sales unit. Since the market is dynamic the inputs have to be continuously updated from Stavanger.

All kinds of different prices are used when analysing different situations. Either fixed, floating or a combination of both is being used. Nevertheless, fixed prices are often used to predict future prices. However, the forward prices only give a momentary prediction of the future and there is seldom match with the actual price. Hvid's opinion is that the market is not wrong-priced. However, he continues to say that if the market moves in a certain direction it is important to position your self right in accordance so that you take calculated risks. In risk management, futures and swaps are used for hedging purposes. Value-at-risk is one of the methods that are used by the Stavanger unit to manage risk. Value-at-Risk (VaR) is the worst loss scenario for a portfolio that can be expected over a given time period with a given probability. The time period is also called holding period.

The most usual financial instruments at the Stavanger unit are futures and swaps. The time horizon is most often up to one year. These contracts can be purely financial, financial with physical delivery, or purely physical. The contact with the counterpart for a contract can be

done by a broker or direct. When direct contact is the case, the tool of communication can be as simple as ordinary telephone or Yahoo Messenger.

In contract negotiations, the counterparts do know little of the current situation at Mongstad. Such information could be inventory levels, margins etc. Information is only given when it seem to benefit Mongstad. The price in the contract is primarily based on basically supply and demand, and not the liquidity of the product. The price does change when, for instance, credit time and special product specifications exist. The buyer cannot change what is agreed upon after the contract is accepted. Any changes are more an exception than a routine.

Convenience is something that could be economical beneficial. Convenience is simply to keep inventory and sale later if it seems that this would give an extra profit. This can sometimes explain the backwardated futures explained earlier in this chapter. Hvid says that Statoil holds the inventory different than the market tells, and sometimes this could be in keeping product inventories to later. Nevertheless, Hvid adds by saying that to do this operation there must be a documented potential profit. It is not a policy to expand inventory if it is only on "nice to have" basis. Moving on with inventories, it could be economical beneficial to buy product components and store them at Mongstad and then sell them afterwards, or as a finished product. Hvid says that this could be a case if it is profitable and there is flexibility for it when it comes to storage space.

The working environment of the Stavanger unit is organised in a way that they work in small groups, usually consisting of two or three. The groups can have loads of different types of tasks. There are no specific daily meetings in the processes but the colleagues have a continuously dialog since they physical sit close to each other. The section where Hvid is working, works with products from Statoil's refineries and supply to Statoil's downstream units. There is no particular full-time employee that works with the Mongstad Refinery. Mongstad is one of several areas that the persons at Stavanger have to work on.

Shell, as a part-owner of Mongstad refinery, has the right of a certain share of the production volume. The Shell volumes are used as fixed input volumes in the production plan. The Stavanger unit can do little about the Shell volume since it is a contractual obligation.

5.6.5. The Mongstad Refinery and its Gross Margin

We would like to close the pricing chapter by discussing the profitability, something that is closely linked to the gross margins. In Aftenposten, a Norwegian newspaper, dated 4th of May 2005, had an article (*Mong ble milliardbutikk*) on the now much so lucrative refinery at Mongstad. Although the high oil prices and taxes the average standard margin has become to be $ 5 per barrel. It is most likely that the refinery margin at Mongstad is higher since it is an upgraded refinery. Even Helge Lund, the president of Statoil, admits that Statoil has never earned so much on refinery than now. Aftenposten reports that in the last five years the average yearly profit has been 900 MNOK. In the first quartile of 2005 the profit was 425 MNOK. This is quite a different situation for a refinery that strived with poor financial performance during the 90's. As long as there is high demand for refined petroleum products, less high-value crude oil and little cracking capacity, this trend could continue for a time.

6. Cost Structure

6.1 Introduction

In previous chapter, we discussed the aspect of price emergence of crude oils and refined products. The price difference of the raw product and the final products gave a gross margin. Gross margin could be increased by reducing the price of input products and increasing the price of output products. Nevertheless, a large gross margin is of little value if the cost of running the refinery is high. Thus the net margin is of equal importance. We will in this chapter discuss how the gross margins are reduced at Mongstad and by such getting an overview of the costs of operations. One word of caution: due to the sensitivity of the material we have used, we are required to withhold some detailed information or present it in a distorted form.

Note that direct costs in connection with purchase of refinery input like crude oil and natural gas is not included in the term used for operating costs. The MRDA account does not include purchase of direct material (exception is additives and catalysts) since this is the financial responsibility of O&S Stavanger. The purchase cost of crude oil and natural gas do also vary a lot, making it difficult to analyse the variations in total costs when included.

6.2 Defining Costs (McNair et Al. 2001)

In the pricing section we discussed the margin that emerged from the price difference between the input and the output, and the characteristics of changes in price of different products.

Roughly speaking, we can talk about a value creation of a refinery when we are focusing on the difference between input costs and sales income of output. This value creation is closely linked to the trading unit at Stavanger, which buys and sells the necessary products. This value creation is reduced by the different costs of operations. We will be discussing several of these costs during this chapter.

McNair et al. (2001) have tried to connect value creation with cost management. Mr Trond Bjørnenak of Norwegian School of Economics and Business Administration has simplified the model with the diagram shown below.
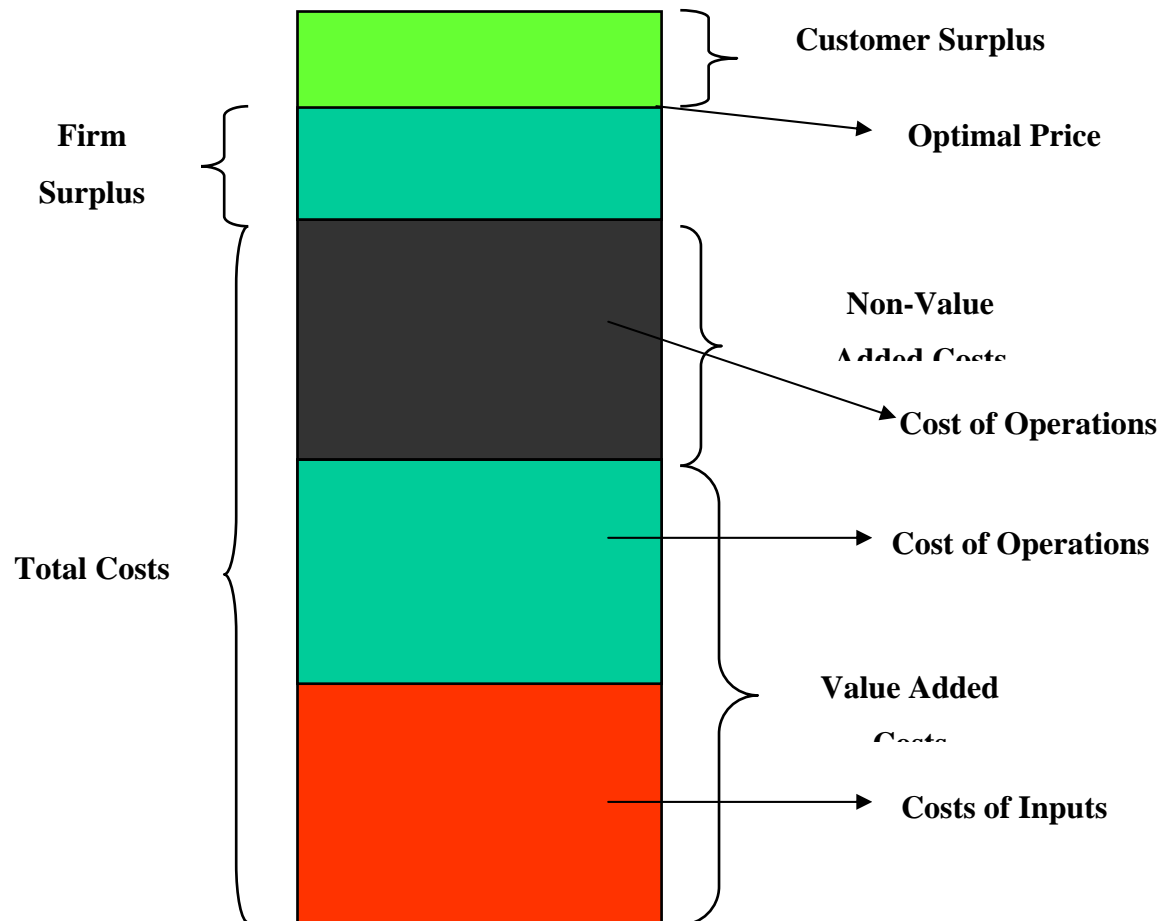
Figure 60 Defining Costs at Mongstad, *Source: Trond Bjørnenak IRRR NHH, 2005 (modified)*

The essence is much the same. Costs of operations can be divided into what brings value to the operations (value added costs) and what brings no value (non-value added costs). Hence total costs consist of non-value added costs and value-added costs. To reduce the value-added costs can be very dangerous for profits since these operations are necessary to maintain a secure and high-value services and products. In worst case if products do not meet specifications of the buyer, customer loss can be the consequence in addition to an economical compensation. Note that we are assuming that the input costs are given in the market so that there are no possibilities of cutting these costs without cutting the amount of input. By so, we are defining the input costs in this chapter to be value-added since the cost

of acquiring inputs like crude oil fixed to given market prices for a certain volume. However, the cost of inputs can vary when you decide on how to use it in operations, like how much of the different types of oil should be used during a certain setup. We will be discussing the aspect of input combination but not so much on the cost of acquiring the inputs.

Value creation is quite a new field in academic circles. The theories are so general that they enable the user to customise the model for its own use.

6.3 Costs in the Refinery Industry

Operation costs at a refinery are usually classified material. Thus information concerning costs is difficult to plot. We experienced a tough time to gather the necessary information from Statoil Mongstad and in cases where information was handed to us, we were told to treat it strictly confidential.

The entire refinery industry is based on secrecy, and information is only passed on if it serves a good purpose. One such purpose could be the Solomon refinery performance benchmark where different refineries send their performance information on different areas like manpower costs, capital costs etc. Information used in the benchmarking is kept anonymous but it ranks your own company amongst the rest. We will discuss the Solomon benchmarking later. The reason for all the secrecy is the need for hiding important information from counterparts in negotiations and in competition. If your customer counterpart knows your refinery costs under negotiations of a contract, then your counterpart could press you on price, especially since refining is a standardized process that can be easily bought from other places. In addition, the refinery industry has many of its traditions from the US industry where much information is classified in general. However, every single company wants to know its competitors advantages when they sell a standardized product like refinery processing. So they are quite interested in ranking list on different cost aspects to benchmark themselves with the others in the industry.

The cost during the whole life of a refinery can be compared with the theory on *Life Cycle Costing* where one tracks the cost of a product during its life time. In this case, the refinery

process is the product as we found in our pricing model during a product life time in the Price Structure chapter.
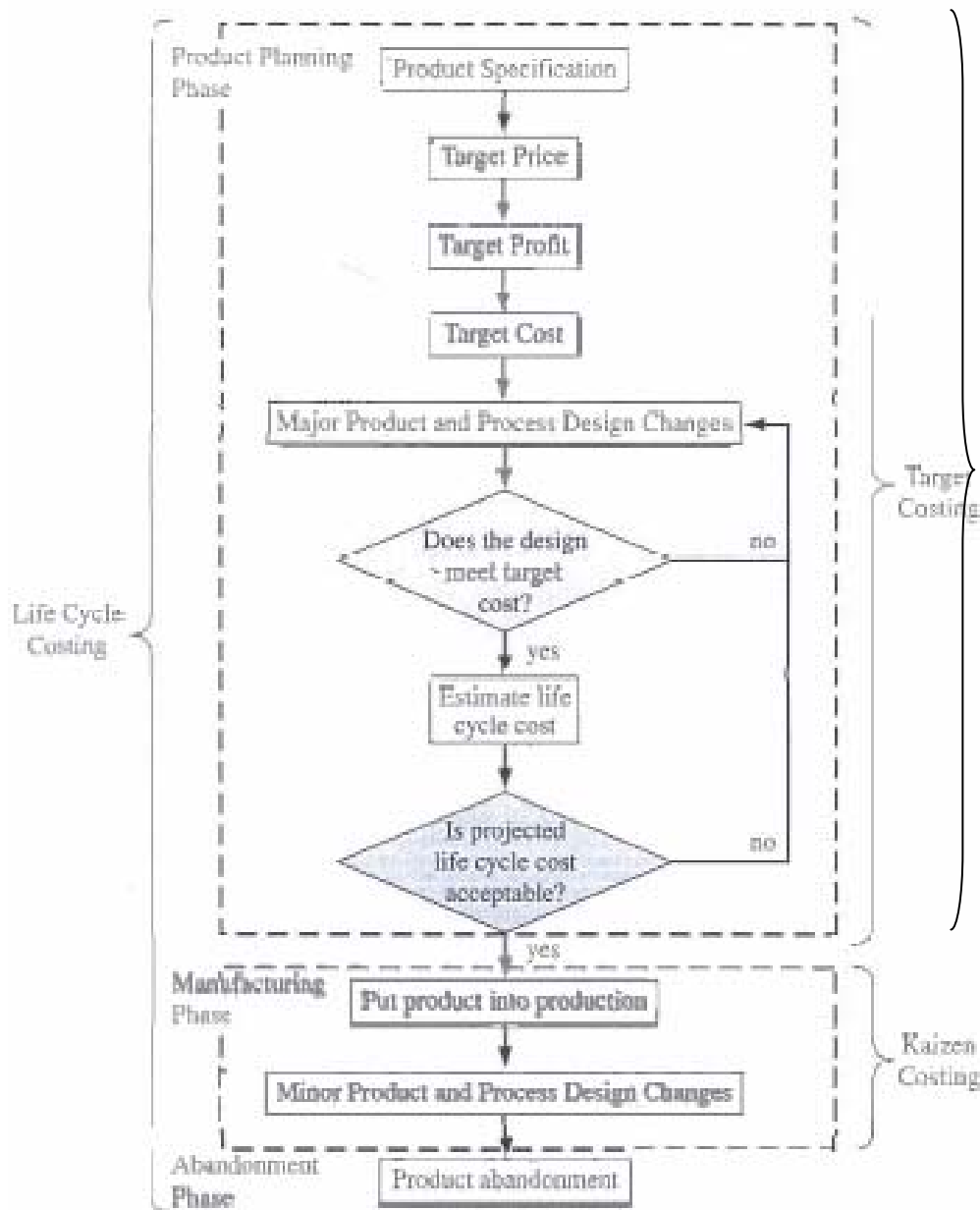
Figure 61 Steps in Life Cycle Costing, *Source: Kaplan&Atkinson 1998*

The life cycle costing consist of *target costing* and *kaizen costing* (see figure above). While target costing focuses on the planning phase, and to choose product and design process that give an appropriate cost level for given market conditions, the kaizen costing is focused on cost improvements during the manufacturing phase.

One theoretical estimate is that 80 per cent of a product's costs are committed in the design stage in general (Kaplan & Atkinson 1998). This is illustrated by the figure below. During the design stage, planners will try to decide which products that the refinery will use and which to supply, and try to design the most production effective and cost effective process. Investments in infrastructure can be a quite expensive affair but ineffective production and cost processes can be even more expensive in the long run.
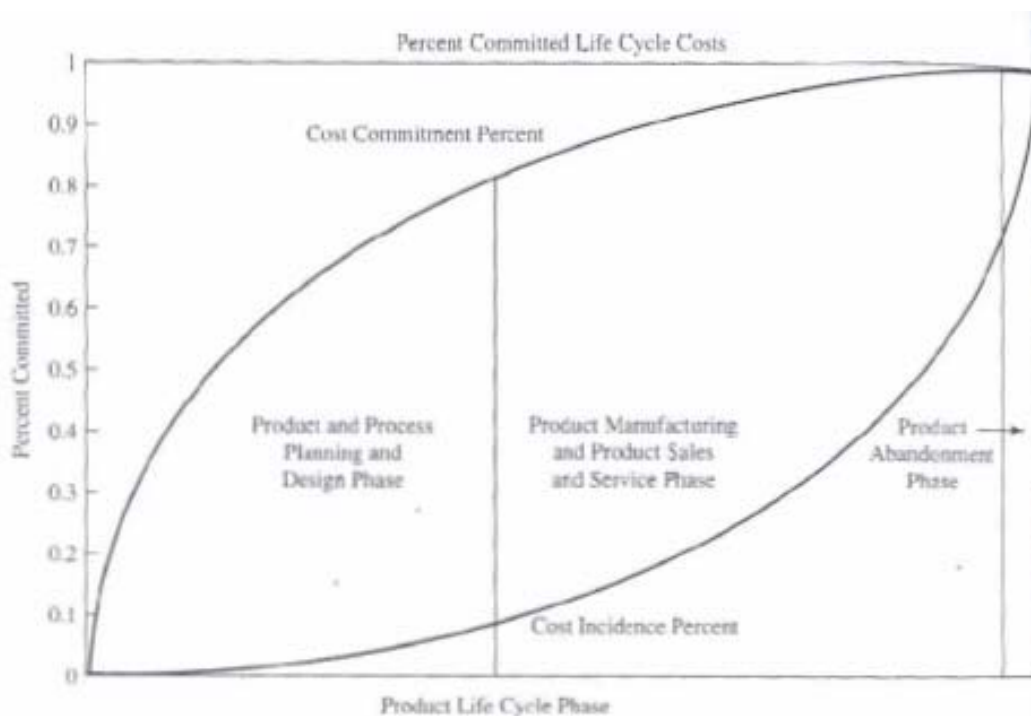
EXHIBIT 6-2 Cost Commitment versus Incidence

Figure 62 Cost Development during Life Cycle, *Kaplan&Atkinson 1998*

In the early periods of the refinery industry, cost effective design was not primarily focus but rather technical aspects. With pressure on both sides of a refinery margin due to increased competition, refinery builders cannot afford to pay more than necessary. By such, target costing has become more relevant for an industry that has been consolidated and increasingly integrated in the supply chain of the large oil companies. When investing in an oil refinery, investors often establish a part-ownership to share the costs and risk. Naturally, the type and size of refinery is dependent on how much money the investors are willing to

inject, the market conditions today and future trends. By targeting future crack spreads and profits, the desired operating target cost of the refinery can be obtained and a refinery can be designed. If the estimated life cycle cost and cash flow is of satisfactory then the refinery design can be completed.

Capital costs take the largest share of costs when refinery is being built. Capital costs in the oil & energy industry are also called CAPEX (Capital Expenditures). The infrastructure at a refinery are highly specialised with high construction costs. However, CAPEX also includes the development costs of the infrastructure that require highly skilled personnel. When first looking at a refinery, the whole refinery process seems to be hard to get an overview of. Tubes and boilers are only few of many types of equipment that have to be in place at a refinery. Thorough engineering is required to make the whole system work according to the law of physics. In addition, most refineries have its computer based controlling unit that monitors and controls the whole process such that process controllers only have to make sure of everything is running as planned. Such hi-tech and specialised equipment makes a refinery costly to build. Refineries, of course, are not mass produced and production is based entirely on specific purchase orders from contractors.

Also, each refinery is customised to the market needs it tries to satisfy. For instance, the excess capacity of heavier oils have made light oil components more scarce since the conventional oil refineries without conversion capacity end up with a large amount of low-value residuals. Many American refinery owners have in the last 2-3 years made additional investments to upgrade existing refineries with cracker capacity so that they can use more of the residual components to supply the market with more of the highly demanded light petroleum products (EIA 2005). The gross margins for upgraded refineries have been very lucrative in the last years due to scarcer supply of lighter crude oils. Thus, a refinery that is up-to-date with the market needs can profitable although of the high investement costs.

Mongstad itself was upgraded and expanded in capacity during the late 80s and the investments have proved to give high returns, especially in these days when crack spreads between crude oil and light petroleum products are very high which in turn produce high operating results.

When the refinery is in place and operating, other types of costs appear and capital costs become less important. The focal point is to operate the refinery in the most effective way.

In theory, this is called kaizen costing which focuses on how managers and operators can reduce costs in an existing system. These cost reductions can be driven by periodically targets, often financial. The cost reductions are based on changing the operating processes, not significant changes in the products that are being sold. The efforts could be directed towards overhead costs like administration, maintenance costs, capacity costs and production costs.

When a refinery has been constructed and its necessary additional infrastructures like storage tanks, port facilities, and labour power, operations can be initiated. The costs of keeping operations are often called OPEX (operating expenditures) in the oil and energy business. Although the refinery industry and the oil industry in general are capital-intensive, cost cut potentials often lies in costs of workforce since capital costs are often locked in operations.

In Norway the labour rights have a strong position in the petroleum industry and it has resulted in both good working conditions and well-paid jobs. However, the high cost of labour has begun to price the workforce somewhat out of the market, with the exception of managers, Sahabanik (2005). One of the results can be seen in the offshore production where new production fields are put up with unmanned infrastructures, not only because of technological progression but also to cut labour costs. In the last years, the Solomon benchmarking and other performance indexes have also showed that Norway has disadvantage on labour costs. However, high labour costs do not necessarily mean that the labour power in Norway is economically unviable. The productivity of Norwegian industrial workers is on average higher than many of our competing countries in the OECD according to recent studies, thus making Norwegian labour not as expensive as otherwise. Nevertheless, if the higher productivity is a result of a more advanced Norwegian machine park and this is not correctly adjusted for in calculations, then the justification may be incorrect. The labour power may be in connection to the administrative work, technical staff that for instance must approve the quality of produced products or control the process, or more basic functions like security, cleaning or cafeteria. Note that many of the services are often outsourced to external businesses or supplied by other parts of the group. This has been a general trend in businesses and the oil business is not without exception. By letting other handle services that is not in the core business of oil, the refinery can focus its strengths to what is most important. We will discuss this later in our cost chapter.

Another large cost post in operation of a refinery is maintenance costs (Abdel et Al, 1992). Maintenance costs are high due to the need of both specialised equipment and skilled workers. Procurement responsible makes requests to different suppliers when service or/and equipment is needed. There are some few large suppliers that have the necessary expertise. This makes maintenance costs often expensive in the refinery industry due to their market power.

High regularity in production is also important due to the fact that production stop give sales loss. Also, the unit cost increases when the total production decreases since there are less volume units to split the fixed costs on. High regularity is a focus area that many technical managers have when controlling the process. Although high regularity is important, high utilisation at any time does not necessarily be in the best interest due to setup to another production process or other reasons.

For any processing facility, energy is required to run the processing process. A refinery needs much energy to start up the process. The energy is taken from the petroleum flow to the refinery system. However, much of the light hydrocarbon elements are left unused and flared.

The newly suggested gas power plant at Mongstad will use the light hydrocarbon components more effective and supply the whole refinery with much needed electric energy. Also, the suggested power plant will be able to supply outside power consumers with electricity. One thing that also should be noted is that the energy potential at Mongstad refinery is quite high. Water is usually used as a cooler at plants that produce much heat. This water becomes hot and is a carrier of energy. With a hot reservoir and a cold reservoir, one can create energy from the temperature difference and the large amount of heat exchange. The main challenge is that the low-temperature difference between the reservoirs makes it difficult to make good use of it. However, the Statoil refinery at Kalundborg has made use of such technology to exploit the possibilities that lie in heat from waste water. In Denmark, it is not allowed to let excess heat from industry go to waste. In fact, if Mongstad could use the excess heat, it is said that it is possible to create enough energy to supply half of Bergen with heat (Mongstad refinery guiding tour, 2004) and thereby transform non value added costs to value added costs.

6.4 Pre-Commissioning Refinery Costs

6.4.1 Designing a Refinery

In the previous section, we talked about target costing and costs before refinery production initiation. When designing a new refinery, many things have to be thoroughly planned and cost-estimated, especially due to the large investment capital needed. Abdel-Aal et al (1992), mention four different aspects of information that has to be in place in order to initiate and proceed with the economic design of the refinery:

- Factors that have an economic influence on refinery location.

- Capital investments.

- Refining costs and total product costs

- Profitability analysis based on future predicted income to determine the return on capital.

6.4.2 Refinery Location

In the price structure chapter we discussed the aspect of geographical location of a refinery to decide which market Mongstad was a part of. However, geographical aspects do not only apply to which markets the refinery buys and sells its products but it has also to consider that the choice of location is based on many factors:

- *Raw materials*, like crude oil, must be available with both present and future reserves with a short distance to secure input supplies with low transporting costs.

- *Markets*, as mentioned earlier, should essentially be close to the refinery so that the transportation costs do not cut more in the crack spreads than necessary. Also, the demand in the serving market must not be too small for a refinery or else the

refinery will end up with high unit costs because of low refinery utilisation due to low demand.

- *Power and fuel supply* are important factors in the localization decision. Enough energy is required in order to keep the processes going.

- *Water supply* is needed foremost to cool down the refinery and its many processes. The need is in large quantities and it has to have a certain minimum quality. Refineries are often placed near sea, large rivers or lakes. Consumed hot water can be both an income and a cost. Income in a way that energy in the hot water may be used as source of heater for residents and commercial surroundings. However, hot water that is let out in a lake can kill many fish and other living creatures in the water. Thermal shock can be a large environmental cost that has to be avoided in the interest of CSR (Corporate Social Responsibility).

