Gas to Liquids: Shell Middle Distillate Synthesis Process and Products

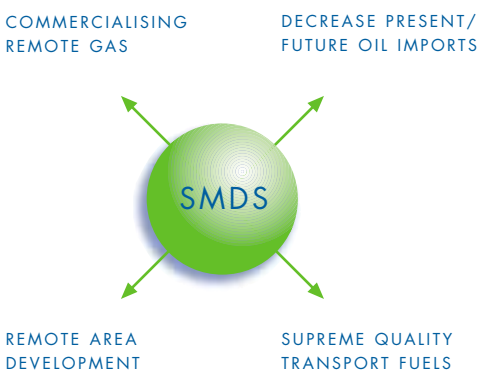
Taking Gas and Power Further

Shell Gas & Power

INTRODUCTION

Over the past few years, there has been substantial and sustained growth in proven natural gas reserves around the world. Today the combined size of gas reserves is close to that of oil and, if this trend continues, looks set to exceed them.

Distillation columns of the SMDS plant in Malaysia



SMDS provides benefits for a region/country with stranded gas

Gas is a clean, versatile and therefore desirable fuel. When a natural gas source is near a significant market it can be transported to customers by pipelines. However, when markets are remote, the gas needs to be converted into Liquefied Natural Gas (LNG) in order to be transported economically. Alternatively the gas can be converted chemically into products such as fertilisers, methanol or liquid hydrocarbons, which can also be readily transported.

Over the years, Shell has been looking beyond its traditional role in LNG and pipelines in order to seek new opportunities for the commercialisation of gas reserves. The Shell Middle Distillate Synthesis (SMDS) technology was developed using natural gas as a feedstock to produce middle distillates such as naphtha and gasoil. SMDS has significant logistical advantages over LNG. There is a large open market for middle distillate products. Dedicated customers, required by LNG, are not key to development of a project. Nor are dedicated expensive ships and receiving terminals required as existing distribution systems can be used to access the oil products market. The importance of this technology goes beyond providing a means to monetise gas and open up new reserves. By converting gas into oil products, for countries which have both oil and gas reserves, the process can extend the life of indigenous oil reserves. For countries with gas but no or insufficient oil reserves, its application can reduce the cost of imports of crude oil or oil products.

The environmental concerns regarding fossil fuel combustion have resulted in legislation to improve the quality of transportation fuel, notably to reduce sulphur and aromatic levels. Presently, refinery technology reduces the concentration of these components in middle distillates derived from crude oil to the level set by specifications. The SMDS technology, however, goes beyond this: it produces fuels with virtually no aromatic and sulphur components, which can be used directly, or as refinery blending components to improve the quality of crude-derived gasoil. Blends of SMDS gasoil with conventional gasoil give significant reductions in regulated emissions (NO_x, SO_x, HC, CO and particulates). SMDS gasoil can also be used as a neat fuel in diesel engines with minor modifications.

TECHNOLOGY

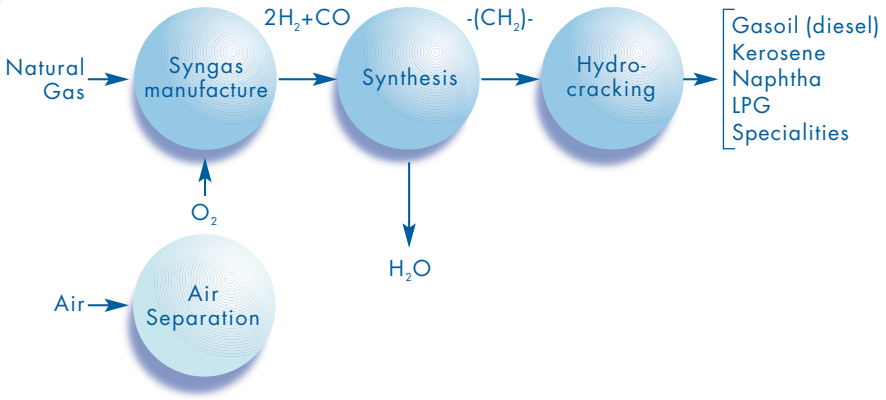
In essence the SMDS process, as shown schematically below, is a three-stage process. In the first stage, the Shell Gasification Process (SGP), synthesis gas is obtained by partial oxidation of natural gas using pure oxygen.* In the next stage, Heavy Paraffin Synthesis (HPS), the synthesis gas is converted into liquid hydrocarbons using a modernised version of the classical Fischer-Tropsch Synthesis. In the final stage these liquid hydrocarbons are converted and fractionated into high quality products, predominantly middle distillates, by means of the Heavy Paraffin Conversion (HPC) process.

The amount of unwanted smaller hydrocarbons or gaseous products produced as by-products is substantially reduced by opting for the production of long chain paraffin molecules in the synthesis step. By exploiting the high selectivity towards middle distillates in the hydrocracking step, the overall process achieves a high total yield of product in the desired range, and by varying the operating conditions, the product slate can be shifted to a maximum gasoil mode or optionally a maximum kerosene mode, to meet market requirements.

The synthesis gas is converted to synthetic straight paraffins in the Heavy Paraffin Synthesis (HPS) section via the Fischer-Tropsch reaction. This is a chain growth reaction of CO and hydrogen for which a Shell proprietary catalyst is used:

$$2H_2+CO \longrightarrow -(CH_2)- + H_2O$$

The Shell Middle Distillate Synthesis Process



THE SHELL GASIFICATION PROCESS IN THE SMDS(M) PLANT

The Shell Gasification Process (SGP) was developed in the 1950s, primarily with the objective of gasifying heavy residues in refineries for the production of fertilizers. Commercial plants have been in operation since 1956. During the subsequent 40 years, the process has achieved wide acceptance in the industry. The SGP is capable of converting natural gas at pressures up to 70 bar using oxygen from an air separation plant. The process is operated at around 1400°C.

*The synthesis gas can also be produced using coal instead of natural gas as feedstock. For this purpose the Shell Coal Gasification Process (SCGP) can be used instead of the SGP

In the chain growth reaction a wide product slate is produced ranging from very light paraffins up to heavy paraffinic waxes. The proprietary catalyst developed by Shell has a high selectivity towards longer paraffins. The catalyst is very robust with an estimated economic lifetime of five years.

The mixture of straight paraffins is converted to middle distillates in the Heavy Paraffin Conversion (HPC) step, where the waxy part of the syncrude is selectively hydrocracked. Simultaneously the product can be isomerised to improve the cold flow properties. The HPC product is subsequently fractionated in a conventional distillation section.

The Heavy Paraffin Synthesis reactors of SMDS Malaysia

The Shell HPS catalyst has a high selectivity towards long chain paraffins, a very high activity and a long economic lifetime

SMDS MALAYSIA

The world's first commercial full-scale gas to liquids plant, built alongside the LNG plant at Bintulu in Sarawak (Malaysia) commenced operation in 1993.*

The plant converts 100-120 million cubic feet per day of natural