- *Installation must be adapted to climate* to take account of the humidity and temperature in the region.

- *Transportation* is needed for the products that are going in and out of the refinery system. Fast and effective transport system with different mean of transport is required to secure a refinery operation with high regularity.

- *Labour costs* must also be assessed when placing a refinery since it will affect the operation costs.

- *Land area* has to be flexible for expansion for later investments and low property tax is necessary to keep costs low.

Mongstad has an advantage in freight costs on raw materials (crude oil) due to its location close to the oil fields in the Northsea, short shipping distance (ca. 6 hours) and two pipelines for crude, one pipeline for NGL/condensate. And a disadvantage on freight costs on products due to location because of long distance to the market (relative to competitors) and no pipelines out for products.

When it comes to selling the refined products, Mongstad has to live with the extra costs of being far away from the European and the US market. Only 50 per cent of the selling

products go to the local market in Norway (Statoil Mongstad 2005). So the advantage of being close to the production sites offshore is somewhat balanced with the disadvantage of being far away from the end-product markets in 50 per cent of the cases. Bearing in mind that the main purpose of the refinery at Mongstad by its earliest owner, BP (previous British Petroleum, now Beyond Petroleum), was to make the refinery a strategic marketing centre for receiving oil from the Middle East and storage fuel for the shipping industry. Now the purpose of the Mongstad refinery has changed dramatically and by such also the cost structure.

The power and fuel supply to Mongstad produce much of its energy. The source is the natural gas delivered from the Vestprosess DA pipelines. However, to meet the requirements of the planned increase production, permissions for emission increase for different gases and building a gas power plant has been applied for. This problem still remains a hot potato in Norwegian politics.

Water supply is, as said before, important for cooling and cleaning processes at Mongstad. Mongstad Refinery has in the last years worked to become more environmental friendly by trying to change according to the nature surroundings. Interestingly, new wild-life has appeared and is sprawling (DVD of Wildlife at Mongstad). However there is still much to do to make Mongstad fully environmental friendly *regarding energy efficiency.*

Transportation location is an advantage for Mongstad since it is accessible from the sea and by road. The seaway to the port is usually free of ice but the narrow road to Mongstad needs salting to make it free from snow and ice during winters.

The cold and wet weather in the West-Coast Norway can put a refinery under extra stress, especially corrosions due to much rain and high humidity. This will require special adapted equipment for the harsh weather, given a somewhat higher capital costs. As earlier mentioned, the labour cost in Norway is also a disadvantage for Mongstad. There are many high-skilled workers in Norway but their wages are often not competitive compared to other countries.

6.4.3 Capital Investments

When investing in a new refinery, or a new module, both fixed capital and working capital is needed to complete the installation. Based on empirical studies by Abdel-Aal, a rule of thumb for fixed capital in new refinery include following items:

- The cost of principal process equipment that usually cover foundation, platforms and erection (illustrated in the figure below). With a calculated multiplication factor of 1.43 for the delivery cost. The product is the column for *process equipment*. The other columns are empirical based suggestions of what the other costs may be compared to the *process equipment costs*. *Process piping* is the cost of building a pipe system to transport fluid or gas through the refinery system. *Electrical auxiliaries* include electrical substations, feeders and wiring.

- Other costs in connection with constructing a refinery are the labour costs at the construction site like manual and craft labour, indirect labour costs like accountants and clerks, other indirect costs like travel and insurance. However, these costs remain small compared to the costs of acquiring the physical equipments.
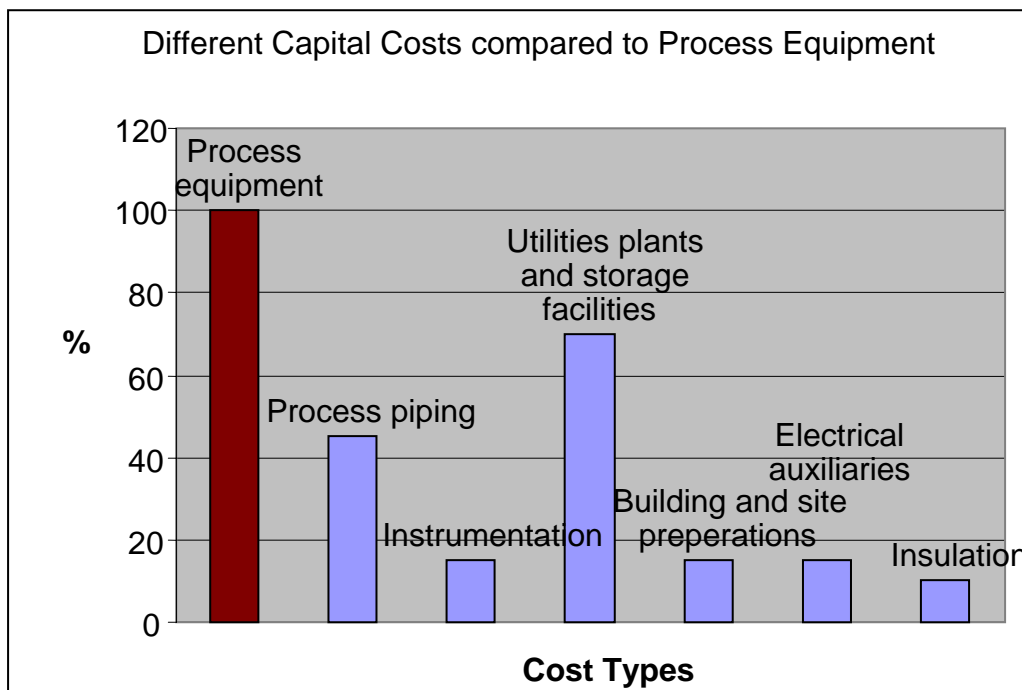
Figure 63 Theoretical Investment Costs at a Refinery, *Source: Abdel-Aal et al, 1992*

There is also a need of working capital before starting the refinery operations. Working capital gives the refinery financial strength to handle the difference between cash inflows and outflows. The author says that the working capital is usually determined by the sum of one month supply of crude oil, one month supply of work-in-process products and one month supply of final products. This is said to be 15 per cent of the total capital costs. Nevertheless, working capital varies a lot from project to project and one has to take in account the risk of the project and the underlying realities of the need for current assets.

The Mongstad refinery expansion in the 80s became a costly affair for Statoil, which was state-owned at that time. Statoil's first president had to resign from his job in 1988 after costs exceeded the budget by 6.4 billion NOK (Aftenposten 2005). This figure of 6.4 billion NOK was later known as one unit of "mong" that was meant to measure later deficit in later state-owned projects. When the estimated cost of investment was presented in 1982, the total expansion was to cost 3.8 billion NOK in 1982 money (Strømsvåg 1983). The large deviation in costs proves that cost-controlling in such a large investment project can be very difficult. However, the Mongstad project is not the only project that Statoil has exceeded its cost estimates. Also the ongoing Snøhvit project offshore and onshore will be exceeding the cost estimates dramatically. With several examples of projects exceeding budgets, it can be fair to ask if these extra costs are beyond Statoil's control or/and is it a case of poor cost estimations.

In an article by Pettersson (Aftenposten 2005), he presents an interesting theory why investment projects in the petroleum industry exceeds the cost estimates. The investment projects are structured almost like a venture company to spread risk where there is a partnership between several companies and one of them has the operator status. By being an operator of a project, gives the company valuable technology knowledge and operator experience for later projects. Pettersson argues that there is little incentive for the operator to focus on costs since the operator gets all of his direct costs in connection with construction fully covered, in addition to getting a share of the indirect costs like administration and R&D covered. Sometimes the partners have to pay the indirect costs as a depending amount of the direct costs, so that the there is a small incentive to increase the direct costs to get more of the indirect costs covered. In addition, there could be some incentive to relocate joint costs to projects as much as possible to get them covered. Also, different projects with different operator share of costs will give different incentives to reduce costs regarding to risk-taking.

An operator in a project with a large share of costs will be more focused on costs (taking less risk) than in a project with smaller share of costs. This theory is an example of agent-principal problem where the agent (operator) does not act in the interest of the partners (principal). This theory on incentive problems in investment projects is also relevant in operation costs since operations are most often structured as partnerships.

In the chart below, we see the development in investment costs from 1990 to 2004. The figures are given in nominal value. The investments have been varying a lot from year to year. With ordinary operation investments like maintenance investments and small modification investments on existing equipments as small inevitable costs all years, the total investment cost makes a large leap every time large investment projects are initiated.
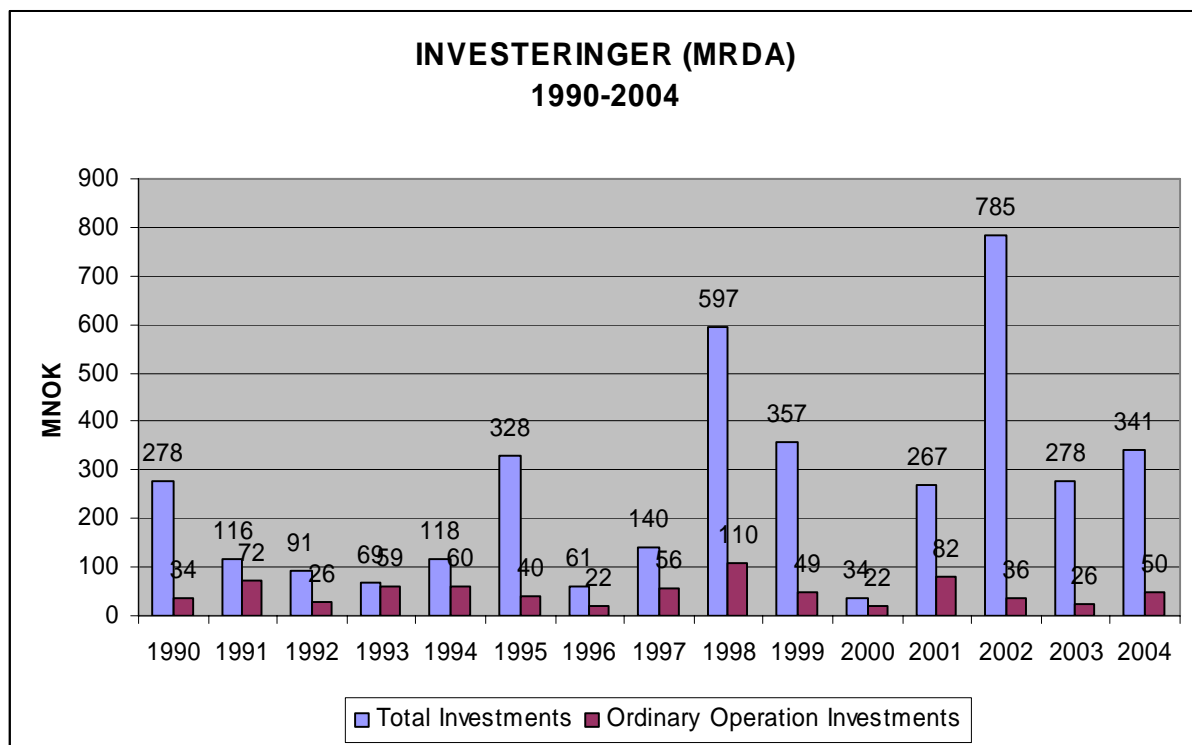
Figure 64 Investments at Mongstad Refinery, '90-'04*, Source: Statoil ongstad*

The investments in installations are being depreciated on analysis basis of 20 years (Mongstad 2005) although most of the installations have a longer life time. The deprecation costs are the largest non-payable cost at Mongstad, amounting to be almost 1/3 (Mongstad 2005 accounting information) of the total cash operating costs. During the installations' lifetime, some components have to be replaced. It has never been necessary to replace an entire installation. Following large investment projects have been registered in the figures

below that can explain the high investment costs in the years 1990, 1995, 1998, 1999, 2001, 2002, 2003 and 2004:

Year	Investments
1990	Finalising the refinery expansion and upgrade. Buyout of Noroil share of 40 per cent.
1995	New installation for reducing sulphur in diesel and gas oil.
1998	Revamp of Cracker-installation R-1501 and upgrade of the crude oil tower due to Vestprosess pipeline system expansion.
1999	Upgrade of the crude oil tower due to Vestprosess pipeline system expansion.
2001	Desulphurisation installation to improve quality of gasoline.
2002	Desulphurisation installation to improve quality of gasoline. Investment in flaring gas compressor to reduce flaring.
2003	Investments in energy recycling and upgrade of steam production. Also, system for quality improvement of auto diesel.
2004	Expansion of the Vestprosess installation. New jetty for ship to ship loading of crude oil

Figure 65 Description of the largest Investments during '90-'04*, Source: Statoil Mongstad*

There are three different ways of deciding investments at Mongstad. They use net present value (NPV), internal rate of return (IRR) and pay-back time. NPV gives the value of the investment measured in today's money and the IRR is the discount rate that gives an NPV zero. The payback time is a very simplified tool and measures how many years it takes before the investment has paid-off. The latter tool is not appropriate for investments with a long time profile due to not including the different discount rates. The best tool for deciding the profitability of investments is NPV since the IRR suffers from business logical failure (Jan Bergstrand 2005). This is due to two different investments with different IRR is a logical failure since the same time period should have the same discount rate. For investments at Mongstad, the decisive method is the NPV (Øyvind Arnesen 2005). In the NVP calculation all prices regarding crude oil and products are according to EPA (Economic Planning Assumptions). EPA is a common tool (prices, exchange rates, etc) for all investmenst projects and other economic forecasts in the Statoil corporate. Due to these assumptions, the oil price is to some extent fixed and the basis of the cash flow. The cash flow to total capital is after tax and they use real discount rate after tax. The discount rate is confidential. It is recommended by the department "Group Planning and Analysis" (Konsernplan og analyse) and the corporate management decides on the investment above the limit of internal decision at Mongstad (discussed soon). The group management, the division and Mongstad will normally demand a substantial positive net present value so the actual rate of return must be higher than recommended by "Group Planning & Analysis".

Mongstad is delegated to make investment decisions with an upper limit of 50 MNOK (Øyvind Arnesen). In practice, investment decisions less than 20 MNOK are taken at Mongstad. To estimate the cost of investment, the project environment at Mongstad investigates about the cost and works on a project plan. Until 3 October 2005, the responsibility was under P&U (Plan & Development) for projects concerning business development and T&U (Technology & Development) for projects concerning project deployment and modifications of existing investments. The new unit is VMP (Maintenance, Modifications, Projects) that has its responsibility of the two previous units.

6.4.4 Economic Balance in Refining Costs and Total Product Costs

Design should be customised such that an economic balance in refining operations is achieved. With economic balance we mean that the costs must be reflected in the estimated

revenues so that profits are optimised. One can design the equipment according to the needs of a refinery. For instance, direct costs like power costs in connection with pressure drop for fluid flow on one side, and on the other side the fixed costs of building these pipes. While the power costs decrease as pipe size increases, the fixed costs of building the pipes increase with the costs. The pipe size should then be where the total costs are optimised to a minimum. The difficulty is that once the pipelines are build it is a sunk cost, and any optimisation of the pipe size should therefore be based on the needs and the variable costs of operations during its life time. Hence, when analysing the different aspects of design only the variable costs varying with operations (direct costs) that are of relevance. In this case, the marginal increase in power costs when increase in production will be the relevant cost and compared to the marginal increase in income. The point of intersection of these two cost types is the optimal pipe size. However, without historical data about the cost structure of the refinery in operations, it is difficult to know the incremental costs.

Another example given by Abdel-Aal is designing a bubble plate distillation column for distillation of crude oil. Three main things must be calculated:

- Number of plates.

- Optimum reflux ratio.

- Diameter of the column.

Following relation exists between reflux ratio and number of plates: The same separation level can be attained by increasing the reflux ratio (R) and reducing the number of plates. Fewer plates mean lower fixed costs. Also, when R increases, then the vapour load inside the column will increase and by such increase the pressure inside the column. The increased pressure will increase the velocity of the vapour. To keep the vapour at same velocity, the diameter of the column must be increased. The annual fixed costs are basically the depreciation costs for the column, the reboiler and the condenser. The operating costs can be simplified as the cost of steam and the cost of cooling water. Below you can see a table overview a given case.

Reflux ratio	Actual plates required, number	Column diameter, ft	Costs $/yr					
			Column	Condenser	Reboiler	Cool water	Steam	Total
1.14	*	6.7	*	2805	5940	8,670	66,450	*
1.2	29	6.8	13,395	2865	6060	8,910	68,250	99,48
1.3	21	7.0	9,930	2925	6195	9,300	71,250	95,60
1.4	18	7.1	8,880	3000	6360	9,705	74,400	102,34
1.5	16	7.3	8,235	3075	6510	10,110	77,550	105,48
1.7	14	7.7	7,935	3225	6810	10,935	83,550	112,45
2.0	13	8.0	7,815	3420	7200	12,150	92,700	123,28

Figure 66 Table of Cost Relationship between the different Technical Aspects, *Source: Abdel-Aal et Al, 1992*

Another example of thinking more economical when designing a refinery is to use most of the already existing heat in the system to heat up other elements. For instance, by using a heat exchanger you can use the heat of the hot products coming out of the distillation column to preheat the crude oil coming in to the system. This may save much energy costs. Also, by heating up heavy crude oil, you can increase the flow since the crude oil becomes more viscous when it becomes warm. This is something that is widely used in the oil industry when transporting crude oil in pipes.

We will end this part about design costs in connection with refining costs with saying that this is a field that requires in-depth technical knowledge and understanding on how to apply business ideas on it. Calculations include scientific formulas as well as business formulas and therefore can be difficult to handle.

6.4.5 Profitability Analysis and Target Costing

Since investing in a refinery requires large amount of capital, many refineries are organised as partnership. Note that partnerships are quite usual in the oil industry offshore to share the large burden of financing. In addition, the refining industry has its risks like becoming obsolete due to new energy sources and the low profitability in historic terms. Target costing can be used to decide the cost budget of building a refinery. First, we have to find out the

owners' yield expectations of the investment. For instance, the owners' expected return on investment[25] can be 10 per cent per year. If one, in addition, can try to predict the future revenues based on profitability analysis then one can try to find the target cost by multiplying the future revenue with 90 per cent (100 per cent - 10 per cent). The target cost is then the economical frame for deciding the design. For instance, designing a distillation column that exceeds the target cost will not be economic feasible. By using value engineering, one can adapt the technical specifications of the distillation column so that it is most appropriate to satisfy both the market needs and the target cost.

Target costing and value engineering have been widely used in the car industry where the pressure on costs have forced car manufacturer to integrate suppliers in their design construction. This pressure on costs has generally been somewhat lacking in the Norwegian oil industry due to high profitability. However, Statoil has been focusing in integrating its suppliers much more (Statoil Procurement Bergen, 2005). By having design teams with suppliers and collaboration on other fields, the benefit can go beyond cost aspects. Target costing and value engineering are two large academic fields, and going in detail is beyond the scope of this thesis.

6.5 Costs during Operations

When the refinery has been commissioned, the structure of costs changes from being one-time sunk cost to more variable recurring costs, this applies especially to indirect costs like maintenance and administration costs. By being both variable and recurring, gives the management the chance to do cost improvements by learning from experience. This introduces the concept of *kaizen* costing to improve continuously to achieve lower costs. By learning from experience and systemising cost data one can reduce these costs. One way is to use ABM (Activity Based Management) to focus on cost reductions.

Costs during operations can be divided into two main groups: the direct costs that directly are being affected by the operations, and the indirect costs that are not in direct connection to the operations. Direct costs can be different input products like crude oil (these input costs

[25] ROI = Profits / Investment

are excluded in operating costs as mentioned earlier) and additives, man power in connection to process control, or electric power to run the processing system. Indirect costs can be cost of administration, maintenance, security and other services not in connection to the processing.

Note that not only the variable costs are under consideration for short-term cost cutting but also fixed costs that are reversible are also relevant when cost improvements are considered. We will not be discussing long-term cost-cutting in detail in this chapter due to the scope of this text.

Note that there are different definitions of what operating costs depending from a MRDA (Mongstad Refinery) perspective or an industry perspective (with Solomon Benchmarking as a basis).

MRDA (Mongstad Refinery) definition:

   Operating cost ex depr. (incl. catalysts/chemicals + purchased el.power) (but excl: Additives

  and fuel gas/other ref.produced energy)

+ Depreciation

= Operating cost incl depr.

(Additives + fuel gas/other ref.produced energy are reported as reduction in "value added". That means that they are considered as reducing factors of the refining margin)

Industry definition (Solomon):

  Cash operating cost ex energy (incl. additives)

+ Energy cost (=el.power, steam, fuel gas)

= Cash operating cost (incl. energy)

+ Non-cash expenses (=Allocated general & administration costs, depreciation, interest)

= Refining expenses

In the figure below, we have charted the cost of operations noted in the financial statement of MRDA during the last four years. Note that the financial statement perspective varies from the two other perspectives. In cost of operation we include all costs in connection with daily activities except of the purchase of crude oil and natural gas. We see that the cost of operations has been steadily increasing all years except 2002. We will analyse what the reason could be.
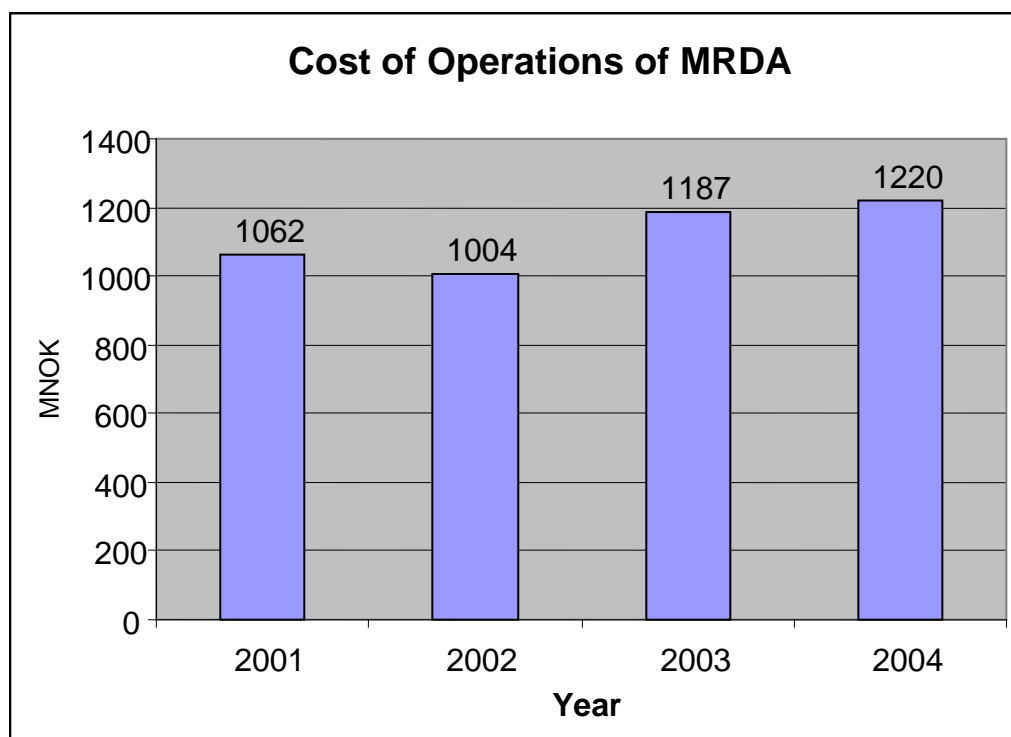
Figure 67 MRDA, Operation Costs 2001-2004

6.5.1 Direct Costs

Input costs

In a refinery, crude oil is the basis raw material. During different processes (distillation, catalytic etc) the crude is beeing split. However, different requirements from regulations in different countries and different industries oblige the refinery to add additives. In addition, it can be economic feasible to buy semi-processed petroleum products to increase the value creation. This could be to buy externally residuals at a low price and use the conversion capacity existing in refinery system. A last aspect concerning inputs can be what combination should be used to optimise the process yield for some desired refined products.

As discussed earlier in the pricing chapter, the crude oil input is mainly bought from the NCS. This crude oil has a high-value since it is relatively light so the refinery does not have to use the conversion capacity so much to produce the same amount of high-value light products like gasoline. Nevertheless, light crude oil is more expensive than heavier crudes from the Middle East but the transportation cost balances the price somewhat between the two types of crude oils. The natural gas bought from the Vestprosess DA pipeline system is sometimes used to increase the value of the final petroleum products like increasing the butane component in gasoline during winter seasons. Sometimes excess butane and propane are sold to Vestprosess from Mongstad. A gasoline product may consist of 6-8 fragments (Eivind Blindheim 2005) of different petroleum components, depending on the requirements to the country it will be shipped to. As a component refinery, Mongstad keeps 8-10 different gasoline components stored in component tanks. When a ship is waiting at the harbour, the product is being blended to be loaded on board. One component in gasoline is butane. This component must be varied in amount dependent on the season for the country of consumption. During winters in Scandinavia, more butane is permitted to add in the gasoline since low temperature helps keeping the pressure of butane low. When the temperature rises, light components like butane increase in pressure due to higher kinetic energy and the result is that the gasoline pumped into cars dampens away. During summer seasons the amount of butane must therefore be reduced so another input combination must be arranged. The main components of gasoline are:

- RCCN (also called cracker naphtha) produced at Mongstad.

- Reformat and MTBE to increase octane levels in gasoline. Reformat is produced at Mongstad and the MTBE is imported from the market at Amsterdam. MTBE must sometimes be replaced by ethane due to environmental regulations in countries like the US. MTBE is known to pollute groundwater but has only been proved to cause smelling problems in drinking water.

- LNAF (also called light naphtha) produced at Mongstad.

- Isomerat produced at Mongstad.

- Polymerat is being used instead of alkymerat due to lower costs. Also produced at Mongstad.

- Butan.

As you can see, many input components are necessary for making gasoline. Some is made from crude oil, while other is bought from other places. Inputs at Mongstad can be classified in four major classes in cost order manner, where the first is largest cost and the last being the smallest cost for Mongstad:

1. *Crude oil:* as discussed in the pricing chapter, the price of crude oil is based on the Brent Blend dated adjusted from $2 per barrel or much more for qualities and an adjustment for transportation is also made. Transportation costs from Statfjord and Gullfaks usually fluctuates in the interval of 30 to 40 cents per barrel (Blindheim 2005).

2. *VP C_5+* is a mixed product mostly made of naphtha but also butane and ethane that Mongstad buys from the Vestprosess DA. The butane and ethane are mainly used in the process of making naphtha and methane is used to supply the refinery with energy fuel. Sometimes the flow is turned around so that Mongstad sells these components to the Vestprosess.

3. *Res LS/NS* is the abbreviation for residuals where LS indicates low sulphur content and NS indicates high sulphur content. Residuals from all over the world are being brought to Mongstad for further processing.

4. *MTBE/ISOMERAT* is mainly gasoline components. Isomerat is usually produced at Mongstad but sometimes it has to be bought.

5. *Catalysts* are bought from the petrochemical industry to enhance chemical reactions in the process.

6. *Additives*. Those in charge of operations take care of the purchase of additives while the other inputs are fixed by the PPL[26] department at Mongstad.

The first two costs are the two largest at Mongstad naturally due to being main inputs for final products they are used in large amounts. In addition, the cost of crude oil is maybe the input that fluctuates most among the given in the list above. The price of crude oil must therefore be monitored, both the present price and the future predicted price. A minimum crack spread is necessary for the refinery so that a dissent net margin can be obtained. If an increase in oil price is not followed up with an increase in its final products then the margins will be threatened. Note that it is O&S that is responsible for the buying costs of inputs. Other inputs are used in limited areas and in limited amount and they are often not that variable as crude oil.

Some of the end-components made by Mongstad are so-called *space products*, components that Mongstad cannot do anything with. Bi-products like coke, which is sold to the aluminium industry, and sulphur, which is used in wood processing. The sales price from these products covers the cost of transportation.

Which specific inputs to run in the system is based on experience and rule-of-thumbs by the decision makers in PPL. Their decisions are supported by business models in excel spreadsheets. This could remind of ad-hoc type of solving problems and makes it difficult to know the product costs at any time in a continuous refinery system. However, there is some planning involved due to a certain overview of which deliveries that are going to be made next month.

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[26] Production planning.

Another typical problem at a refinery is the joint cost distribution. Different end-products have been produced from different parts of different inputs. How should one relocate the costs to the different end-products? Is the physical consumption the correct way, or should relocation of costs be based on what value the end-products produce? Important is that any distribution of costs are arbitrary. How you distribute the joint costs must be based on what incentives and justification the products should have. If you want to keep a broad spectrum of products then a joint cost distribution based on net realised value could be a solution since each product will be burdened with a cost amount that reflects the value it creates. However, if you think that the only correct way is to relocate joint costs to the actual consumption of inputs for each product the profitability may change drastically. We will not dwell on cost of inputs due to the limit of this thesis.

There are no specific product calculations at Mongstad so the total costs of the different refined products are not estimated. However, in the everyday work the product differentials between products that are close substitutes in production are registered in an excel spreadsheet that proves important for decision makers. The product differentials are based on the margins of selling an extra unit of a given refined product compared to another. The figure below shows the production choice between the unleaded gasoline octane 95 (UG95) and unleaded gasoline octane 91 (UG91). The ultimate choice is to choose to produce the octane 95 since the unit margin is higher than for the octane 91. Since there are not components at hand to blend the requested volume of octane 91, this order has to wait for more components to be refined. The marginal cost is represented by the horizontal dotted line. The differential in the spreadsheet represents the difference between the margins of the two products.
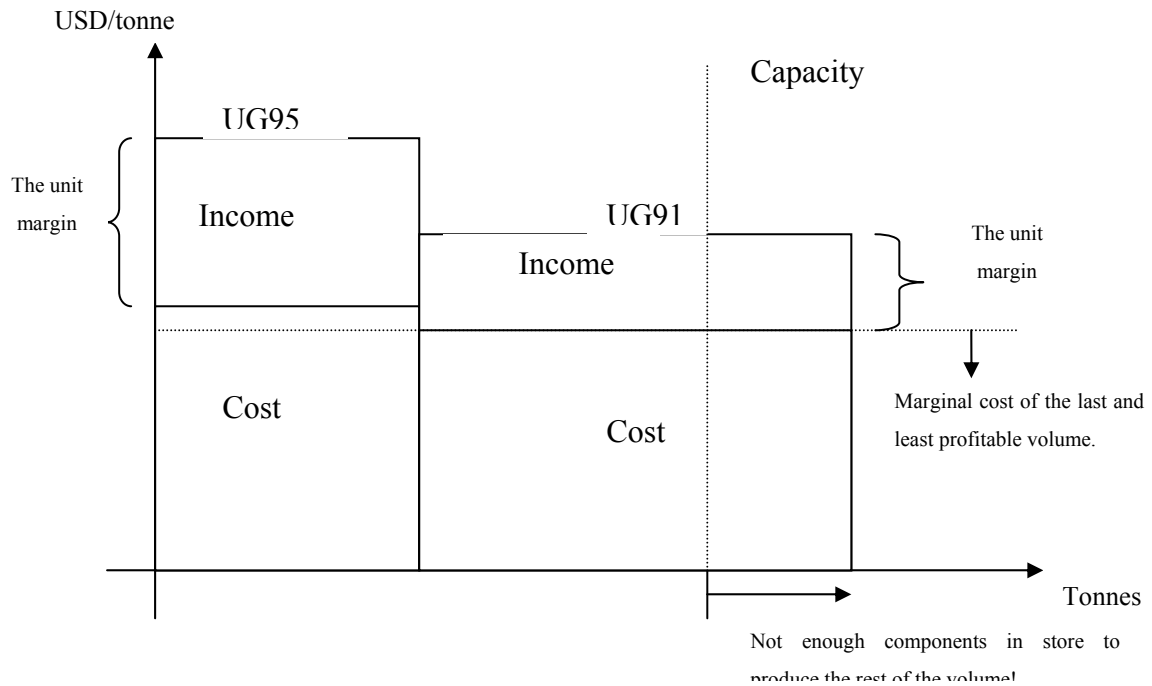
Figure 68 The Economical side of choosing which Product to Produce

The use of marginal costs in the spreadsheet differentials is not a decisive management tool since there are many other relevant considerations that have to be taken. This will be further studied in the production chapter. The spreadsheet looks like the one below. The prices are gathered from the Platt's system and noted in the spreadsheet. The spreadsheet then produces the differentials of the products that are trade-offs in the production. The refinery margin is then produced (removed from the exhibit below due to sensitive information).

DAGLIG PRISTABELL med 2005 produktportefølje MARGIN FOR ....: 11-mar-05

SM budsjett 2005 produktportefølje		Priser for:		vs.		Dagens dato 14.03.2005
		11-mar-05	10-mar-05			
RÅOLJE/IMPORTER		USD/BBL	ENDRING	Kjøpspris Brent-$/t.		
BRENT Blend dated MEAN		53.13	-0.22	402.6		
SM gj.snitt. Råoljedif mars-05	BB dated +	0.35				
SM gj.snitt.frakt plan mars-05	BB dated +	0.23	Troll C5 +	Øseb. NGL C5 +		
Beregnet pris for Troll VP C5 + og Øseberg NGL C5+			451.35	465.16		
STR.RES 0.7% PCFH		296.0	0.00			
MTBE PBFH NWE faktor 1.10		525.0	1.00			
PRODUKT		USD/tonn		Volumpriser		
PROPAN SEAGOING MEAN		449.50	0.0			
BUTAN SEAGOING MEAN		433.50	0.0			
BUTAN CIF 3000+ MT		454.00	5.0			
UNL PREM .PCCH_NWE		472.00	0.3	356.4		
UNL REG PCCH NWE		469.50	0.3	354.5		
Platts US MS barge (conv. 87 OI)		504.63	12.8	381.0		
Platts US MS barge (conv. 95 OI)		549.32	29.7	414.7		
NAPHTA PCCM NWE		473.50	-3.0			
JET PCCH NWE		538.50	4.3	430.8		
10 ppm (diesel) PCCH NWE (fra 1.1.2005)		556.00	15.8	469.8		
ULSD (engelsk diesel kval) PCCH NWE		554.00	15.8	468.1		
GO 0.2 PCCH NWE		493.25	2.8	416.8		
FO 1.0 % PCCM NWE		242.25	-5.0			
FO 3.5 % PCCM NWE		193.75	3.0			
			snitt mars 05	Manedsforutsetn.		
PRODUKTDIFFERANSER - USD/TONN		11-mar-05	Hittil i måneden	Mar rev.08.03		
PUSMSBarge95-UG95		77.3	50.2			
PUSMSBarge87-UG91		35.1	31.1			
PUSMSBarge95-PUSMSBarge87		44.7	21.6			
UG95-UG91		2.5	2.5	N.A.		
UG95-JET		-66.5	-70.8	-66.5		
UG95-GO2		-21.3	-26.6	-19.5		
UG95-LDF		-1.5	-0.8	5.5		
UG95-STRN		176.8	173.4	169.5		
JET-GO2		45.3	44.1	47.0		
JET-ULSD		-15.5	1.1	6.0		
10 ppm diesel - ULSD		2.0	-2.2	N.A.		
GO2-STRN		198.0	200.0	189.0		
ULSD-GO2		60.8	43.0	41.0		
STRN-FO3%		101.5	· 102.9	106.0		
STRN-FO1%		53.0	62.4	77.0		
Raff.marginer			snitt mars 05	Mar rev.08.03		

Figure 69 A Spreadsheet Sheet example of Differential Calculations at Mongstad, *Source: MRDA 2005*

Referring to the theory presentation of this chapter, we will not include raw material like crude oil and natural gas used to process refined products as a part of the operating costs. Thus, we separate the operating costs and the input costs. We have dealt with the aspect of inputs in the chapter on pricing. Hence, all figures concerning operating costs are not including the purchase of crude oil and other inputs that are to be processed to refined products.

Direct Labour Costs in Connection with Internal Services

A refinery is dependent on top skilled workers that can operate the highly sophisticated processes. The main labour force is the technical staffs that are in direct connection with the production. The technical staffs consist basically of mechanic workers and engineers but also emergency staffs like fire-fighters. Operators are needed for maintenance of the installation and install new equipments, in addition to measure different physical aspects like temperature and pressure in the refining system. The engineers are mainly employed in management positions in different teams at an operational level. They control the processes and take important decisions that affect the processing system. Thus, keeping machinists, engineers and other workers connected to the production can be categorised as direct labour costs. Usually, the cost of keeping an engineer is higher than a mechanic due to higher education and specialised skills. Note that the cost of labour is not only the salary that is paid out but also employee benefits like pension, employer tax and social costs.

Mongstad has a total of 680 employees and an additional 70 apprentices (www.statoil.com). 100 of these employees are contractors. Many of the employees and almost all of the apprentices are directly connected to the production operations at the refinery. The total labour costs at Mongstad, that is both the direct and the indirect costs (mainly administration) excluding the labour costs in outsourced services, are at approximately ¼ (Mongstad) of the total operating costs. Of these costs, 1/3 of it is connected to other employer costs than salaries like pension and employer tax. The cost of manpower is in general higher here in Norway compared to the location of other refineries. This has been presented by the Solomon benchmark as one of the disadvantages for Mongstad. However, one should bear in mind that the cost of management is in fact not amongst the highest. So the ordinary worker implies higher costs than, for instance, refineries in countries in Eastern Europe but the management costs are competitive.

The distribution of joint costs of internal services is a common problem for many organisations. Pricing internal services can motivate the internal units to act more economical rational so that resources are used more optimal. In addition, internal pricing gives possibilities of more fair cost distribution to the units based on resource use. There are following types of internal pricing (Jan Bergstrand 2005):

- *Cost based*. The most common in practice due to the fact that costs can almost always be calculated.

- *Market based*. The most correct pricing method due to market mechanism that helps allocating resources optimal.

- *Negotiation based*. This method can increase motivation among units since they can affect the method of cost distribution directly. However, this requires more work due to the negotiations efforts that have to be put down.

- *Two tariff system*. Can be suitable in some special cases, for instance, to cover fixed joint costs in addition to variable cost of operation.

In academic circles (Bergstrand 2005), the recommendations are market price with a small discount on a homogenous product to make it favourable to trade internally rather than externally for the buying unit. In some cases, negotiations with the market price as a fundament can be a solution. Where the market price does not exist, cost based pricing like full costing or ABC (Kaplan & Atkinson 1998) can be a solution. Note that ABC is in many cases difficult to use for product calculations due to complexity. The concept is summarised in the matrix below.

	No Competition	External Competition
Rutine Work	Pre-Calculated Full Cost	Market Price
Strategic Services	Pre-Calculated Full Cost	Consider Two Tariffs

Matrix 1: Pricing of Central Services, Bergstrand 2005

The central service costs can consist of a joint cost element and a direct cost element. Joint costs in internal services can be distributed to the profit units as well as the administration cost (discussed later). However, variable costs with a cost driver should be charged to the unit that buys the service. The figure above shows how the variable costs in central services should be charged. If there is an external market, then a market based price for the central services is appropriate. When there is no competition, the pre-calculated are most appropriate. Pre-calculated costs are recommended instead of after-calculations since the units then have efficiency incentives, Bergstrand (2005).

When MRDA is pricing the labour costs, the focus is on tasks rather than cost types. A task can include workers from many different areas. To make it easier to charge the purchasing unit for its consumption of labour force, Mongstad refinery use pre-calculated full cost prices for the different tasks and the workers used. The idea is to avoid the problem of distribution keys for distributing the joint costs at a later stage.

Mongstad refinery separates between the unit that orders the task (the task responsible) and the units that offer the resources for the given task (the resource responsible). The task responsible has a budget for the certain tasks like daily operations but the unit does not necessarily have the responsibility for the worker. The responsibility of the worker lies at the resource responsible that can use the worker internally or outsource him to a task responsible. The resource responsible unit has the responsibility of competency development, recruitment and other personnel aspects. Costs can also have a project focus where the project is charged with the consumption of resources from different units.

Units that are responsible of tasks are (before October 2005): Planning and Development, Production Area A, Production Area B, Mongstad Infrastructure, etc. By using the SAP system, one can go in detail in the different task areas, for instance, Production Area A is divided in Pro A1 and Pro A2, and for each task one can read in the SAP system how much they have been using of different resources.

The pre-calculated price per hour is called a basis hour. The basis hour is based on the year wage of an installation worker or an administration worker. Then there is an add-on the time price depending on where the resource is retrieved from. The time price also includes the use of standard infrastructure and equipment. Special material and infrastructure are being charged separately. Note that R&D is never distributed to the time prices.

The budget for next year is the first step in calculating rates. The budget for previous year is modified based on information from the business units on their predicted hour consumption for next year and the joint costs from the service suppliers like KTJ (Group Services). In addition there are assumptions like wage increase and change in pension costs. The preliminary budgets are done during June. Then in November, the pre-calculation rates are roughly made by updating the earlier information and finding the equivalent unit costs. When the year is finished and the accounting information is ready, then the final calculations of the rates can be completed.

The rates have increased from 2004 to 2005 on a general basis. For analytical purpose, the rates have been decomposed into wages, pension and insurance, and joint costs like administration of a business unit. The calculated rates have been increased due to 3.5 per cent increase in wages, increased pension pay agreed with the trade union (OLF: The Association of the Oil Industry), and higher administration costs. The figures given from

Mongstad also show that the rates are lower when using manpower for production purposes than administration purposes.

The main motivation of charging the consuming unit with a time price is to put a pressure on costs. However, there is much noise in finding the correct time price and there is usually a large deviation between the normal calculation and the actual numbers. Even a change of 1 per cent can give large deviations in total amounts.

We sum up that MRDA does not use any kind of ABC-calculations. In ABC-calculations the unused capacity is adjusted for and joint administration costs are kept unallocated. Øyvind Arnesen of Statoil Mongstad Finance says that it is possible that some IT-costs have been distributed after the ABC-model. The main costing model used at Mongstad is the full-cost method (not including calculations in production) or possibly market price where it exists. The Statoil Time Price System (Statoils Timepris System), mentioned in the labour cost description earlier, is such an example.

Please read the part on administration costs in the section of indirect costs for further information on labour costs concerning administration.

Energy Costs

Abdel-Aal (1992) has found that in the industry around 40 per cent of the fuel is based on the refinery's own gas and 30 per cent from imported natural gas. The rest of the fuel can be oil fuel and coke, and sometimes even coal. Energy costs at a refinery can make up a large part of the total operating costs.

In the case of Mongstad, an approximately 50 per cent of the operating costs (excluding cost of unprocessed raw material like crude oil and natural gas) are connected to energy supply (www.statoil.com). Today the energy is generated mainly from the fuel that is acquired from the natural gas bought from the Vestprosess installation and the refinery's own produced gas. The fuel is used for heating up heaters, generating steam and electricity, running gas and diesel engines, and as a heating catalyst in the process of catalytic cracking.

Since energy costs are huge regarding to operation costs, any small improvements could imply in a significant cost reduction. At moment time, the utilisation of the energy supply is

poor and improvements are certainly possible to achieve. The suggested CHP-station (power supply using natural gas as feed) will reduce operating costs due to higher energy efficiency, in addition to more stable energy supply. The efficiency rate, measured as produced kilowatt hours (kWh) per natural gas feed, is estimated to be at start up in 2008 of 70 per cent (www.statoil.com). It is estimated that the new power installation will produce 250 MW of electricity, and if the total heat generated are converted to energy there is a potential of 350 MW. The investment in the power facility is estimated to be 4 billion NOK in 2005 money. The new power station will be, if completed, run by a separate company that will both own the power station and operate it.

Capacity Costs

Capacity costs are another term for fixed costs. It is titled "capacity" since fixed costs exist to keep a certain capacity of production. When production is high the capacity costs per unit of refined crude oil is low, and when the production is low then the unit costs are high. Thus, one important factor in keeping the unit capacity costs at a minimum is to maximise the regularity and the utilisation grade at the refinery. The capacity is changed continuously (due to market prices) one should be careful of comparing different years.

Both these two measures are important key figures for production management and their performance at Mongstad. Utilisation grade is closely monitored on a daily basis. Based on figures from Mongstad (classified) the utilisation grade is high. The aspect of profitability in upgrading heavy oil components to lighter components makes it almost always economical to use spare capacity for upgrading activities with the cracker module. However, one should bear in mind that it is not always lucrative to choose maximum utilisation grade. Sometimes certain special production orders must be prioritised so that the refinery utilisation grade is reduced until the order can be initiated or transporting the received oil to another place directly without processing. Setup costs in changing production to different products must also be considered. Different aspects like temperature and pressure arise when production is changed. Note that when the utilisation is at a maximum, the equipment gets faster worn-down so that it becomes less efficient and operates at higher costs due to increased maintenance needs.

Mongstad refinery is also required to do a revision stop (Turnaround) every four and five year that puts the production on a halt for one month. Revision stop is also expensive due to

accommodation costs of many workers. The whole installation must be cleaned both inside and outside, in addition to ordinary repairs of equipment that reduces production. Both moments reduces the regularity of production. Also, the fire incident in 2004 added to the expenses in form of lost production.

6.5.2 Indirect Costs

Maintenance Costs

The cost of keeping the installation and equipment maintained is a serious task for keeping a high production with high quality. Maintenance includes different fields of skills like electro, automation, mechanics and much more. The question that arises for the decision maker at the refinery is whether to initiate maintenance when malfunction or break-down (diagnostic maintenance), or maintenance as a regular planned activity to avoid malfunction or break-down. Note that this trade-off is well-documented in academic circles as cost of quality.

The following model below illustrates the trade-off between planned maintenance costs (*forebygging- og inspeksjonskostnader*) and diagnostic maintenance costs (*feilkostnader*). The optimal adjustment of percentage of defects on equipment is where the total costs (*totale kvalitetskostnader*) are at its lowest. Note that total costs also include non-quantities costs.
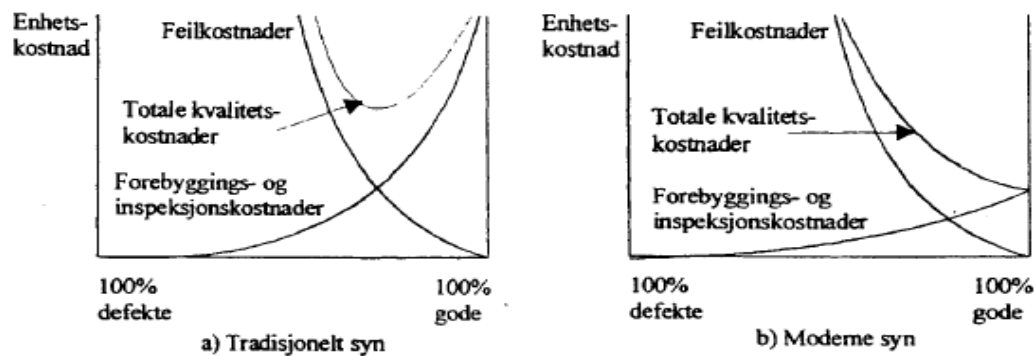
Figure 70 Aspects on Quality Costs, *Source: Jan I Stemsrudhagen 2005*

In the traditional way of thinking (*tradisjonelt syn)*, the optimisation point is where you accept a certain level of defects. Depending on the type of industry and the corporate goals, either one of the perspectives can be optimal. Also the type of equipment could alter the choice of optimal perspective. It can be appropriate to accept higher risk of breakdown when it implies in larger reduced planned maintenance costs than increased diagnostic maintenance costs (Hydro Oil & Energy, 2005). Typical components that are suitable for such strategies are those that are not regularity or/and safety critical, high risk of breakdown and equipment with large share of replaceable parts. Thus engineers should form a common priority list over which equipment that needs most maintenance attention.

As an oil company, Statoil has a social responsibility of safety and environmental concern. This is also manifested in the corporate HSE (Health, Safety and Environment) where zero injury is the only acceptable level. Also, the cost of a production stop will probably inflict a higher cost than regularly maintenance work. So the general rule for a refiner with Statoil's ambitions is maybe to keep a high level of planned maintenance. However, this generalisation calls for caution depending on type of equipment.

The planned maintenance at Mongstad can be based on historical data of the technical status of given equipment. Some equipment cannot be interfered without part of the refinery facility has to be closed down. In connection with *turnarounds*, several certain maintenance

jobs are being done within a "window" of days. Some equipment is required by *Petroleumstilsynet* (Ptil), the Norwegian petroleum commission for operations, to be checked in regular intervals. The intervals are not fixed but have to be evaluated and described in a system, according to the internal control principle. In some areas, Mongstad keep spare parts since they are so important. Equipment like pumps are kept in reserves so when the main equipment fails the spares can be used.

Administration

Operational activities generate administrative work like accounting, sales, procurements and legal at Mongstad. Statoil Mongstad is buying many of the administrative services from Corporate Services, like sales and legal. The price of one hour of administrative in Statoilsevices are higher than the use of one hour of manual and craft labour due to need for own office and PC and other IT costs. Also this is due to the fact that the average worker in the administration has more education. Workers in the administration have varied educational background but most of them have a technical background or an organisational and economic background. However, some administrative workers have started as manual worker and climbed the hierarchy or changed to a different area than their area of educational specialisation.

In Norway it is usual that more education pays off in higher salaries, according to various statistical studies, but the difference between workers with and without higher education is much smaller than in many OECD countries. Thus, the administration costs at Mongstad are competitive to some extent while the labour costs seen as whole are a disadvantage (Solomon Benchmarking Year X).

Measures to cut costs in administration at Mongstad are limited like the costs in direct labour. Cutting wages are usually not an option in Norway where the trade union stands strong. Cost-cutting measures to reduce the amount of resource used are therefore limited. Also, keeping a high number of employees turn the labour costs, in many cases, into fixed costs. This has led to a general trend of outsourcing and hiring so that labour costs can be transformed into more variable costs, Sahabanik (2005). Variable labour cost is a strength for the refinery when it experience down periods since it can be a control variable in cost reductions. In addition, outsourcing in fields that Mongstad Refinery and Statoil have little

or none expertise to externals with expertise can in some cases lead to more effective use of resources and thereby becoming cheaper in use.

At Mongstad, many of the administrative work have been outsourced. Security, IT-technical support and canteen have been outsourced to externals or to other units in the Statoil group. We will discuss the aspect of outsourcing next in this chapter.

The different locations in Statoil get their share of the joint cost of administration by adding the time hour price of services with a certain amount, depending of what kind of service.

Equipment and Service Suppliers

A refinery is made of many specialised and complex components that require highly skilled workers that the refinery owner do not always have. The cost of specialising in all areas would be too much to be economical viable in the long run. The refinery must therefore choose between which activities it wants to do itself and which activities to outsource to external parties.

According to Trond Bjørnenak of NHH, the decision on what to self-produce of goods and services is based on cost-efficient and strategic importance argument. If a service that has no strategic importance of keeping it internally and is cost-inefficient then it should be outsourced to a supplier. However, there can be reasons to keep the activity internally if it is competitive or has a high strategic importance. Note that when keeping an activity that is strategic important but not efficient, it has to improve its efficiency to be competitive. The box below illustrates the main points in the theory on "make-or-buy".

Strategic Importance of Internal Production

	Low	High
Low	Outsourcing	Efficiency Improvement
High	Reasoned with Efficiency	⭐

Cost-Efficiency (vertical axis label)

Figure 71 The Make-or-Buy Problem, *Source: Trond Bjørnenak 2005*

Equipments are usually bought in from large suppliers in the petroleum industry like Halliburton and Schlumberger but also much smaller companies. The large suppliers are often specialised in technical equipments and offer services along them worldwide. This gives them the advantage of cost efficiency in form of economics of scale and the learning effect that Statoil alone cannot acquire by small-scale production. However, it is known in the Norwegian oil industry that the many supplying firms take prices with lucrative margins. There has been little cost pressure towards suppliers to reduce costs and there are cost-cutting potentials based on experience from the petroleum industry. Statoil in general has become more active to integrate its suppliers in their activities. Hopefully this can lead to cost cutting efforts on a higher level. Note that not all equipment are bought but rather rented or leased.

Services like production planning have been kept in the Statoil system due to its strategic importance and Mongstad's expertise. Support activities like security and canteen have been outsourced to external suppliers. The security company Securitas takes care of the reception at the main entrance while another external company takes care of the canteen operations. Some of the services are brought by other units in the Statoil group. Corporate Services (Konserntjenester or KTJ) serves all units in the corporate. The external company on canteen operations at Mongstad is hired by KTJ. *IT-support* is also an example of service served

from KTJ. External consultants are also a significant service cost at Mongstad but we will not be going into it in detail.

We will not be presenting any accounting figures on contract services due to confidentiality.

Insurance and Property Tax

Property tax is tax that property owners have to pay to the local authorities. However, the tax is optional and it is up to the local authorities if they want to apply it in their district. The property tax is calculated from the estimated value of the property times the given tax rate decided by the local authorities.

The estimated value of Mongstad has been of major discussions. The hot potato is which rate of return should be used to calculate the value of Mongstad. A higher rate of return would reduce the net present value of Mongstad and thereby reducing the property tax. However, the local authorities have argued for a low rate of return and have received support from Knut Boye of NHH. Statoil, on the other hand, argue that the high risk of investments would justify a higher rate of return. Nevertheless, the property tax has a social aspect by the amount of funding it gives the local community.

Insurance is another aspect that requires an estimation of the value of the insured equipment and installation. The basis of insurance value is the price of repurchase of equivalent items. Repurchase value can be retrieved from the US every 12-15 month. By adjusting the given value with a localisation factor, a final value of repurchase of facility can be used in insurance value calculation.

Other Costs

The two major cost types among *other costs* are harbour costs and environmental costs. The harbour at Mongstad is the largest in North Europe after Rotterdam, measured in dead weight tonnage of the harboured ships. The costs that MRDA has, is reduced since the costs are now shared with MTDA. MTDA (Mongstad Terminal) is a partnership with Petoro where Statoil is the operator and has an ownership of 65 per cent. The harbour also generates incomes due to taxes.

Environmental costs are a significant cost for Mongstad Refinery. Costs in connection with emission permits and waste disposal can be quite significant. Also, investing in pollution

reducing equipment can be expensive; however, there can be savings in pollution taxes if emissions are reduced.

There are of course many more cost types at Mongstad but we will not discuss those in this thesis due to their small significance.

6.6 Cost Controlling Measures

6.6.1 Budgeting

Budgeting is an important tool in deciding tactical and strategical directions on a business level. Budget remains as being a central tool in keeping costs under control and taking actions when the budget deviates from anticipations. Budget offers therefore a diagnostic way of management control. Also, the budget tries to give an overview of activities that are planned next year.

Theory (Jan Bergstrand 2005)

The budget can be formed by starting with the assumptions and then working *top-down*. That is working with a suggested budget from the top management and then changes based on feedbacks from the units. The budget can also be formed by working *down-up* by letting the units hand in suggestions to the top management and then adjusting it.

The matrix below shows how these budget processes can appear in real life. The down-up process starts with the assumptions from the top management (*Man*) and guidelines from the budgeting committee (*Bud.Com*). The budgeting unit (*Bud.Unit*) begins then to make different types of budgets like investment budget, production cost budgets etc. The different budgets are then integrated in the budget committee as well as from the other business units. This gives the final budget that will be presented to the top management. The top-down process is based on a budget setup at the top management level and delivered on to the budget committee for suggestions and the budgeting units for further investigations. The investigations at the budgeting units lead to different suggested adjustments. All budgets with agreed adjustments are then integrated in the final budget.

There exist also other methods like *iterative methods* that rework on both the assumptions and the budget during the entire budget process, but also *combination methods* that combine the direct method of top-down and the iterative method.

Down-Up

Man
Budget

Assumptions

Final

Budget

Bud.Com

Integration

Guidelines

Bud.Unit

Temporary Part-Budget

Suggestions

Investigation
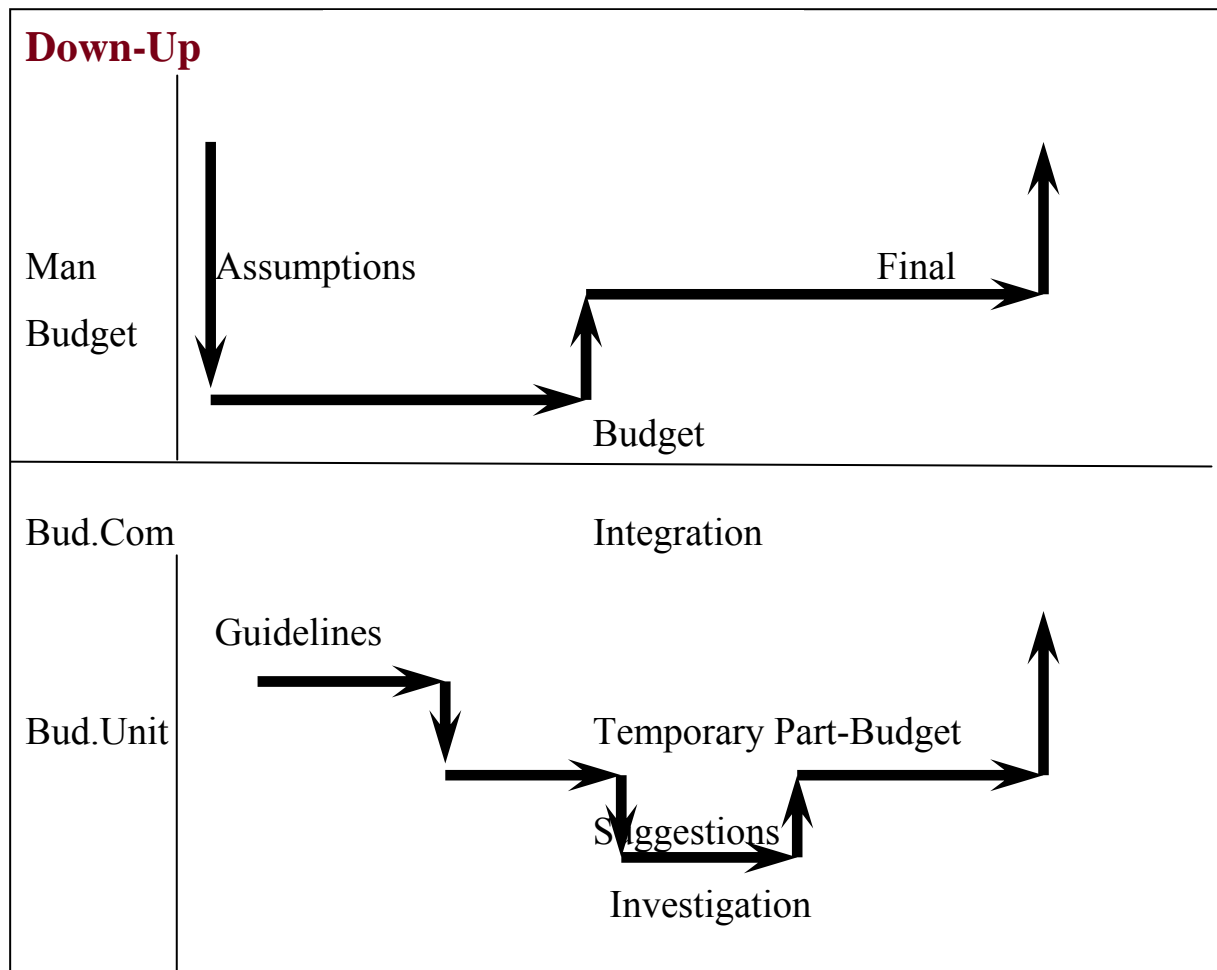
Matrix 2: Different Budgeting Strategies, *Jan Bergstrand 2005*

The choice of budget is based on following aspects:

- Management philosophy

- Level of decentralising

- Profit responsibility

When using a direct method of down-up the basis of choice is motivation and responsibility for the business unit. The budgeting committee has little effect on the decisions in the budgeting process but rather a control unit for the budgeting process and the final budget. The iterative method gives better planning and coordination between the top management and the business unit, however it implies in much work and, in worst cases, reduced motivation among employees in the business unit. A combination method or a direct top-down method will emphasise on what the top management priorities and want to follow-up. The problem with this method can be lack of motivation in the business unit and lack of coordination in the process.

The choice of budget period is important. The choice should be based on what is the strategic nature of the operations. A budget period from summer to summer can be logical for a school in Norway so that the budget follows the school year.

Some budgets are fixed when they have been made but some are revised every given time. Sometimes the budgets are continuously changed when a significant change occur. However, other budget types than the fixed budget will generally imply in more work.

Application

The budgets at Mongstad are based on the long-term ambitions of Mongstad given in plans with a more strategic perspective. Usually, ambitions on cost targets can be over a period of several years and are closely linked to the both financial and non-financial measures in the Balance Scorecard at Statoil[27]. The budgets will reflect on the actual goals that have been commonly settled with Statoil headquarter, and give the user an overview on how much of given resources are needed to reach the short term goals and thereby the long term ambitions in different fields:

- Operation investments.

- Production volume.

- Operation costs.

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[27] See the chapter on Organisation for further elaboration on the BSC and the BRA system at Statoil.

Operation investments can be divided into two main groups: modifications and new investments. Modification is, roughly speaking, an upgrade of existing equipment of different size. All prioritised modifications must be reported in from each of the sections at the refinery to the management with a given ranking. New investments are sometimes made, like installing a new module on the existing installation, and they are often large projects in terms of costs and other resources. These projects must have detailed project description and a rough profitability analysis. All the investment suggestions must be delivered to ØPA (Finance, Plan and Analysis) and RFU (Refinery Business Development) will make a total investment plan.

PPL (Production Planning) is responsible of making a realistic production budget (more detailed and short term) and plan (more strategic perspective and long term). With inputs on the installation conditions for production outlook, and input from the Vestprosess and Shell contractual conditions, the production budget can be formed. Also, PPL must make a superior (not detailed) production plan with a time horizon of 5 to 10 years. This superior production plan will incorporate the effect of future planned or possible investments. Both the production budget and production plan must be delivered to ØPA.

All sections of the refinery must give feed back on operations costs and the activity of their own section for the current budget. The purpose is to track permanent and temporary changes in patterns regarding to man power and other recurring costs. By using this information, a tentative budget for next year can be made with the different rough estimates of time prices. One moment of caution is that Mongstad has a task focus on costs and not regarding to type of cost. So the costs are measured and controlled regarding to each task. Information concerning operation costs must be handed to ØPA.

The budget process at MRDA is most likely a top-down type of budgeting. The budgets are made in the business units within given budget frames from Statoil central, and then given to the budgeting committee called ØPA where the budget is integrated and passed on to the top management for approval. The budget must also be approved by Statoil centrally as well as Shell (partner). The budgeting year is from the beginning of the year to the end of the year. However, the budget process starts already in June with budgets from the different units. The suggested budget is then ready in September. In the months from October to December the approved budgets are a basis for detail planning for the different units. The use of fixed

budgets is used. In addition, quarterly prognosis is used to update changes in the economic environment.

The controllers at Mongstad have the responsibility of making sure that the budget aims are secured and reporting to both local and central authorities in the Statoil system. The Mongstad Terminal (MTDA) has its own controller as well as Mongstad Refinery (MRDA). The Mongstad terminal controller has the resource responsibility in MRDA and task responsibility in MTDA. All are members in the financial network in Statoil Corporate that gives support.

These two controllers report to the controller for the entire Mongstad unit. The controller for Mongstad must then, with controller for Vestprocess (VPDA), report to the division FOR (Processing). These controllers must all report hierarchy to their superior. In addition, they give and get support to/from the local finance units and their finance directors.

6.6.2 The Balance Scorecard and BRA System for Controlling Costs

Balance Scorecard is a more appropriate tool for connecting strategy with the daily activities than ordinary budgeting activities. With focus on both financial and non-financial aspects, it can pick up elements that the budget does not integrate. We will not be elaborating the BSC-model in this chapter since we will go in-depth in the organisation structure chapter.

The BRA (Better, Faster, Administration) system at Statoil implements the BSC-model. Each unit have their own scorecard on the intranet with selected KPIs, updated monthly.

These measures can be financial like ROI[28] (Return on investment) that are updated continuously as new figures arrive. By being an important management tool, the managers increase their focus on the financial aspects that are important and by such increasing their focus on costs. Also, with an incentive system connected to results of the selected measures, there is increased motivation to get more focus on costs, for instance, because an increased ROI by reducing costs will potentially give bonuses (simplified). At Mongstad the

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[28] Profit / Investments

investments are measured to repurchase value when using ROI. However the main tool of measuring financial performance is ROCE[29] (Return on Capital Employed).

Balanced score card allows the unit to focus on the totality, not only costs, and to follow up trends.

6.6.3 The Solomon Benchmark

The refinery industry is more or less a standardised industry located in the middle of the petroleum value chain. Keeping costs and other important economical aspects like regularity at an unfavourable level can be dangerous since they will reduce the net profit of the refinery. To keep the competitive level high many refineries hand in information that, otherwise is confidential, to the Solomon benchmark which ranks the refineries in different areas.

The Solomon benchmark is released every second year. The Solomon ranking system is divided into four quartiles where the first quartile indicates the refineries in the best group while the fourth quartile is the refineries that perform poorest. However, different types of refineries are not put in the same analysis when comparing. Some refineries have conversion capacity while some do not. This and some other things are adjusted in the ordinary Solomon benchmarking when making a competitor analysis.

Mongstad is ranked as a refinery with high operation costs due to high labour costs. However, the high regularity in production puts them among the best in production efficiency. The energy efficiency at Mongstad is low compared to Statoil refinery at Kalundborg, most because of the fuel gas that Kalundborg can sell to its neighbours. The Solomon benchmark also tries to measure the "net cash margin" based on the production volume reported. However, the reported figures can be direct misleading due to some of the volume is imported/exported and misreporting of volumes occurs.

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[29] Profit before interest costs and taxes / (total capital – interest free liabilities), Source: Iver Bragelien 2005

Benchmarking like the Solomon will remain to be an important tool to measure the competitiveness of the Mongstad Refinery and thus being a basis for actions to improve cost performance.

7. Supply chain analysis

7.1 Introduction

We have up to now presented to you different aspects of refining from an economic perspective. Competence on pricing, costing, production and organisation is essential to be successful in the refining business. However, to produce most value for the customer at least cost requires an efficient supply chain that responds to changes in the market adequately. By performing well in all these fields, Mongstad refinery can keep and even increase its business profitability. We will in this final chapter bring you to Statoil Mongstad's supply chain. The knowledge and understanding that we together have built up in previous chapters will be useful in analysis.

7.2 The Theory of different Supply Chain Strategies

The theoretical reasoning for integrating the supply chain is mentioned by Simchi-Levi et Al (2003) as improving performance by *reducing costs, increasing service level, reduce bullwhip effect, better utilise resources, and effectively respond to changes in the market place*. Strategies must be customised for the type of products and the supply chain structure. There are three different main strategies noted:

- Push-based supply chain

- Pull-based supply chain

- Push-pull supply chain

In the *push-based supply chain*, long-term forecasts on production and distribution are used in decisions. This is why it takes longer time for such supply chain to adapt to changes in the market conditions that can lead to problems in meeting demand and thereby obsolescence of existing inventories. Also, the well-known *bullwhip effect* where order variations are much higher than the demand variations lead to costs in connection with excessive inventories due to need for larger safety stocks, larger and more variable production batches, unacceptable

service levels and poorer resource utilisation due to higher variability in serving the demand. This higher variability also implies an increased transportation costs. However, the push-based supply chain gives opportunities in making the supply chain more effective for instance by lean management (due to economies of scale) to cut cost in every parts of the supply chain since it is not required that the supply chain must adapt to a fast moving market.

In the *pull-based supply chain*, production and distribution decisions are based on the true customer demand. In an ideal pull-based system there is no or little inventory since the production and distribution follow the demand. Such systems must be heavily supported by information systems for customer demand like POS (point-of-sale data) to the supply chain members. This strategy can be very attractive due to decrease in lead time because of better anticipation of arriving orders which in turn give lower required safety stocks at retailers and manufacturers. By having an agile supply chain that responds fast to market changes the bullwhip effects can be reduced. However, the pull-based strategy implies in heavy investments required in information systems to supply the whole chain with real-time information throughout the supply chain. In addition, if the lead-time is very long it can be difficult to implement a pull-based strategy due to difficulties of reacting to the demand information.

The *push-pull supply chain* strategy tries to use the advantages of both the strategies. The concept is to have a push strategy up to appropriate point then apply a pull strategy to the end-customer. Roughly speaking, this implies in forecasting production and distribution up to a point in the supply chain then turning to production and distribution based on the specific customer request. The result is that a lean strategy can be applied in the first part of the supply chain to make the chain much more resource efficient, and then an agile strategy can be used for second part of the chain to increase responsiveness to customer requests. The bullwhip effect will be reduced from the *push-pull boundary* to the end-customer since in this part the supply chain will try to follow the customer demand. In addition, the use of aggregated forecasts for raw material from raw material production to push-pull boundary will reduce the bullwhip effect in this part of the chain too since aggregated forecasts are more accurate and thereby lead to less required safety stock. The push-pull strategy is often applied in the case of delayed differentiation, also called *postponement*, where there is a *decoupling point* that separates the push side of the chain from the pull side of the chain. Up

to the decoupling point, the raw materials are produced and separated into different components. When the customer's request arrives then final product is made at the decoupling point and distributed to the end-customer. Such a strategy will also add flexibility in meeting the customers by customising the final products to their needs.

	Push	**Pull**
Objective	Minimise costs	Maximise service level
Complexity	High	Low
Focus	Resource allocation	Responsiveness
Lead time	Long	Short
Processes	Supply chain planning	Order Fulfilment

Table II: The difference between Push and Pull, Source: Simchi-Levi et Al (2000)

The choice of appropriate supply chain is based on industry and products. Simchi et Al have generalised the problem of choice by demand uncertainty and importance of economies of scale. High demand uncertainty gives a preference for realised demand and thereby a pull strategy. While a low demand uncertainty lets supply chain members to use long term forecasts. A similar trade-off applies for economies of scale. If economies of scale are important then the value of aggregating demand and long term forecasting will be of larger value, and thus calling for a push-strategy as an appropriate solution. Following matrix illustrates the point:
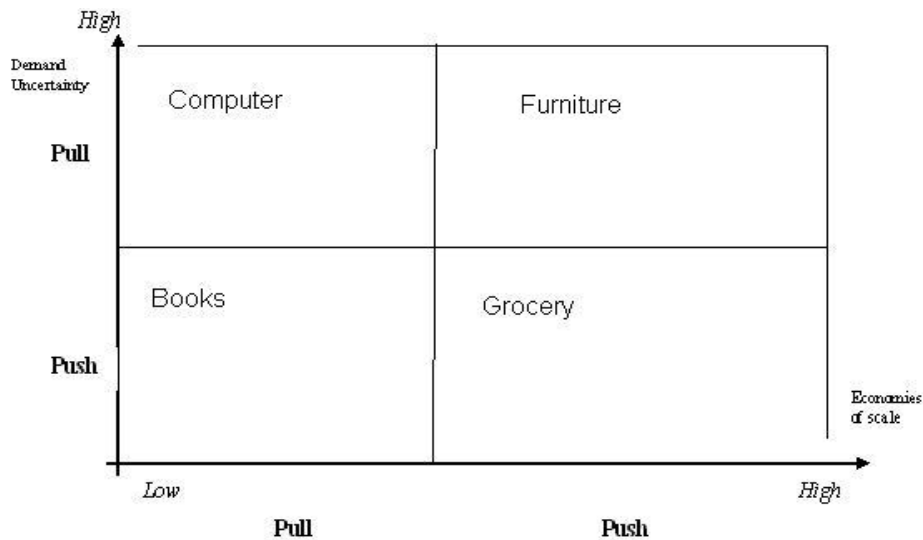
Figure 72 The Choice of Supply Strategi. Source: Simchi-Levi et Al (2000).

Highly specialised computers have a high demand uncertainty due to the fast technological development, and the economies of scale have limited importance since advanced computers often have to be customised to the different customers. The suitable strategy would then be a pull-based. For books that have no risk of getting outdated, the demand uncertainty will be much lower. However, the economies of scale would be less important due to each particular book title is produced in small volume to satisfy a certain demand. A mix may be suitable in this case. Groceries have demand that is quite more certain since the products are of importance for the customer and the product properties changes little over time. Thus the demand uncertainty is very low. In addition, the products are homogenous and produced in large volumes so the economies of scale can be large. A push strategy may be appropriate here. Furniture products (for instance IKEA) can be produced in high volume regarding to similar components but the demand uncertainty for each product can be larger since the manufacturer do not know the customers' preferences in shape, colour etc, for instance, on their chair of choice.

Raw materials like crude oil are produced in large volumes so the economies of scale can be large and so is the case for most of the finished petroleum products but at a smaller extent. However, the demand uncertainty can be high due to a supply chain with long lead time (more than one month in most cases, see *pricing structure*) and supply interruption due to

production stop at oil fields and refinery centres, or risk of war in oil reserve areas like the Middle East. For such supply chain a push-pull strategy may be appropriate.

7.3 Introduction of different supply chain models

With volatile crude prices, excess refining capacity and fluctuating demands and prices for different products, refiners are looking for new approaches to manage their business to profitability. Supply chain management provides an immense opportunity for organisations to reduce costs and improve performance, and hence contributes to added value. A number of models have been designed or developed in order to help organizations in improving their value chains. In this section, we will discuss two of these models.

Value Chain Operations Reference (VCOR) model[30]

The VCOR model was introduced to us by Stein Erland Brun from Statoil P&L. Although Statoil is not a member of the Value chain group (VCG), Stein suggests that this is a useful model.

The Value Chain Operations Reference (VCOR) model is described as a framework designed to improve Value-Chain performance. The VCOR model provides to the value chain group members a common terminology and standard process descriptions to order and understand the activities that make up the value chain. The model also helps companies use benchmarking and best-practice information to prioritise their improvements, quantify the benefits of implementing change, and to pursue specific competitive advantages discovered in the process. The VCOR model can also provide to members or organizations an opportunity to see their entire value chain in a form to compare with other companies across multiple industries. As Statoil is not a member of the VCG and we consequently have no access on VCOR information, it is not easy to comment this model.

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[30] From the value chain group website: www.value-chain.org

Value Chain
A sequence of highly structured organizational processes and partners to create, produce and deliver a product or service satisfying customer and market
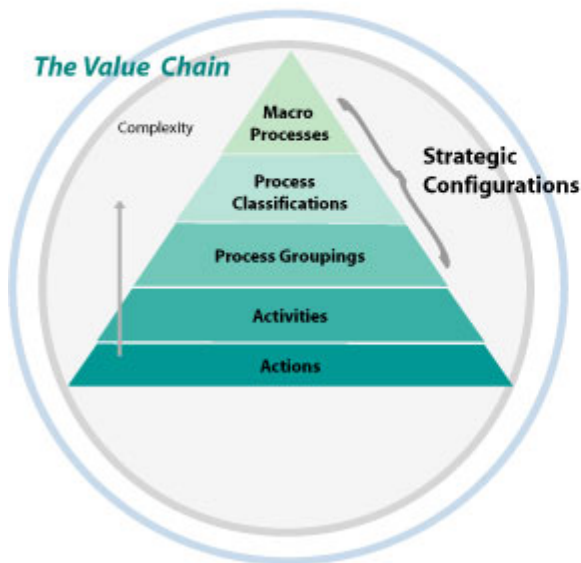
Macro Processes
The macro business processes of an Enterprise

Process Classifications
Process classifications that express context as a subset of the company's macro processes.

Strategic Configurations
The level where specific process groupings are assigned to an applicable business strategy.

Process Groupings
The lowest generally applied level of the framework. Process Groupings are general process that contain specificity to establish a link between enterprise specific activities.

Activities
A decomposition of a VCOR process groupings, each activity is specific to an enterprise that may or may be shared among partners.

Actions
Individual work instruction item. Cannot be decomposed.

Figure 73 The structure of the VCOR model. Source: http://www.value-chain.org

The VCOR model has six levels of hierarchy. From bottom to top, there are actions, activities, process groupings, strategic configurations, process classifications and macro processes. The level and magnitude of process details, and hence the complexity, increases as we move from the top to the bottom.

The Supply-Chain Operations Reference-model (SCOR)

This model is included in this section since Statoil has performed two pilot case studies based on SCOR. The case studies were not related to Mongstad but to some up-stream supply-chains. The supply-chain operations reference-model (SCOR) is described as a process reference model that has been developed and endorsed by the Supply-Chain Council as the cross-industry standard diagnostic tool for supply-chain management. SCOR enables users to address, improve, and communicate supply-chain management practices within and between all interested parties. The SCOR-model has been developed to describe the business activities associated with all phases of satisfying a customer's demand. By describing supply chains using process building blocks, the Model can be used to describe supply chains that

are very simple or very complex using a common set of definitions. As a result, disparate industries can be linked to describe the depth and breadth of virtually any supply chain. SCOR is a management tool. It is a process reference model for supply-chain management, spanning from the supplier's supplier to the customer's customer. A process reference model integrates the well-known concepts of business process reengineering, benchmarking, and process measurement into a cross-functional framework. SCOR model is based on five distinct management processes: plan, source, make, deliver and return.
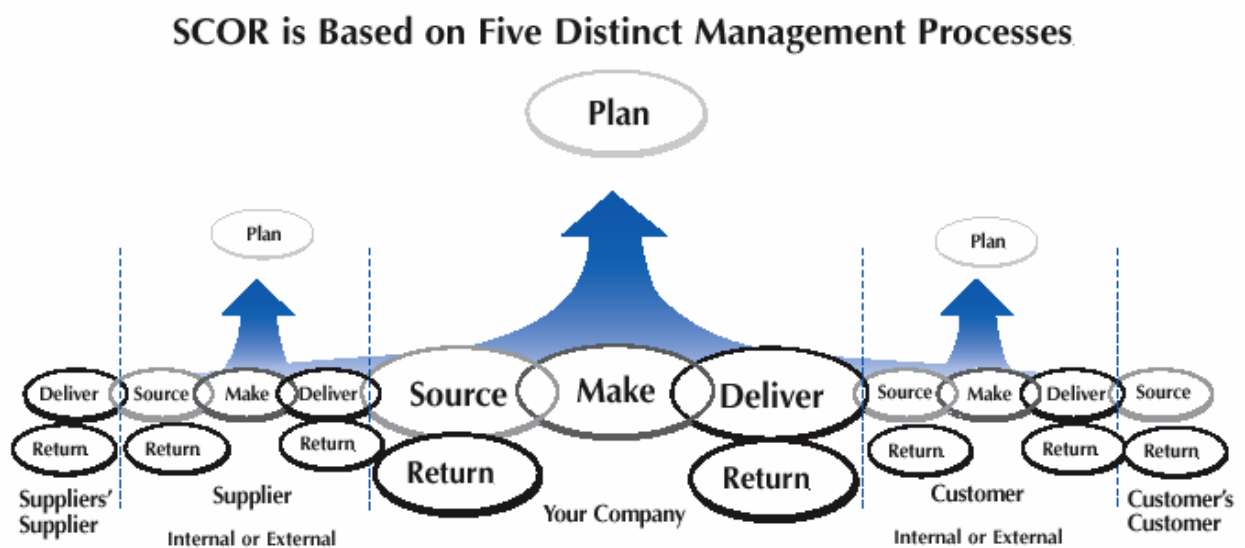
Figure 74 SCOR's five management processes   Source: SCOR Version 7.0 Overview

The five distinct management processes are also called generic processes:

- Plan: includes processes that balance aggregate demand and supply to develop a course of action that best meets sourcing, production and delivery requirements.

- Source refers to processes that procure goods and service to meet planned or actual demand

- Make: processes that transform product to a finished state to meet planned or actual demand

- Deliver: processes that provide finished goods and services to meet planned or actual demand, typically including order management, transportation management, and distribution management

- Return: processes associated with returning or receiving returned products for any reason. These processes extend into post-delivery customer support

Some generic processes like sales and marketing (demand generation), research and technology development, product development, and some elements of post-delivery customer support are outside the scope of SCOR.

The SCOR model contains three levels of process detail that are shown in the graph below
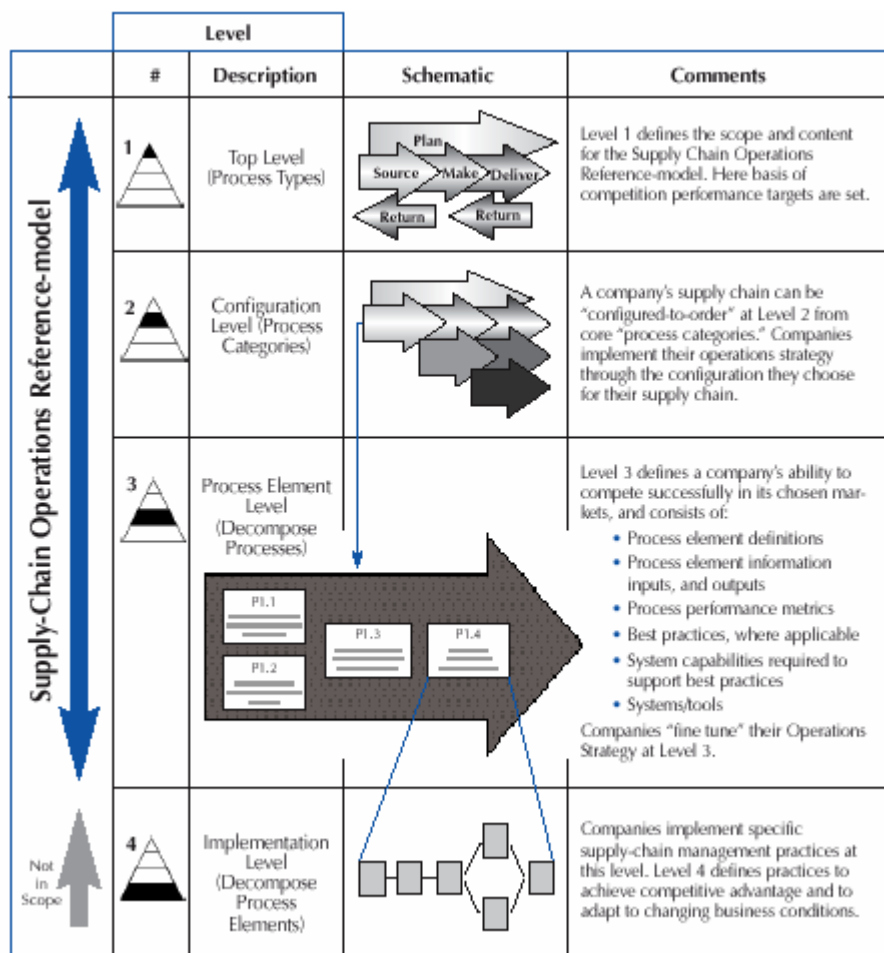
Figure 75 SCOR process levels.   *Source: SCOR Version 7.0 Overview.*

The graph shows four levels. SCOR decomposes the generic processes from the top level (level 1) down to process element level (level 3). At the first level (i.e. SCOR level 1) the model provides scope and content and the competition performance targets for the supply chain in focus. At this level, companies define or choose processes. Level 1 metrics are high level measures that may cross multiple SCOR processes. At level 2, companies implement their operations strategy through the configuration they choose for their supply chain. Each SCOR process at level 2 can be further described by process type. This is shown on the graph by the arrow from level 2 to level 3 under 'Schematic'. Level 3 presents detailed process information for each level 2 process category. The detailed information includes process flow, inputs and outputs, source of inputs and output destination.

The fourth level is not in SCOR's scope. In real life supply chains; there is always a level 4 below the process element level (i.e. level 3). Level 4 consists of process activities. It is the company specific implementations of level 3 for a given supply chain. Level 4 is where best practices are to be found.

In the figure below, Statoil compares its KPI and SCOR's suggested KPI for Maintenance, Repair, and Operations at offshore plants. MRO refers to Maintenance, Repair, and Operations while SC refers to Supply chain.

SCOR level 1 metrics for sourcing consumables and non-critical standard products for MRO at offshore plants · STATOIL

Performance attribute	Importance for this S-C	SCOR's suggested KPIs	Statoil's KPIs Some of which belong to SCOR level 2 or 3
SC Delivery Reliability The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.	Very high	–1) Delivery Performance –2) Fill Rates –3) Perfect Order Fulfilment	% Offshore Deliveries On Time in Full (OT to Cycle Time Limits) Status 200r: 75-80%. Proposed Target: 90-95% % Offshore Deliveries on Time (to Customer Request Date) Status 2004: 45%. Proposed target: 90% % Offshore Deliveries Non-Conformities Status 2003: Measurements not reliable. Poor data quality.
SC Responsiveness The velocity at which a supply chain provides products to the customer.	Medium	–1) Order Fulfilment Cycle Time	Requisition Cycle Time Status 2003: Metric specified and to be implemented
SC Flexibility The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.	Low	–1) Supply Chain Response Time –2) Production Flexibility	None
SC Costs The costs associated with operating the supply chain.	High	–1) Cost of Goods Sold –2) Total Supply Chain Management Costs –3) Value-Added Productivity –4) Warranty/Returns Processing Costs	Total Upstream Logistics Costs – North Sea Benchmarking Status 2002: Rank two of top 10. Target: Regain rank one. Total Transaction Costs for Upstream MRO Products Status 2000 (Tampen Area): 24 Mill. NOK/y Target 2005: 12 Mill. NOK/y % Automated Purchases Status 2003: 44%. Target 2007: 80%
SC Asset Management Efficiency The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Medium	–1) Cash-to-Cash Cycle Time –2) Inventory Days of Supply –3) Asset Turns	Value of Inventory Status 2002 (Tampen Area, all MRO-materials): 500 Mill. NOK. Target 2007: 255 Mill. NOK Warehouse Costs Status 2002 (Tampen Area, all MRO-materials): 80 Mill. NOK/y Target 2007: 41 Mill. NOK/y

Figure 76   SCOR metrics in Statoil. *Source: Statoil P&L 2004*

The above figure (76) shows, at SCOR level 1, the supply chain performance attributes such as delivery reliability, responsiveness, flexibility, costs and asset management efficiency. The importance of these attributes on this type of supply chain is also mentioned. It is classified in four ranges with the highest as 'very high', then 'high', 'medium' and the lowest 'low'. We can see that SC delivery reliability is the most important as is classified as 'very high' in this supply chain. SCOR model suggests the following KPIs: delivery performance, fill rates, and perfect order fulfilment. Statoil's KPIs er % offshore deliveries on time in full (to cycle time limits), % offshore deliveries on time (to customer requested date), % offshore deliveries non-conformities. By comparing SCOR's and Statoil's KPIs, we can see that Statoil KPI's are all on delivery performance and no KPI's on fill rates and perfect order fulfilment.

The SC costs is classified as of 'high' importance. SCOR and Statoil KPIs are different. SC asset management and efficiency and SC responsiveness are classified as of 'medium'

importance but by 2003, Statoil had no KPI in application for SC responsiveness. Statoil has no KPI for SC flexibility that is considered to be of 'low' importance in this type of supply chain while the SCOR model suggests some KPI. The common thing on all metrics is that Statoil by 2003 performed lower than proposed targets.

The SCOR model is potential decision tool support regarding supply-chain design. According to Stein Erland Brun, the model is rich in suggested metrics for supply-chain; however putting these metrics in practice is challenging mostly due to the ability of having valid and reliable data sources.

7.4 Transport

Favennec (2001) discusses different means of transport used in refineries. He classified them in two main groups that are transport for crude oil and transport for finished products.

7.4.1 Crude Oil

As described in the pricing section, many oil production areas are far from the industrialized countries that are the major consumers. Therefore, a large proportion of crude oil must be transported in massive quantities over long distances. Most crude oil buyers have no choice in the method of transport used as that is imposed by the limits of the available logistics system. The most widely used mean of transport available to both producers and purchasers is the marine transport. All North Sea production, the production from most African countries and a large proportion of production in the Middle East is transported by sea. In some cases, the buyer can choose between transport entirely by sea and a combination of marine and pipeline transport. For example Saudi Arabian crude could be shipped to Europe by tanker using the long sea rute around the Cape, or by use of the Egyptian pipeline Sumed linking the Red Sea and the Mediterranean. Prices and costs of transport are considered in the chapters on the pricing and costing.

Marine Transport:

Oil tankers are clssified in three categories according to their dead weight tonnage (dwt) in other words their carrying capacity.

- **VLCCs**: Very Large crude oil carriers are tankers of more than 160 000 dwt. The largest size VLCCS are used for Europe and the United States. In this category there is also ultra large crude oil carriers (ULCCs) that have a carrying capacity between 325 000 and 600 000 dwt.

- **Suezmax**: the carrying capacity of these tankers is between 100 000 and 160 000 dwt. They are capable of transiting the Suez Canal fully laden and they are also used for voyages from West Africa to the Caribbean and the United States and for long-haul voyages from the North Sea Loading ports.

- **Aframax**: The carrying capacity is between 80 000 and 100 000 dwt. They are used for regional movements.

Two-thirds of these oil tankers are owned by independent ship owners. The remainder is owned by oil companies.

Transport by Pipelines:

Pipelines are used as a link in the supply chain and complement marine transport. Operators of pipeline are required by refiners to maintain the quality and quantities of crude oils. A scale of permitted contamination levels between different crudes oils of different qualities must be agreed on between pipelines operators and refiners. Looking at the quantity, the maximum accepted losses are defined in the contract. Pipelines need to be kept in good condition as unplanned shutdowns can be very disruptive to refinery production.

Crude oil storage at refineries:

The terminals have a responsibility of holding crude oil ensuring that the quantity and quality remain constant. Volumes discharged at the terminal must be onforwarded to the refineries with minimal losses. Therefore, the terminals take all practical measures to ensure that losses during storage essentially leaks and evaporation are minimised. The quality is maintained by minimizing contamination between different crude oils. Terminals ensure full segregation of high and low sulphur crude oils.

7.4.2 Finished products (despatch)

Since many countries have refineries that enable them to meet a good part of their own products requirements, there is less long distance shipment of finished products than of crude oil. However, the need to balance product supplies between different regions does require a certain level of product shipments, which are generally made in smaller sized tankers than those used as crude carriers.

Despatch by Pipeline:

Despatch by pipeline is the simplest operationally. It can be effected by equipping a line system with remote controlld valves so that the despatch pump can be started and operation undertaken by simply pressing a few buttons in the control room. However, this despatch can not be used alone due to different factors. Some products cannot be dispached through this mean due to their nature as their high viscosity or their propensity to solidify. Morever, to be connected to a pipeline network reduces flexibility and requires a substantial investment made by a refiner, and managing pipeline programming is very complicated because the network may be linked to several lines in paralel, with product flowing in both directions.

Despatch by Water:

Some refineries benefit from an advantegeous location in that they can despatch products both by inland waterway using barges and by deep-sea going tankers. Barges have a capacity between 1000 and 2000 tonnes of oil products. At Mongstad, 98 % of despatch is done through the mean of ships.

Despatch by Rail:

All products can be be carried by rail. Train sizes vary and depend on the refinery's loading capacity, the depot's reception capacity and the capabilities of the rail network. 20 rail tank cars (rtcs) with a capacity of 1200 t products may be considered as standard.

Despatch by Road

Products can also be dispached from refineries by road loading racks. At Mongstad 2 % of product despatch is done through road trucks.

Transport and Despatch Process:

The process differs from one another due to the method used. However some common check up lists include quality and quantity control of the products, safety and environmental control, and administrative formalities.

7.5 The Supply Chain in the Oil Industry

7.5.1 Description of the Supply Chain

As we discussed in the product life cycle of the petroleum industry in the pricing chapter, we found out that the large oil companies took control of their entire value chain during the years of consolidation in the 80s and 90s. These companies are also called integrated oil companies where they operate in different main activities of the value creation for bringing petroleum products to the end customers. Such integration of the value chain can only be possible for large companies with good financial backbone.

The supply chain connects the supply side with the demand side. Information from the end-customer about their demand should be matched by the supply of products. The supply chain for most products can be illustrated by the figure below. The integrated oil companies most often control many of the steps in the customer value creation. They operate many of the oil fields on the NCS (*development and production*), facilitates the transactions in upstream activities (*Sale, trade and transport*), refines the incoming raw material to finished products (*manufacturing and refining*), facilitates the transactions in downstream activities (*Sale, trade and transport*), and finally, serves the end customer with the finished products (*marketing and distribution)* at pumping stations etc. To make the flow of information in the supply chain smooth appropriate organisation structure, information systems and other infrastructures are needed all the way from the end-customer via the refining centre to the production sites. On the other side, the flow of products in the supply chain from the production sites via the refinery centre to the end-customer must be efficient and highly responsive to changes in demand.

| Development & | Sale, trade and transport | Manufacturing & | Sale, trade and transport | Marketing and distribution |

Push from supply side   **Pull from demand side**

Figure 77 The Supply Chain of an Oil Company. *Source: Sales and Trading Department, Statoil 2005*

The refinery is the push-pull boundary in the supply chain where raw materials are split up in different components, ready to be mixed into different finished products. The refinery is exposed to both push and pull forces in the value chain. While the down stream activities send demand information and pull the products from the refinery, the upstream activities push the flow of goods onto the refinery. One of the reasons that many supply chains in the petroleum industry has a push-pull strategy is due to the fact that many of the refineries have possibilities to blend components to finished products when an order is processed. Then the refineries act as a decoupling point in a supply chain that can use both push and pull strategies. According to Simchi et al, the pull strategy should be used in the part where the uncertainty is highest while the other part should use push strategy to focus on cost minimisation. The upstream activities can be adapted to long term aggregated forecasting used in a push strategy while the down stream activities can be more adapted to the current market demand used in pull strategy. Usually, this means that in a push-pull strategy of an integrated oil company, the inventory of crude oil is usually relatively larger than the inventory of finished products to produce the finished goods when the orders arrive as observed at Mongstad. This is due to the tactical planning of holding a crude oil inventory while the inventory for finished and component goods is mostly due to order fulfilment.

7.5.2 What makes the Oil Supply Chain different?

Anderson (2003) mentions four aspects that make the petroleum supply chain a bit different from other supply chains:

1. Field development costs must go down if marginal fields on NCS will be put in production.

2. Integrated oil companies are getting larger by both mergers and acquisitions. For companies like Hydro, acquiring oil companies on other continents like the America is one way to grow and invest their money.

3. Oil prices vary a lot.

4. Integrated oil companies are often exposed to political pressure.

The case of falling productivity on the NCS and the use of less desirable fields have made it more important to produce efficiently. With the tough competition between the different integrated oil companies for operator licences and doing business within the gross margins, the requirement of cost-efficient supply chain is getting more and more essential for maximising shareholder value and adding value to the environment around the supply chain. Some analysts use the mergers experienced during the 90s (for instance, BP and Amoco) as an example of consolidation to absorb risk better and reduce relative operating costs. However, one should think that there is an upper limit on how large an oil company can get before it becomes too difficult to run, for instance, the logistics and the supplies. Fortunately for the big oil companies, the use of information systems has made it easier to manage the product flow and information flow in the supply chain, thereby making it easier for the integrated oil companies to grow, Anderson (2003).

According to Anderson (2003), the increasing size of integrated oil companies makes their buying power stronger. Also, they can to a much larger extent choose to integrate specific suppliers or base their procurements on reverse auctions if they wish so. While Statoil, in general, has chosen to integrate its suppliers in a much larger degree to its supply chain on several areas, Hydro Oil & Energy is more focused on the suppliers keeping the costs under

control. This is maybe the reason that many of Statoil's projects have exceeded cost estimates while Hydro's projects are mostly on budget[31]. Anyhow, the size of the integrated oil companies has given them the opportunity of taking charge of the supply chain. The supply integration challenges have been solved in different ways and Eric Anderson has noted following aspects, with some modifications and additions:

- An activity is outsourced to a main contractor, which buys on behalf of the oil integrated company from the suppliers. This is especially the case where the integrated oil company does not have the special competency on the given field. Such an example is Kværner Subsea solutions that will be used in the Statoil's Snøhvit field. The problem is that the contractor may not have the incentive to push the suppliers on prices. This makes it important for the integrated oil company to frame agreements with the contractor so that the contractor has less room for agreeing terms with suppliers that are not in the interest of the integrated oil company.

- Suppliers often have a contract with the integrated oil company to engineer, procure, install and commission a given unit. However, the service costs of these units can be expensive since only the supplier has the competence of the servicing it. This gives the supplier a larger bargaining power. By integrating the operator (here: the integrated oil company) in the development and implementation processes of the supplier, the bargaining power of the supplier can be reduced as well as the operator can build up important competency, Anderson (2003). Building up competency is also important when the government decides on which companies will get the different licences for production on the NCS. However, by taking over more control of the supply chain will in turn imply in higher risk for the integrated oil company. This is a trade-off that the integrated oil company has to consider when applying different supply chain strategies.

- Less opportunities of differentiating for the suppliers and contractors due to more interaction with the integrated oil company have made them relied on other

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[31] (Thorbjørn Sjøholt (Trainee Statoil Procurements 2005) and Debasish Sahabanik (Summer Intern Hydro Oil & Energy 2005))

competitive edges. Contractors and suppliers are now competing on project execution time to make themselves an attractive partner for the integrated oil companies. Shorter project execution time implies in less costs for operator due to less rental days on infrastructures and equipment, and other costs of delay.

- The implementation of information systems all through the supply chain has helped integrating the suppliers and contractors more to the integrated oil company. The project execution time has been reduced, the flow of products has improved and the demand is better matched by the supply chain.

- The suppliers themselves try to sell higher volumes to fewer customers. One way they do this is to contact the oil integrated company directly rather than a contractor, and try to establish a long-term relationship.

- The globalisation has also affected the supply chain by outsourcing more of the activities to low-cost countries. Information systems are sometimes developed in low cost countries as well as IT-support. Equipment is more often made at a lower cost in such countries.

So far, we have presented the trend in supply chain on the NCS. The oil integrated companies are also experiencing other challenges than supply chain integration. The problem of today's supply chain of these companies is that it is near full capacity utilisation on many levels of the chain. The general supply of refined products has difficulties to match the demand. There are little spare capacity on production and transportation in the upstream activities where the production has moved towards more of the less desirable heavy and/or sour crude oil, the drilling rig capacity of the world is at a full level, and the tanker transportation system has tankers that are busy. In the downstream activities, the refining capacity is used to full extent. New upgraded refineries are planned in North America to combat the lack of refining capacity as well in other places of the world. Nevertheless, the main problem of the supply chain of today is that it has difficulties to facilitate a product flow that meets the world demand.

7.5.3 Supporting tools in a refinery

In a supply chain of a refinery business, there are a big number of different tools used such as trading software, simulation packages and many more (figure 78). As these tools are beyond the scope of this study, they are not discussed in details in this work. However, they are mentioned due to their important contribution in making a good supply chain. The following graph shows the important components of the refining business supply chain and the interplay between them and different tools.
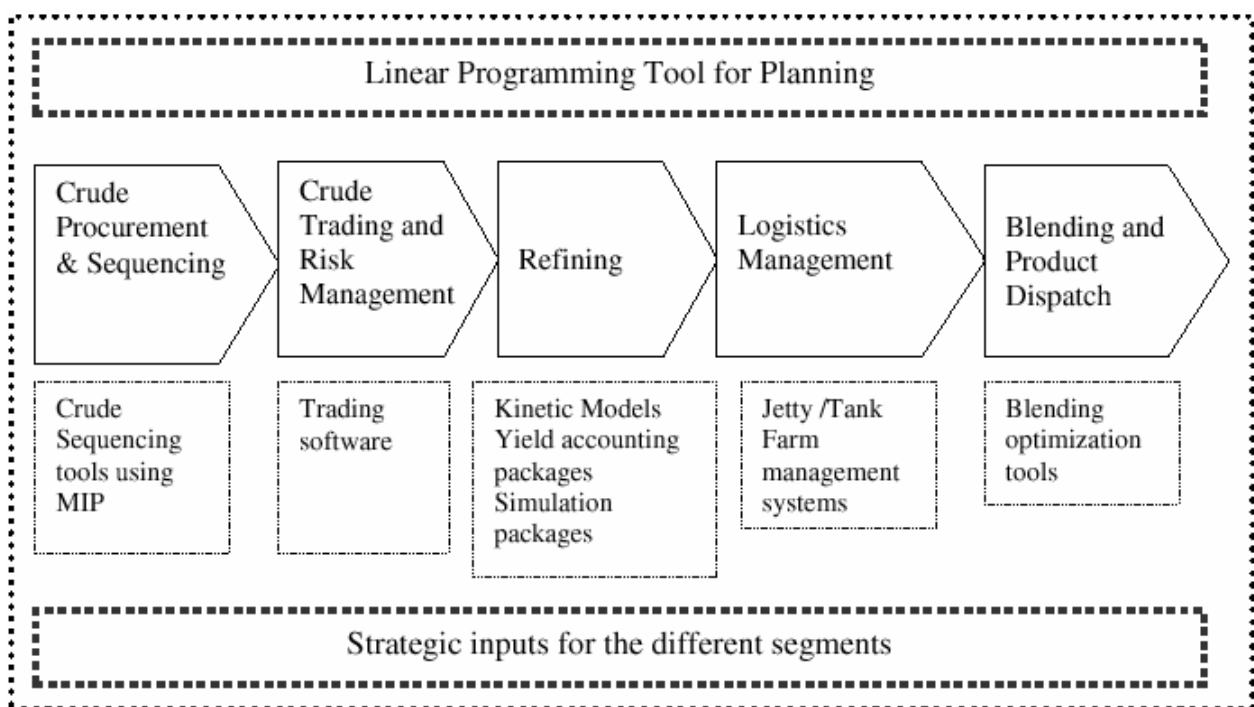
Figure 78 LP tool for Planning in a refinery. *Source: Balasubramanian*.

As it is shown on figure 78, there are many different tools used in each component of the refining supply chain. According to Balasubramanian, the major challenges in this kind of supply chain are the integration of all these packages with trading software and with transaction tracking packages like SAP. Hence, he argues that even considering the benefits of LP model and scheduling tools, the disconnection between the kinetic models, yield

accounting packages, trading software and the LP does leave some room for making the supply chain more responsive and headed in a single focused direction.

Freyman and Brumbaugh (2005) state that computer-based technologies can enhance the quality of refinery monthly schedules; however, they are no substitute for an inclusive and comprehensive scheduling process that promotes well-reasoned interpretations of scheduling model results. They argue that some of the key organizational characteristics leading to successful refinery scheduling are that all stakeholders contribute with meaningful participation. Participation in the process focuses on value-added activities, and technical ability is carefully blended with intuitive knowledge. In this context, stakeholders are referred to as individuals and groups within the entire company who are affected by the final product from the scheduling process. This is a broad definition and, for many refineries, the optimum number of participating stakeholders is more than those who actually participate on a regular basis. That is, the involvement across an organisation may be narrow or focused. Although one group may lead a task within the process, several other groups are frequently needed in support roles for the same task. Also, a more broadly supported effort is frequently required for certain roles than many refiners seem willing to invest. The backgrounds of the stakeholders participating in the various roles are varied, but this is usually helpful in synthesizing a schedule from a system that has high calculation accuracy but difficulty developing repeatable and relevant guidance.

Balasubramanian argues that an important characteristic of the refinery scheduling process is that it is both continuous and repetitive. It is continuous because programs must be adjusted as refinery operational changes and major pricing changes occur. It is also repetitive since new production programs must be generated every month. Non-linear relations are mainly caused by multiplication of quantity and economic variables. Balasubramanian also states that in downstream oil industry, planning and scheduling are resource-intensive, complex, rolling processes as decisions are taken at different stages within the supply chain and at different levels in the management hierarchy. Aligning each step of this complex process is critical to competitive advantage. At the strategic and global planning level for a network of manufacturing plants, decisions have to be taken on feedstock procurement and distribution, utilisation of production capacities, utilisation of modes of transport and demand allocation. Not only existing capabilities have to be considered, but also new opportunities in all areas

have to be evaluated. At Mongstad, new opportunities are considered in the monthly planning by considering future projects.

Julka et al (2002) state that the integration of planning and scheduling processes requires information from multiple sources such as expected stocks from previous planning cycles, expected product demands, ship arrival information, jetty and tank availability, etc. Often, the plan and the actual operations develop lags due to unaccounted events and human factors, which are not usually considered while developing the planning systems.

As a refinery business has many sub-processes, refineries need an integrated supply chain to achieve a competitive advantage in the current, dynamic business environment. Therefore, a need for taking integrated decisions based on the entire supply chain is hence obvious. However, according to Julka et al (2002) an attempt to represent the entire refinery business process comprising all the sub-processes is still missing.

7.6 An Introduction to the Supply Chain of Statoil

7.6.1 The Supply Chain Organisation

The supply chain of Statoil is organised what is typical for an integrated oil company. Each stage of the supply chain is organised in separate division or department. This is illustrated in the figure below. The division for *Exploration & Production* has the responsibility of finding and producing crude oil and natural gas from the NCS. Other production fields in the world are placed in a separate division that handles international business, called *International Exploration & Production*. Note that the production of natural gas has its own division called *Natural Gas*. The department for *Oil Sales Trading & Supply* in the division for *Manufacturing & Marketing* at Stavanger has the responsibility of getting raw material to the refinery. The refineries that are located in the Statoil value chain are Mongstad, Kalundborg and Pernis. The finished products must then be sold and transported by the product department of the *O&S* unit. The department of *Nordic Energy* (also in the *Manufacturing & Marketing* division) then distributes the oil products to different places in the Nordic market by using different storage facilities as distribution centres. By operating 15 oil terminals, 140 distribution centres (where as 50 of them are connected to airports in

Northern Europe) and 500 road tankers (www.statoil.com). *Statoil Retailing AS* runs all the Statoil retail stations and is also engaged in a partnership with Ica, a Swedish supermarket chain, in a separate retail concept to increase the product assortment. However, *Statoil Retailing* is separated from the Statoil Group as a more individual and autonomous from the parent company since it is not instructed from the corporate level on organisation, management control and strategy as the other divisions. For instance, the bonus system for employees deviates from the Statoil Group.

In the entire value chain, there are several suppliers adding to the product value. External suppliers can be suppliers of raw material, services, equipment or infrastructure. Integrating these suppliers can be challenging work due to the high number of suppliers and the long supply chain regarding to both time and geographical area[32]. Also semi-finished products are sold to customers. According to Statoil Sales and Trading department, crude oil and natural gas can be sold to other market players. The supply chain is therefore more like a network rather than a streamlined supply chain. Also, the use of transhipments is seen to make the supply network more flexible to shorten lead times to customers and improve service levels. It is common that crude oil is transported in from other supply networks or to other supply networks from Mongstad, Skjøhaug et al (1997). Also the different distribution centres (storage tanks) in Norway are used to level shortcomings in supply of refined products. That is, transportation of products from distribution centres to distribution centres, (Statoil Sales and Trading Department 2005).

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[32] Debasish Sahabanik Summer Intern Hydro Oil & Energy 2005
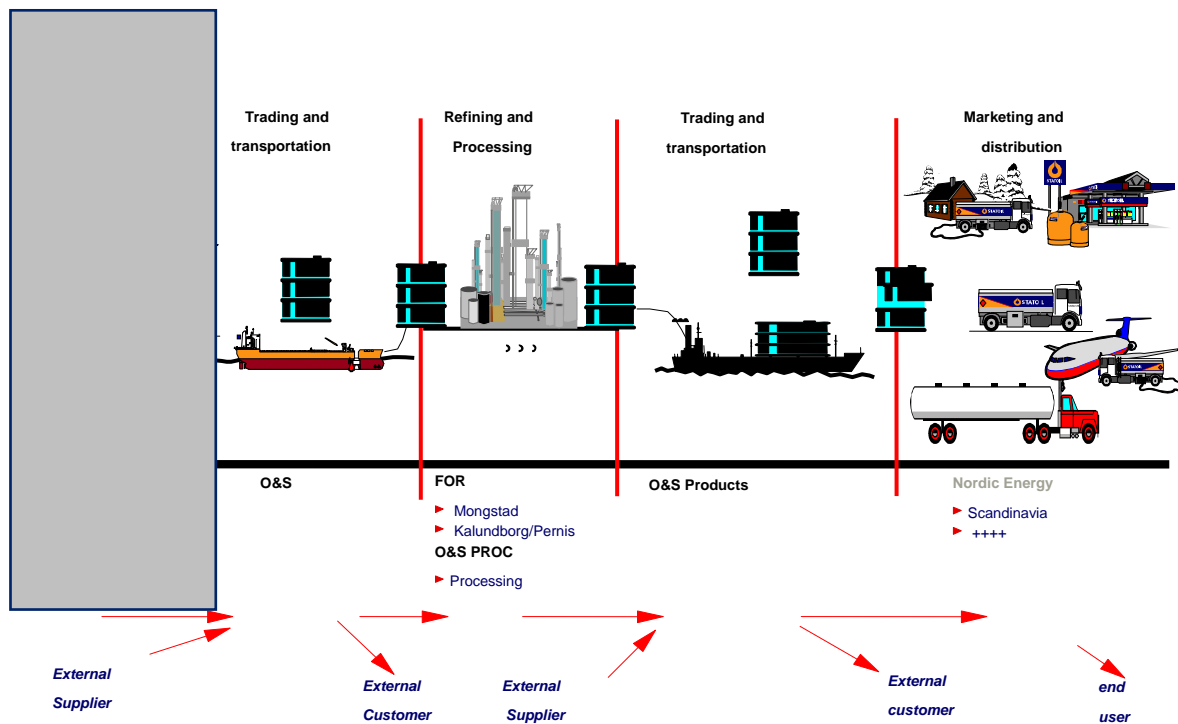
Figure 79 The Supply Chain of Statoil from an Organisational Perspective.
Source: Statoil Sales and Trading Department 2005

7.6.2 Postponement

The concept of delayed product differentiation was first introduced in the marketing literature by Anderson (1950). Several more recent papers have developed analytical models to explain and quantify the operational benefits of delayed differentiation. Postponement can occur along the entire supply chain, from sourcing to final distribution. The concept can be applied to a minor or major share of the operations in the supply chain.

In applying postponement, firms can customise and localize products according to customer demand and local market circumstances from a vantage point close to the market. This enhances the efficiency of various operations, as they avoid uncertainty about the specification of orders and order mixes. The company can cope with complexity without having to lower product variety. Besides customizing postponed operations, those activities that are not postponed can be run in a mass production environment, thereby maintaining efficiency. Companies can then finalize the output in accordance with customer preferences and even customize their products. At the same time they can avoid building up inventories

of finished goods in anticipation of future orders. Moreover, transportation between warehouses and factories can be avoided by shipping products directly to the customer rather than keeping them in stocks. The general notion of postponement has also been studied from different perspectives. It can explain great variety of notions.

Postponement is a strategy that attempts to reduce the risks associated with this product variety by exploiting the commonality between the items and by designing the production and distribution processes to delay the point of differentiation, wrote Aviv (1999). Ernst and Kamrad (2000) considered postponement as a value added process for a set of end products whereby the common processing requirements among them is maximized. The customized, or unique processing requirements for each product variety, are delayed/postponed as much as possible in the value added process. This provides scope for exploiting scale advantages without compromising the variety of products (scope advantages) from a process design approach. For Hoek (2001) postponement means delaying activities in the supply chain until customer orders are received with the intention of customizing products, as opposed to those activities in anticipation of future orders.

Mongstad refinery applies a postponement strategy in that it delays the blending activity. The refinery stocks components rather than blended products. Components are blended together to make various products right before shipping them. This particular characteristic makes Mongstad a component refinery. This has different advantages such as increased flexibility in meeting demand; reduce the risks associated with blended products, etc. For instance, in the gasoline market where different countries have different requirements on gasoline properties, blending the product when a ship arrives is a much cheaper and time efficient. Previously, refineries could produce the order in batches. This could imply, in high set-up, costs and waste of time. By being a component refinery, a continuous production is applied.

7.6.3 Decision-making

The refinery business involves different tasks such as crude procurement, logistics scheduling, storage scheduling and crude purchase, production planning, refining,

production control, products despatch etc. All these activities process large amounts of data and require interaction between different departments. Hence, as we have seen at Mongstad in the planning section, decision-making is distributed across various departments in a refinery and outside the refinery. According to Julka et al (2002) each department solves sub-problems, but local improvements do not necessarily assure that the overall process is moving towards the optimum. Sometimes, the departmental objectives can be conflicting, and thus all decisions do not contribute positively to the overall performance of the refinery. Lasschuit and Thijssen (2004) assert that these decisions differ in scope, time horizon, data certainty and accuracy, process detail and optimising mechanism. These decisions impact the overall economic performance of the refinery. Decisions taken in these tasks are normally based on business policies and guidelines, and with the help of support tools such as linear programs (LPs). At Mongstad as in any other refineries tasks are divided in different departments as it is seen in the organisation chapter.

Julka et al (2002) say that crude procurement process varies from refinery to refinery. The crude procurement process in a refinery provides an illustration of the integrated nature of the refinery business. It involves several departments. **Wiig (2001) states that procurement of goods and services constitutes more than 50 per cent of an oil company's costs.** Efficient and optimal crude procurement largely determines the profitability of a refinery. Julka et al (2002) discuss that crude procurement has a direct impact on refinery profits; a crude stock out would necessitate unit shutdowns and must be prevented under all circumstances. The above makes crude procurement one of the most important business processes in a refinery. They also say that scheduling of processing equipment, storage tanks and transportation related facilities is also strongly linked to the crude procurement process. Uncertainties in the choice of logistics and ship arrivals also impact the crude planning process. Therefore, they conclude that crude procurement is a highly complex and multi-faceted process towards the single objective of making more profit. However, at Mongstad, decisions around crude procurement are beyond the refinery's decisions as these decisions are under the O&S responsibilities as seen in the organisation structure.

At Mongstad, crude selection and purchase is done based on the recommendations of the monthly plan performed using the PIMS model. Julka et al (2002) say that the amount of crude purchased in each time is an important decision for a refinery, and this amount would be based on the present inventory, schedule of crude arrivals and demands for the products.

At Mongstad, as we have seen in the production chapter, crude oil purchase is determined through PIMS model, which does not take into account crude oil inventory levels. Neither, does the PIMS model take into account components products' inventory at place; this makes the monthly plan performed through this model independent of present inventories. The physical inventory of intermediate and component products is taken into consideration by the scheduling section of Statoil Mongstad.

Crude refining is also a process that involves several departments in a refinery. For instance, one crude mix can yield different qualities and quantities of products depending on the cut points, blending and other process parameters. Variable crude prices, crude availabilities, product prices and product demands must be matched to achieve an optimum combination of crudes purchased and crude mix refined. To perform these tasks effectively, there is a continuous collaboration between the planning department and production area from Statoil Mongstad and O&S from Stavanger. Products blending and despatch are performed by Statoil Mongstad based on customer contracts contracted by the O&S department.

The ability to handle demand fluctuations is also a key to economic performance. Simichi-Levi et al (2003) argues that the ability to respond to customer requirements is the most basic function of supply chain management. This function includes not only the physical attributes of product distribution, but also the related status information and access to this information. Simichi-Levi et al (2003) also affirm that in today's customer driven market, it is not the product or service itself that matters but the perceived value to the customer of the entire relationship with the company. The ability to offer what a customer wants and need is a basic requirement to economic success. However, The refinery at Mongstad has no direct contacts with customers as production targets, **planning and scheduling processes at Mongstad** are based on customer contracts and product demands estimated (or contracted) by the sales department (O&S).

As we have seen in the organisation chapter, Statoil is an integrated company. Although procurement and logistics of other materials is performed by Statoil P&L, crude oil procurement, crude trading, risk management and products selling are under the O&S department. Physical inventory management are performed by Statoil Mongstad. As, all decision-making centres do not totally belong to Statoil; an interaction with other external

parties is inevitable and crucial to the profitability of the refinery. Some of external elements in a refinery supply chain are oil exchange, oil suppliers and logistics providers.

The figure 79 shows also how the O&S department plays an important or crucial role in the refinery's decisions. Thus the refinery's profitability (margin) would mainly depend on the O&S performance as main decisions around crude oil and finished products is outside the refinery namely under O&S responsibilities. The refinery itself has a responsibility on decisions of every day running its activities.

7.6.4 Overview of the Information Flow

To make the flow of information and products smooth and efficient, the supply network is heavily supported by different information systems. Some systems are common for all activities on the NCS (especially in upstream activities) while there are specific Statoil information systems that are being used solely for Statoil's own supply network. While SAP is used as an ERP system (Enterprise Resources Planning System) for all administrative processes, the DaVinci system is used for planning helicopter transportation to/from the NCS.

The SAP system is used for many purposes like material ordering, accounting information etc. It was implemented as a part of the standardisation of administrative processes across the value chain to increase integration and automation of routines during the *Process Orientation Initiative 1997*-2001. The SAP R/3 system was decided in 1995 to be implemented. The SAP R/3 system is an enormous information system used by other integrated oil companies like Hydro Oil & Energy. Like described in the *costing structure*, each process has its own process owner. In same manor, the responsibilities of the processes most places in the value chain have its own process owner. The process owner has the responsibilities for process properties and requirements. As in other Statoil business areas, there is an operational Procurement & Logistics department at Mongstad. An operational P&L department performs, monitors and gives advices in the local P&L processes. This is done in accordance with governing documents given by the corporate P&L process owner. The process owners in different stages of the value chain have continuous contact with each other. The SAP R/3 system enables to have an electronic communication throughout the value chain in real-time.

Figure 80 The Supply Chain after Activities, *Source: P&L Statoil 2005*

The DaWinci system is an example of a common tool used by the operators on the offshore to order helicopter transportation from the mainland to the platforms. Order of helicopter transportation to the NCS must be done in this system. However, DaWinci and other information systems are integrated in the SAP R/3 system.

The information flow must be integrated in the entire supply chain so that the customer information in downstream activities is effectively communicated to the upstream activities. The Statoil pumping stations have systems that register the level of gasoline and diesel. This information is brought backwards in the supply chain so that the supply to pumping stations is a result of demand-pull. The figure below shows different tools for achieving the improvements in flows. The red arrow indicates the product flow in the supply chain while the blue arrow indicates demand information moving from the customer and backwards in the value chain. With information systems, the information from the retailer about customer demand is shared with the distribution centre and the manufacturer (here: the refiner). The refiner then uses its information system to order required components from supplier to facilitate the supply of raw material.
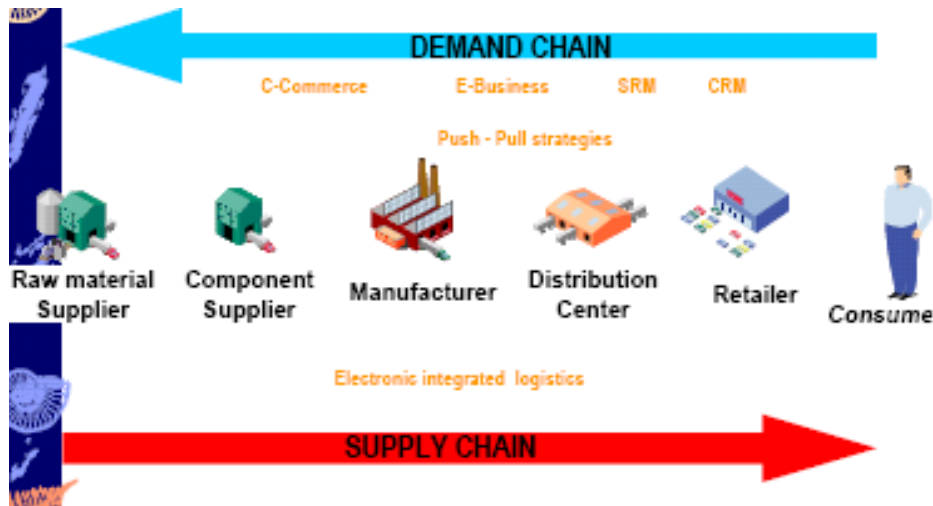
Figure 81 The Flow of Information and Products, *Source: Statoil P&L 2004*

7.6.5 A General Overview of the Product Flow

With product flow, we mean primarily the flow of raw materials like crude oil that is being processed to finished goods through a supply chain. However, to facilitate this product flow the need of equipment and infrastructure is required. These equipment and infrastructures must often be purchased from suppliers. This can be called a secondary flow of products. We will discuss the procurement strategy later.

The primary flow of products through the supply chain starts with the crude oil and natural gas mainly from the NCS. In the *pricing structure*, we found out where Mongstad's oil and natural gas where produced. Mongstad crude oil terminal receives crude oil from shuttle tankers from offshore fields like Gullfaks, Draugen, Norne, Åsgard and Heidrun. The terminal also facilitates the transport of crude oil from Troll (B, C and Blend) and Kvitebjørn. The natural gas (NGL) is transported from different pipelines from offshore to Sture and Kollsnes where it is transhipped to Mongstad by the Vestprosess pipeline.
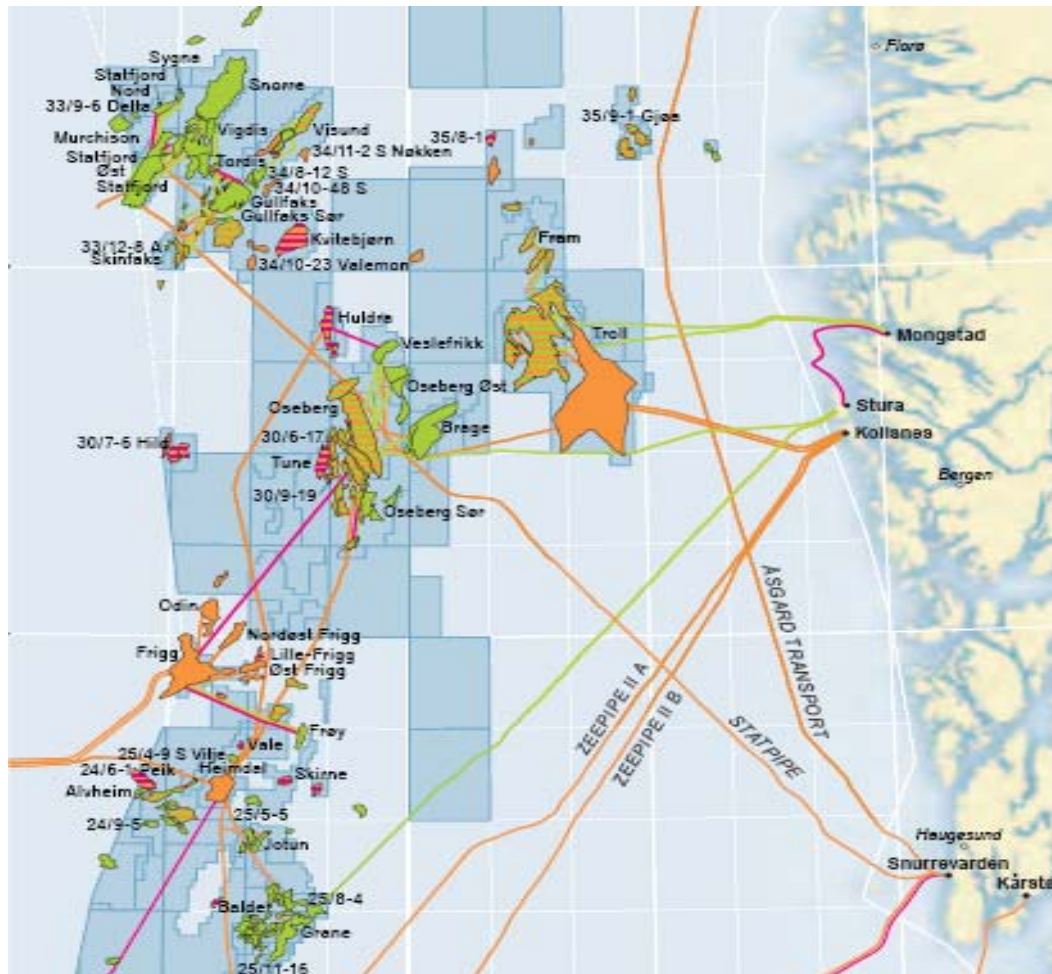
Figure 82 Pipeline System on the NCS, *Source: Facts 2005, Norwegian Petroleum Directorate*

The figure above shows how the gas (orange lines) and oil (green lines) are transported from the North Sea to Mongstad Crude Oil Terminal. The Vestprosess pipeline (red line) connects Sture and Kollsnes with Mongstad where NGL from the Oseberg field and condensate from Troll is transported.

For instance, oil from the Kvitebjørn field is first transported with Kvitebjørn Oil Pipeline and then connected to the Troll Oil Pipeline II. While Troll Pipeline I transports oil from the Troll B platform to Mongstad Crude Oil Terminal, the Troll Oil Pipeline II transports oil from the Troll B. The operator of the two Troll pipelines is Statoil. Unstable crude oil from Oseberg transported through the OTS (Oseberg Transport System) pipeline is processed at Sture into stable oil, LPG mix and NGL. The NGL is transported to Mongstad with the Vestprosess pipeline system. This is illustrated by the figure below.
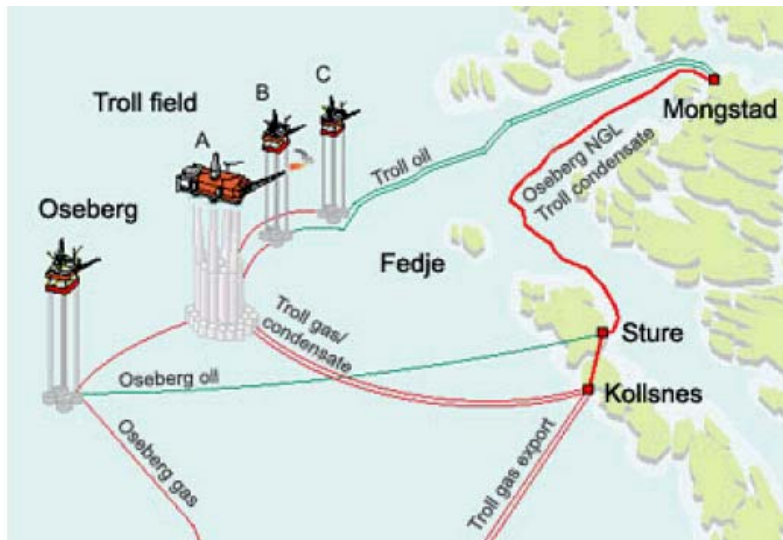
Figure 83 The Pipeline distribution to Mongstad, *Source: PTEK100 Notes, Bjørn Kvamme*

In the figure below, the upstream product flow is illustrated in detail. We see that Mongstad refinery, by being a decoupling point in the product flow, buys naphtha from Vestprosess and sells LPG to Vestprosess so that it can optimise its production to make the refined products. The Vestprosess sells propane and butane to downstream players directly without interferences from Mongstad refinery.
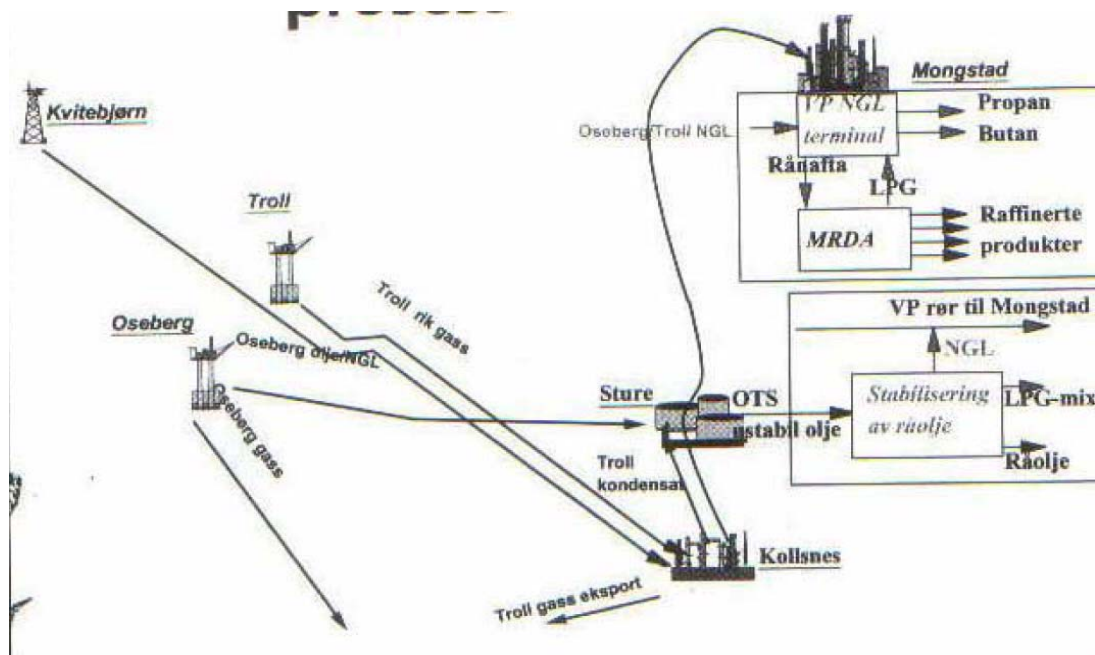
Figure 84 The entire Flow of Products, *Source: Ptek100 notes, Bjørn Kvamme*

While the upstream supply chain is mainly based on few large and more streamlined distributions chains, the downstream supply chain is split up in many distributions chains and spread out on a larger geographical area.

The distribution in the downstream supply chain is more like a network where transhipments between distribution centres and terminals occur. The transportation of refined products across Norway from Mongstad refinery is based on truck and ship transport. For instance, trucks can directly load from the Mongstad refinery to supply nearby gasoline stations. The road to Mongstad is always ice free during winter periods due to salting by road maintenance vehicles. Thus, the supply of gasoline and diesel is fairly stable from Mongstad. To more distant parts of Norway, small tank ships transports the refined products to distribution centres.

The distribution centre is responsible of supplying a region by its demand. These distribution centres are mostly owned and often operated by Statoil through Nordic Energy. However, there are some distribution centres that are operated by independent companies although the infrastructure is owned by Statoil. The distribution centre of Sortland is Vesterålen and is supplied directly from Mongstad by tanker going in shuttle traffic, Skjønhaug et al (1997). The distribution centre is owned by Statoil but is operated by an independent limited company (at least up to 1998). At this distribution centre, there is a pumping station where end-consumers can buy directly its fuel. Also, there is truck transport to supply the service facilities in the other parts of the region. These service facilities are situated in areas where there is fishing industry, recreation boats, in addition to supply the market of heat to residential areas and fuel to vehicles. The service facilities are often ran by independent companies on behalf of Statoil like a franchising concept. Both the distribution centres and the service facilities can have separate contracts with other integrated oil companies or a regional player. For instance, Shell had an agreement to pull 1000 m^3 of gasoil each year from the yearly tank capacity of 15000m^3. Also, the Coast Guard has a base nearby the distribution centres, which makes it possible for Statoil to sell its refined products by agreement.

Mongstad refinery supplies its products to different industries and different geographical areas in addition to Norway. Mongstad refinery supplies jet fuel to both domestic and international airports in both Norway and other places in Northern Europe like Amsterdam.

The gasoline from Mongstad can be distributed to most places in Europe and the US due to the possibility of blending the final product when a ship with an order arrives. This makes it highly flexible to meet the stringent requirements on gasoline content in different countries.

7.7 Procurement & Logistics

P&L is responsible of the secondary product flow in the value chain. It coordinates the supply and logistics of equipment and material of the entire value chain. Below is an overview of the total procurements cost of the Statoil group. We see that there is no significant trend in the procurement costs. It might be possible that the procurement costs are closely linked to the activity of investments, which in turn is linked to oil price. A high oil price will make it more profitable to invest, and increased investments require procuring of equipment and infrastructure. The oil price in 1999-2001 was low and maybe the reason for the low procurement costs.
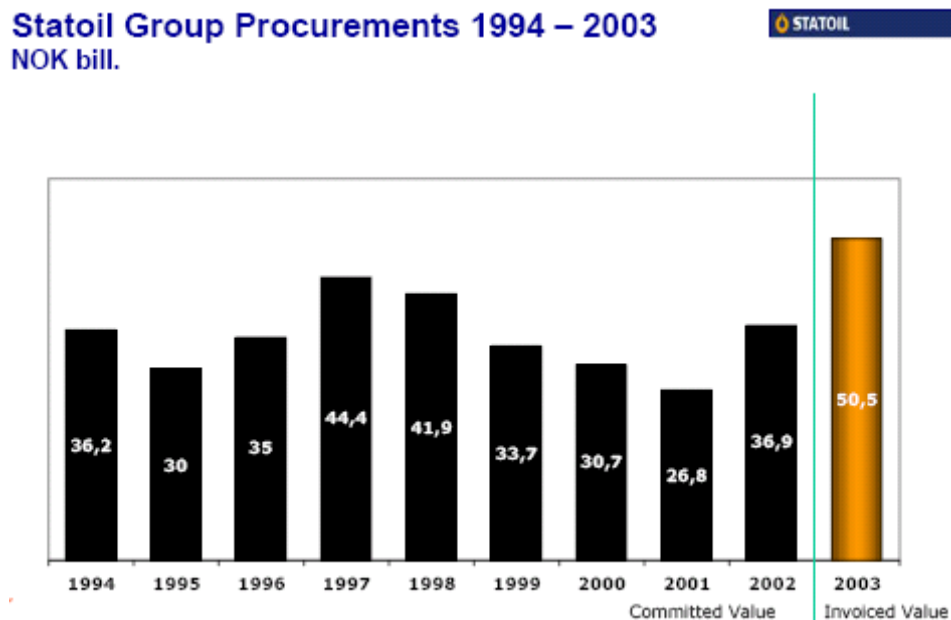
Figure 85 Statoil Group procurements. *Source: Statoil P&L 2004*

The level of spending on procurements varies across the value chain. While the upstream activities in the *Exploration & Production* division have huge procurement spending, the manufacturing and marketing section has a relatively small portion of the total procurement costs, illustrated by the figure below.
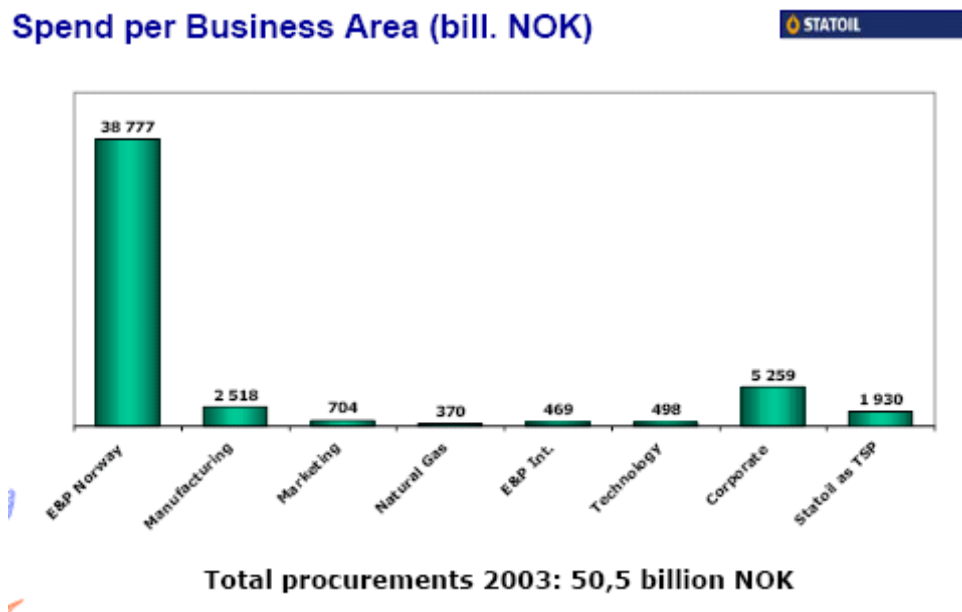
Figure 86 Procurement per business area. *Source: Statoil P&L 2004*

7.7.1 The Goals of the Procurement & Logistic Process Owner

At a corporate level, the process owner of Procurement & Logistics (P&L) has a general responsibility of supporting and challenging the different business units on procurement processes in the value chain on:

- Integrity and business standards.

- Common corporate profile.

- Total corporate buying power towards suppliers.

To achieve these corporate goals on holistic and in the different business units, the process owner must help the business units on identifying, implementing and improving *Best Practice*. Best Practice is guidelines from corporate level or management level of the business units itself to secure quality in processes. However, Best Practice does not imply in the best solution but is a framework for doing business.

To evaluate the processes that are implemented, the use of *Key Performance Indicators* (KPI) is important to analyse performance. Each of the KPI's must be appropriate for the business unit and in some cases comparable throughout the value chain of P&L. From the BRA system of Statoil, the different managers and specialists in P&L can keep themselves updated with the latest figures.

P&L is also responsible of developing, establishing and implementing new tools and information systems that can support and improve the existing business processes. In addition, quality control of the existing tools and information systems are important work. In the theory of decision making following steps are usual (Stemsrudhagen 2005): Plan the process, do the process, evaluate the process, and improve the process. The figure below shows the life cycle of the processes at P&L in Statoil. The P&L as a process owner is responsible of establishing and sustaining the purchase strategy of Statoil. This requires market assessment from people with competence on the field of procurement. The required competence can stretch from law and negotiation skills to technical understanding. Note that the bargaining power of Statoil increases when the group as whole has a purchasing strategy towards its supplier. This requires cross-functional cooperation and planning. The specific processes are then implemented. The outcomes are then continuously analysed by using performance measurement and benchmarking. Based upon the feedbacks, improvements are suggested and tried out. This applies to the entire supply chain regarding to procurement and logistics.
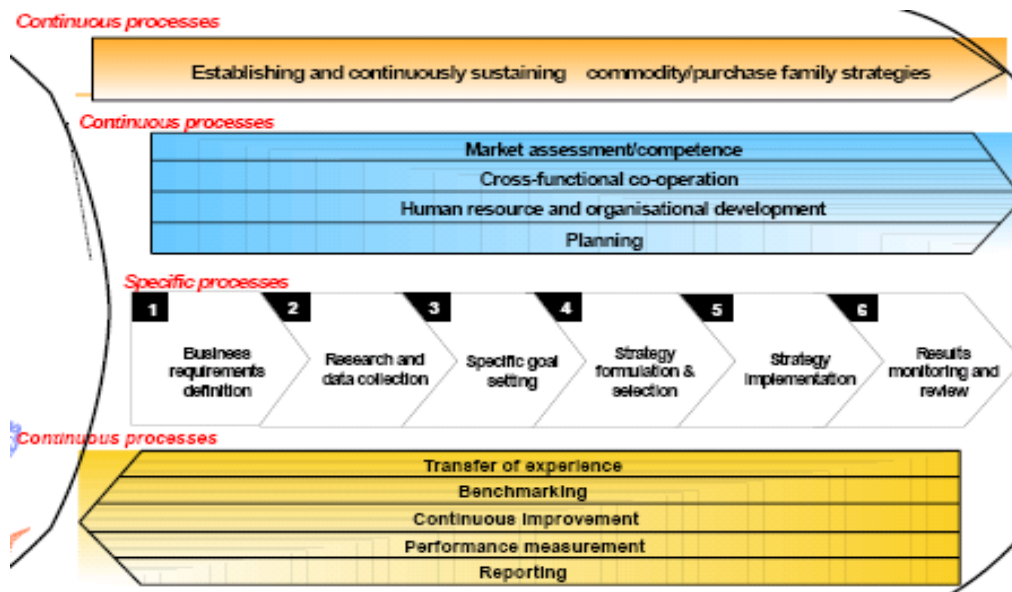
Figure 87: Supply Chain Planning and Processes, *Source P&L Statoil 2004*

7.7.2 The Make-or-Buy Strategy of Statoil Procurement

The strategy of make-or-buy was also introduced in the *costing structure*. Then we discussed about the possible gains of outsourcing. The theoretical framework used by Statoil is based on an article by Peter Kraljic (1983) on what strategies to apply for different product types. The matrix below has strategic importance on the vertical axis and criticality of supply as the horizontal axis. The matrix tells what kind of strategy should be followed for a product given the degree of the two properties. Strategic products should be a focus area for the company to create a competitive advantage on a long-term perspective. Often the solution for this can be keeping the value production of this product within the company. Non-strategic standard products should be minimised in product and transaction costs due to its low criticality and strategic importance. This makes it easier to outsource it since the competency for the product is neither strategic important or critical for operation. The other two quadrants are more difficult to decide on make or buy strategy.

Figure 88: Make-Buy Decision, *Source: P&L Statoil 2004*

Some common general strategy elements for the different product types defined by Kraljic are listed in figure 89 below. While the strategic products should be based on long-term relation with only one supplier by contract or even alliance, the non-strategic product is more based on acquiring at least cost as possible. For bottleneck products it is more important for reliable and timely delivery.

Figure 89: Focus Areas in Strategies – in Principle" *Source: P&L Statoil 2004*

In the figure 90 below, Statoil has placed the different products in the different quadrants based on their criticality and strategic importance.

The arrow in the figure 90 gives an example of office products and consumables offshore and its sourcing strategy. Since the supply of it is important, there is an agreement with two vendors and a vendor managed inventory onshore so that Statoil can secure its supply to its platforms.
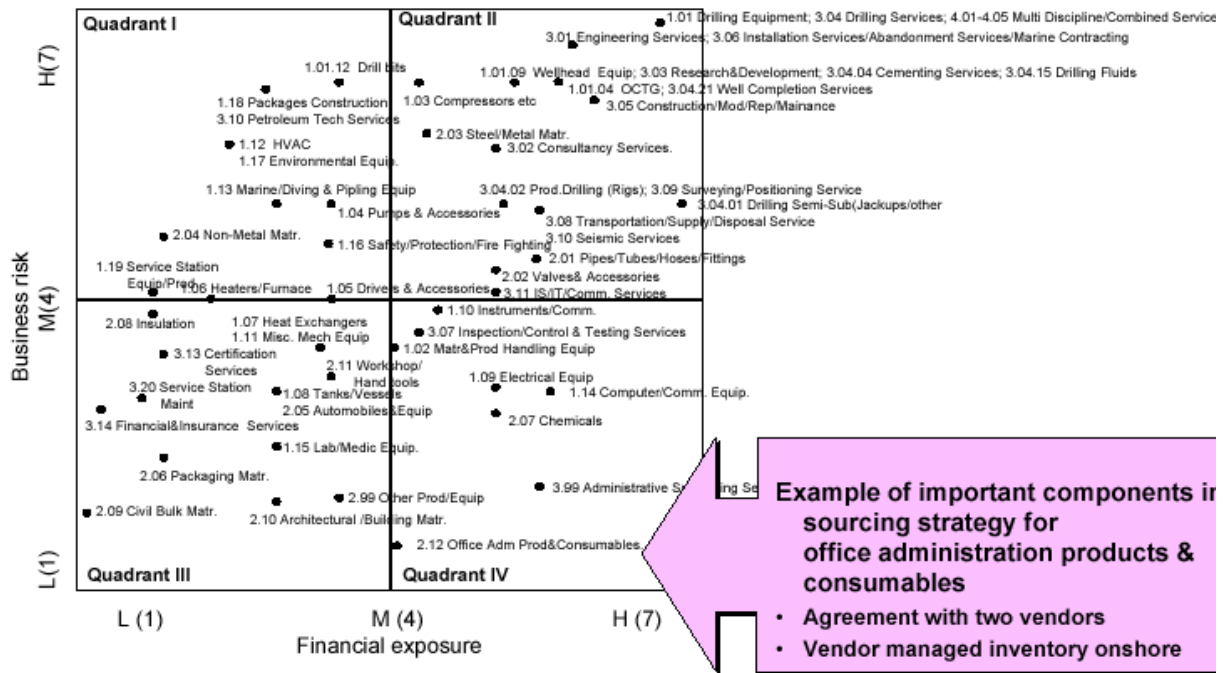
Figure 90 Classification of products and services in the Strategy Matrix.
Source: P&L Statoil 2004

In the following diagram (figure 91), the different business units are measured on how much of the payments to suppliers are to external suppliers and how much go to internal suppliers. We see that Statoil has a strategic interest in securing its operations and R&D. This is likely the usual strategy of an integrated oil company since they often prioritise in being operators to acquire important know-how. We see that drilling and well services are mostly payment to external suppliers, most likely due to the special competence needed for such operations and the buying power of large supplying companies like Halliburton and Schlumberger. The marketing and distribution section of the value chain has 25 per cent of its payments to internal suppliers. The general conclusion might be that the primary activities like operations are often kept in Statoil while the supporting activities like drilling and well services are in much larger degree outsourced.
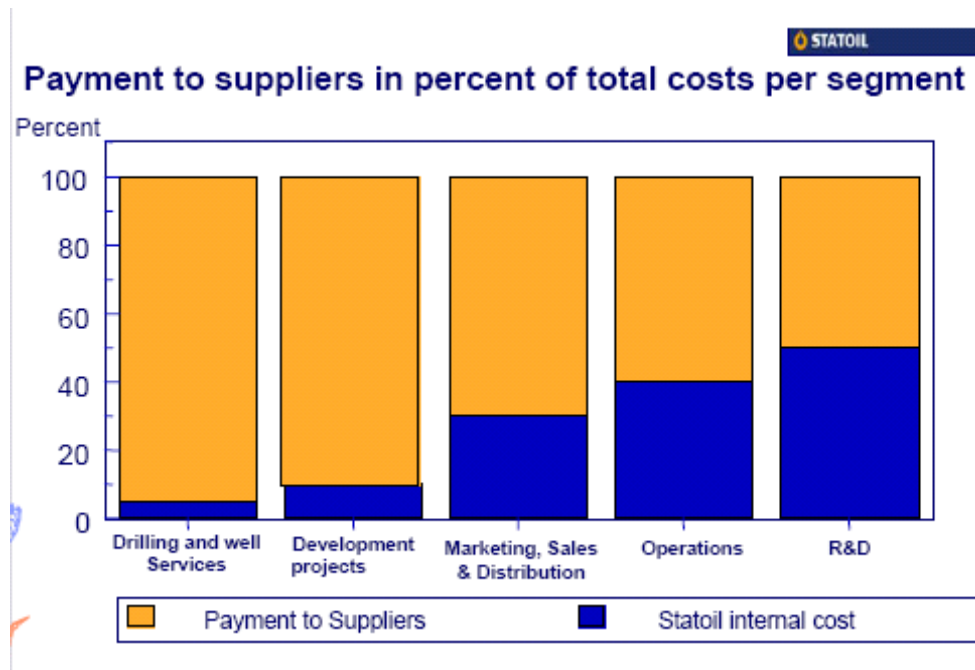
Figure 91 Payment to suppliers and internal costs. Source: Statoil P&L 2004

7.7.3 Selecting the Appropriate Supplier

There are many aspects that must be considered when choosing a supplier in a bid selection according to Stein Erland Brun at Statoil P&L:

- *HSE* (Health, Safety and Environment) is important for a company like Statoil that emphasises the importance of zero-injury and environmental friendly operations. It is well-known fact that existing suppliers face little tolerance level from Statoil if minimum safety requirement is not meet.

- *Price* is important to keep Statoil competitive. More of the services and equipments are being outsourced due to the gain in cost reductions by letting companies specialised on the given field do the work.

- *Delivery capabilities* have been the new competitive edge in winning bids. In an industry with tight time schedule on various projects, Statoil cannot afford suppliers not delivering in time.

- *Technical competence and experience* of the supplier is required to master high-tech solutions for the petroleum and process industry. This is closely connected to safety in highly challenging technological areas.

- *Quality of products* is essential to secure a long lifetime on equipment with satisfying performance and safety level. This is often based on test products from the suppliers that have to pass the internal control systems at Statoil.

- *Business ethics* applied at the supplier must be in the interest of Statoil. Ethics guidelines of the supplier must be added in the bid prospectus. This is required for any procurement above 1 million NOK, and under 1 million NOK when it is part of a closer alliance or ethical issues that are important for Statoil.

The procurement must be, according to Statoil policy, based on competitive bids and the bids must be considered under equal basis. In addition, the supplier must have the necessary capacity to commit to its supplier obligations to Statoil.

7.7.4 Procurement & Logistic Strategies of Statoil

As other business areas, P&L emphasises on maximising value added on a long-term basis. This results in a long-term perspective of integrating suppliers to use both the internal and the supplier expertise at lowest possible cost. In addition, the company is focused on confidence from the society and the industry. To achieve the long-term strategic goals, minor tactical objectives are made (Statoil P&L):

- We mentioned the importance of *buying power* for the integrated oil company when we described the industry. Statoil wants to optimise this by using its market know-how and different sourcing strategies and supplier relations mentioned earlier in the industry analysis. In addition, the make-or-buy decision must be made correctly so that the business development of group is in the interest of Statoil.

- *Reducing supplier base* in different places of the supply chain by achieving more efficient logistics and cut duplication of work. To cut duplication of work, the order chain must be more streamlined so that the same equipment is not double ordered by different material planners.

- *Cutting transaction costs* by develop and improve information systems for procurement processes. This implies in integrating the suppliers much more to the information flow of Statoil.

Figure 92 Procurements and Logistics savings potentials. Source: Statoil
P&L 2004

The savings potentials on procurements and logistics are illustrated in the figure above. According to Statoil P&L, 5 per cent savings in procurement will reflect in 3 per cent improvement on the bottom line. While a 5 per cent savings in procurement will equal to 30 per cent of total salary and social costs of Statoil. We see from the figure above that strategic sourcing will be the most important savings factor in the future.

8. Summary and conclusion

This chapter provides insights and concluding remarks on this study. It also presents some suggestions for future researches.

8.1 Summary

At Mongstad, there are four different entities that collaborate together in their performance. These entities are Mongstad Crude oil terminal, Vestprosess, Product technology and customer service centre, and Statoil Mongstad (the refinery). These four entities are all partly or fully owned by Statoil ASA. This has an influence on the supply chain of Statoil Mongstad.

To analyse value chain activities at Mongstad, we looked at the organisation structure of Statoil Group headquarter, of other departments that work closely with Statoil Mongstad and of Statoil Mongstad. We discussed also some administration tools that are used in conducting activities at Mongstad such as BRA system and Balanced Score Card. These tools have led to a common working system within the integrated company 'Statoil ASA'. We presented some activities performed to ensure production. We gave a general picture and explanations of different production processes used at Mongstad. To match production and demand, a monthly plan is prepared with the help of an LP-model called PIMS. Different inputs and outputs of this model have been discussed. We also show the planning process and scheduling process at Statoil Mongstad. In this study a study of refinery costs and its pricing strategies are also performed. We gave a description on how prices on raw products and final products behaved and gave a gross margin for the refinery. We added an appendix to perform an analysis of delineating a market and explaining price behaviour on the oil market. Then we went further to investigate the cost structure at Mongstad. Finally, we looked at some activities in Statoil supply chain.

8.2 Conclusion

At Mongstad, we learned that there are four different entities (Mongstad – Crude oil terminal, Vestprosess, Product technology and customer service centre, and Statoil Mongstad) that collaborate together in their performance.

Statoil Mongstad is a refinery that is owned by integrated companies (79 % by Statoil and 21% by Shell). Compared to the independent refineries, this is associated with advantages such as access to capital and disadvantages in that many decisions are taken outside the refinery. Being a part of integrated company has influence on Statoil Mongstad decisions making process that depends on other departments in Statoil. We can for example mention here that the refinery has no direct contacts with its suppliers and its customers, as this task is performed by the Oil Sales Trading and Supply (O&S) department of Statoil in Stavanger. This leads to a close collaboration between Statoil Mongstad and O&S concerning activities around production at Mongstad as O&S has the main responsibilities around crude oil providing to the refinery and selling refined products

The organisation structure of Statoil Mongstad has been changed during this thesis writing. One of reasons of changing this structure was different culture between two production areas. This change has an objective of reducing operating costs in order to strengthen its competitive position. We found out that Statoil Mongstad uses the same administration and performance measurement tools as other departments in Statoil as in Statoil Group the work process is standardised.

In making a monthly plan, Mongstad maximizes a whole refinery's margin. By considering the whole refinery's margin, both variable and fixed costs are not distributed to different products. Cost distribution to different products is hard due to the fact that products manufactured from various crude oils are interdependent. However, if this can be done, it can be interesting to know the different products margins. The information that can be given from these products margin may have certain influence in the decision-making for example reducing quantities of less-profitable products. Without the knowledge of the product margins, it is hard to know which products that more or less profitable. These margins may also be used in comparison with the whole refinery's margin. We also found out that Mongstad has an advantage of being a components refinery as this allows it to postpone components blending to make refined products until shipping of products.

By analysing the industry for refining, we concluded that the industry was under a revitalising period due to lack of refinery capacity to face the increased demand and the supply of heavier oil. We gave a general explanation of what uncertainties can affect supply and demand and thereby affect the crude oil prices. We then went further into details by studying the price structure and uncovered that Mongstad has to relate to given crude oil prices on a world market and to some extent also refined products, based on previous academic research and our own analytical framework. To do this analysis we had to do a market delineation to define the market for Mongstad regarding to buying crude oil and selling refined products. A definition of the market of Mongstad can be valuable to understand when changes in supply and demand in different places of this world will affect Mongstad and relating prices. We also found out that Mongstad has an advantage of being close to the production sites but a disadvantage of being a bit distant from the European and the US market. The market analysis is completed with a quantitative analysis in the appendix in order to find out whether the crude oil market in the world is one or separated into several markets. We found out that there is one world market with some modifications. Short-term variations between geographical areas (America versus Asia) exist for instance due to transportation costs and time lag.

We also learned about how the financial market traded crude oil as a world commodity, based on previous academic research. There can be some financial gains in trading crude oil by using downs and ups of the market. We then investigated closer what components the prices of crude oil were based on. Price of crude oil is dependent on the price of the reference oil, adjusted for the quality of the given crude oil, transportation costs and transaction costs. Then we discussed the findings of an article (Asche et Al. 2000) that concluded that the pricing strategy of refined products often where integrated with crude oil price, meaning that differentials of refined product prices often follow the crude oil price differentials. Finally, we took a look on how the trading department in Stavanger bought and sold products for Mongstad. The trading department take most of the decisions on sales and buys while Mongstad refinery has to adapt its production to the contracts of the trading department, although there is a continuous interaction between the two units.

The cost chapter focuses on what reduces the gross margin (income) of Mongstad. We defined these gross margin reducing costs as either value added or non-value added. To create more value for the refinery, the non-value added costs must be minimised. Before we

could show how this could be done, we had to describe the cost structure of a refinery before commissioning and after. Investments in infrastructure can be authorised by Mongstad itself if the cost is under a certain level, otherwise it has to be approved at a corporate level. We investigated also the investment analysis of Statoil and Mongstad and the economic requirements of approval.

The costs during operations are split up into direct and indirect costs. We found that power costs and labour costs were the largest cost groups and disadvantages for Mongstad in a competitive perspective. Suggestions on building a CHP–station (Combined Heating Power) to increase power utilisation and outsourcing more of the routine, non-strategic work to use labour power more efficient are already under way.

The management use diagnostic tools like budgeting and Balance Score Card to keep important focus areas under control. We discussed the budgeting process at Mongstad and in the organisation chapter we discussed the Balance Score Card in detail. The Balance Score Card and the Solomon Benchmarking are used to enhance the performance of the refinery. These two tools and on-going projects for investigating further performance enhancement are a part of an interactive control system. Both the content of on-going projects and Solomon Benchmarking are confidential.

8.3 Suggestions for future research

Value creation is a broad subject; we mainly covered the descriptive perspective. To conduct our work we mainly looked at this problem from the companies' perspective as data used were collected in the company. It would be therefore interesting to look at this issue using other perspectives such as stock market and consulting companies' perspectives; and thereafter making a comparative study with competitors since it would highlight the differences existing between companies that we did not cover in this study. It would be also interesting to make a deeper study on other perspectives of value chain at Mongstad. For instance, a deeper study on risk management and an economic inventory management of both crude oil and refined components and products, which is performed by the O&S, may give insight on inventory's influence on the refinery's profitability. Finally, the monthly plan at Mongstad provides a whole refinery's margin; it would be interesting to make a study that

can give insights into different products' margin as this may contribute to long-term decisions such as production expansion or make/buy decisions.

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Appendix

An Econometric Market Delineation of Mongstad Crude Input Market

Method[33]

Regardless of the consumption pattern of crude oils at Mongstad, we would like to know whether Mongstad is situated in a world market or a local European market. Since Mongstad use the Brent Blend as its reference price, which is widely used in Western Europe, it would be possible to try to statistically test if Mongstad must purchase its crude oil on a world market or a local European market. This can be done by using an econometrical package to test whether price movements in Brent Blend, WTI and Dubai are significant interdependent to conclude with a single world market for crude oil. Then pricing forecasts in Mongstad production plans should take world market conditions in account.

Thus, we have following hypothesis:

H$_0$: *Brent Blend, WTI and Dubai do not create each other price, hence being*

separate markets.

H$_A$: *Brent Blend, WTI and Dubai create each other prices and thereby consisting*

a single market.

To test this hypothesis, we could use the Engle-Granger Co integration test. This test is used when we work with non-stationary series since ordinary inference statistics fails with non-stationarity. The problem is that price series are most often non-stationary. One could also try to use the differential between the initial value and its lag. However, this creates another problem since one removes any trend in the price series. We would like to keep the trend if it exists in the data. With the Engle-Granger test we run pair wise co integration tests by first creating supporting regressions between two and two price series and test the residuals for stationarity by using the Dickey-Fuller test. We choose to run the co integration test for all

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[33] All econometric analysis is made in the econometric package STATA.

price series and put the results pair wise together to see if the reference prices are mutual dependent.

The data set consists of historical prices of Brent Blend, WTI and Dubai acquired from Platt's. We have used contract prices with maturity of one month instead of spot prices since only these prices were available to us. Notice that this may increase the speculative factor in the prices since these contracts do not always have a physical delivery. The time perspective is from January 1990 up to May 2005 and each observation represents each month in this period, a total of 185 observations. The prices have been deflated by using PPI (U.S. Department of Labour) for crude, energy and materials. This reduces the possible problem of spuriousity[34] in connection with price changes. Differentiated series have also been applied in addition to the ordinary price series. By using the differentiated series, we can investigate the grade of price movements in price series. First, we present the nominal price series of the three different crudes:
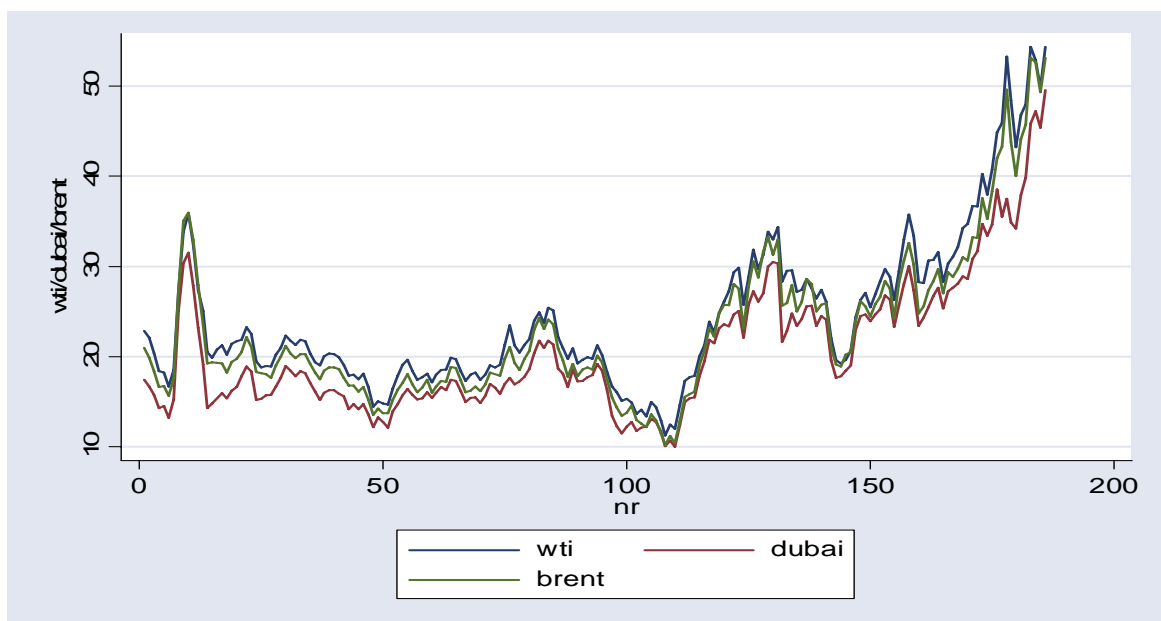
Figure 93 Nominal Prices of Three Different Crudes*, Source: Platt's*

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[34] Spuriousity appears when a third variable affects both the dependent and the independent variable and trick us to believe that there are a dependency between the dependent and the independent variable.

We see that during the first 110 months from the beginning of 1990, the prices of the three different crudes have varied mostly below $20 per barrel with the exception of the Gulf Crisis in 1991 when prices soared in fear of supply disruption. The price series follow each other a great deal, indicating one common market for oil crudes. However, the price differentials between the different oil crudes[35] look like to be varying within a limit. We will look into it later. We see that the price record from the Gulf crises with [$30,$35] per barrel for the different crudes was broken in last half of 2003, and since then the prices have only soared.

We notice that the oil price has been as low as $10 per barrel. The correlation matrix below shows that there is a huge correlation between the three crudes. Nothing indicates that there are geographical different oil markets.

```
(obs=185)    |     wti    dubai    brent

-------------+--------------------------

       wti |   1.0000

     dubai |   0.9827   1.0000

     brent |   0.9952   0.9882   1.0000
```

Table III: Correlation of Different Crudes, Source: Platt's Prices Analysed in STATA

We now turn to deflated crude prices. These prices are, as mentioned earlier, adjusted for PPI.

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[35] Price of WTI vs. price of Dubai, price of WTI vs. price of Brent, price of Brent vs. price of Dubai.
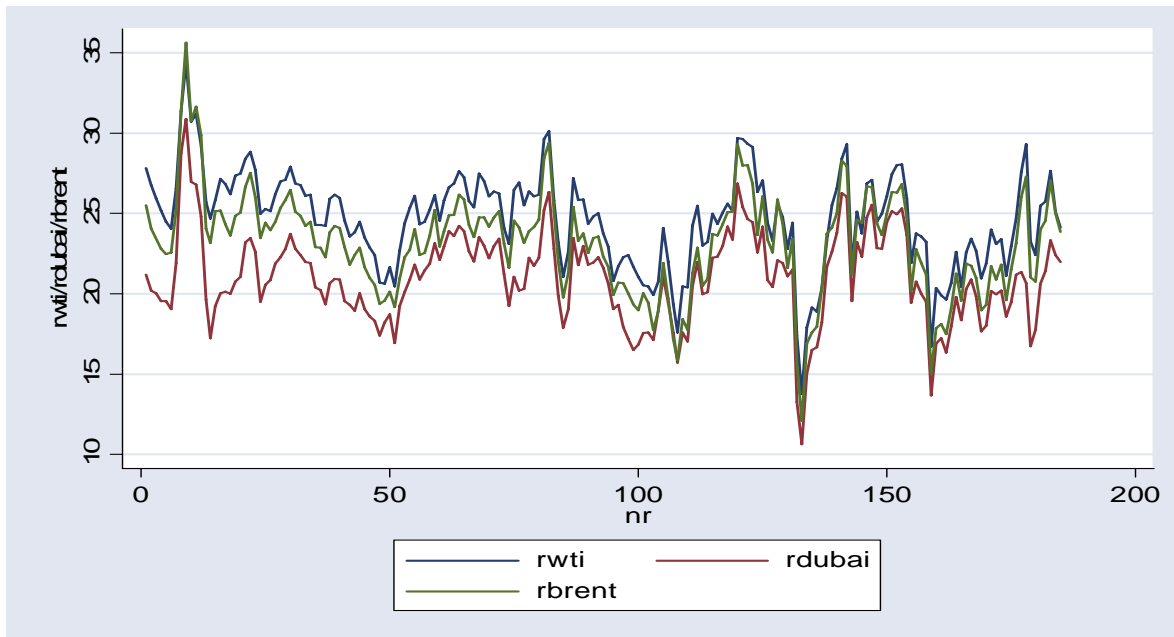
Figure 94 Deflated Prices of Three Different Crudes, *Source: US Department of Labour and Platt's.*

The deflated prices show that there are close relationships between the different reference prices. It might seem that the positive relationship in price movements have decreased somewhat in the later years since the graphs are less synchronic in movements when observations reach above 100 nr. The correlation table below indicate less correlation between the price series than the nominal prices, especially Dubai versus the other reference prices. But the relationships still remain strong enough without concluding any separate markets.

```
(obs=185) |      rwti    rdubai    rbrent

-------------+---------------------------

     rwti |   1.0000

   rdubai |   0.8969    1.0000

   rbrent |   0.9732    0.9280    1.0000
```

Table IV: Correlation of Three Different Crudes, Deflated Prices. Source: Platt's

Moving to differentiated price series[36], the correlation matrix table below do not disprove that there are high relationships between the differentiated price series.

```
(obs=184) |    drwti  drdubai  drbrent

-------------+-----------------------------

      drwti |   1.0000

    drdubai |   0.9284   1.0000

    drbrent |   0.9607   0.9442   1.0000
```

Table V: Correlation of Differentiated Deflated Crude Oil Prices. Source: Source: Platt's

All the essential correlation figures remain above 0.9, referring to high price correlations.
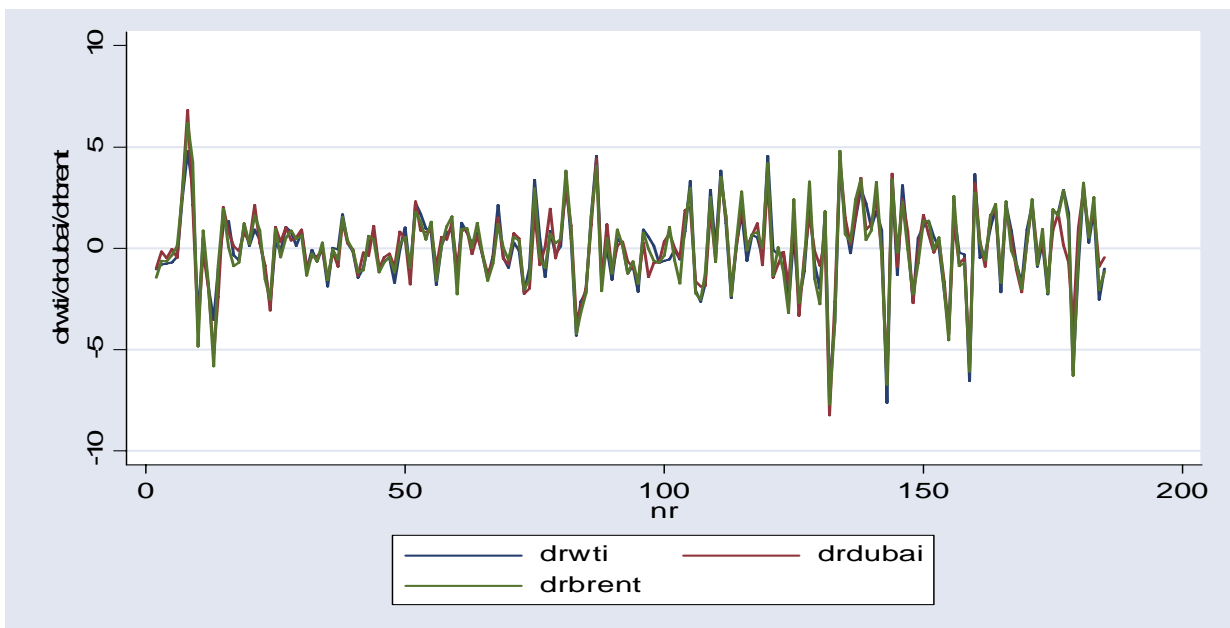
Figure 95 Differentiated Deflated Crude Oil Prices, *Source: US Department of Labour, Platt's*

---

[36] A differentiated price series, in this case, is expressed by $(p_t - p_{t-1})$

Also, we see that graphs in the diagram above support that there is no information what so ever that the markets might be geographical separated. The reference prices seem to vary in the same direction with same intensity. Thus, we are not able to conclude with separated markets by looking at the differentiated prices

There are major problems connected to ordinary correlation studies. They may be as following:

- They do not take account of trends like increase in GDP or inflation. However, by using deflated prices we avoid the problem of inflation somewhat.

- We have not taken common shocks like a reduction in oil taxes in the US into consideration that could make any crude oil types cheaper. One should try to adjust the analysis for external shocks like changes in taxes.

- The analysis does not take internal shocks into consideration like a change in general production technology that may reduce the costs of crude oil production.

- Lack of stationarity in price data could invalid our conclusions.

By using the Engle-Granger co integration test, we could avoid some of these problems. We must however use the Dickey-Fuller test for uncovering non-stationarity.

The DF tests for unity root, that is if ρ is equal to 1 in the time series $X_t = \rho * X_{t-1} + u_t$.

If ρ is equal to 1 then X_t is non-stationary and is often called *random walk*. By being a random walk, the series will have following characteristics (Wooldridge 2003):

- Infinite time memory.

- Increasing variance.

The result of this is that the price of tomorrow is always best predicated with the price of

today. In other words, this means that we have an efficient market since nobody knows more

than others about future prices.

The null hypothesis of the DF-test is that ρ is equal to 1 and thereby being non-stationary. If the produced DF-values are significant then the null hypothesis must be rejected and stationarity must be assumed. Since all three price series do not start from zero we add a constant. We also add a trend since the diagrams presented earlier show a trend of increasing oil prices the last two-three years. Notice that we have also added four lags in case of lagged stationarity.

Deflated Prices	DF-Values
WTI	-3.862*
Brent	-3.960*
Dubai	-4.668*

*Critical DF Z(t)-values: 1% significance = -4.013, 5% significance = -3.439, 10per cent significance = -3.139

Table VI: Dickey Fuller Stationarity Results

We see that our DF-values are all significant at 5 per cent significance level, and Dubai is even significant at 1 per cent significance level. This means that we have to reject our null hypothesis that the price series are non-stationary and assume that the series are stationary.

Although we do not have signs of stationarity in our series we will use the Engle & Granger (E&G) co integration test to be sure of not to suffer from invalid assumptions. As mentioned earlier, the E&G test is done by first creating supporting regressions between two and two price series. Then we run the co integration test for all residual price series. We will include a trend and a constant for the reasons mentioned earlier, and one column without trend but with a constant.

Independent Variables	Dependent Variables	DF-test residual with trend / constant	DF-test residual without trend
rwti	Rbrent	0.000 (-5.901)	0.000 (-6.163)
rbrent	Rwti	0.000 (-5.802)	0.000 (-5.931)
rwti	Rdubai	0.001 (-4.213)	0.001 (-4.776)
rdubai	Rwti	0.001 (-4.178)	0.002 (-4.473)
rbrent	Rdubai	0.000 (-4.301)	0.001 (-4.658)
rdubai	Rbrent	0.000 (-4.383)	0.001 (-4.602)

Table VII: Results of Engle & Granger Test

Since the DF-test use different critical values for the different tests, the DF-values have been set in parenthesis and use MacKinnon approximately values for the DF-values. We see that all tests give significant values so that there is mutual dependence between the different reference prices. We must therefore reject the null hypothesis about geographical separate crude markets and conclude with one world market. Hence, Mongstad Refinery must relate to global prices.

However, how can we explain the difference in prices and small variations in price movements? Most likely it is mainly due to two factors: transportation costs and quality differences. Prices on the regional markets (North-America, Europe, Asia, etc.) may vary within a transportation cost band. The differences in regional prices on crude oil will

therefore be limited to the cost of transporting to the different regions. This was illustrated theoretically and can be exemplified with an oil price of $60 on the American market and the European market. If the cost of transportation is $2 then the American oil price cannot vary outside [$58, $62]. By looking at the price differentials (price spreads) in the diagram below, we see that the WTI-Brent Blend price spread is mostly [$0, $4]. Within this spread, the difference in oil prices does vary significantly. An estimate of transportations costs per barrel is $2, dependent on how large the transportation bulk is. Since we know that the WTI reference oil is of a higher quality than Brent, it is logical that the price of WTI is [$0, $4] higher. It seems that the spread has somewhat increased in favour of WTI, maybe caused by the relative supply decrease of lighter crude oils. This is distinctive in the price observations from '02 up to now. We see that the price spread WTI-Dubai has lately been as high as $16. So in the short terms, there may be a larger price spread than the cost of transportation, indicating that the oil commodity market is not entirely market efficient. In the long term, large price differentials above transportation costs will not be sustainable.

Short time artificial price differentials may allow Mongstad to strike good deals to secure cheap primary oils. Especially, this could be the case on the spot market. If the spot price is cheaper than the future price[37], it might be a *convenience* to purchase and stock oil.

We conclude this part of *Price Structure* to say that Mongstad has to relate to crude prices on the local European oil market when variations in global prices are small. However, when price variations in different global markets exceed transportation costs[38] then Mongstad has to relate to world prices, being able to purchase its input from other parts of the world than the NCS.

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[37] The market is in contago.

[38] Including transaction costs.

Figure 96 Price Differentials between Different Crudes, *Source: Platt's*

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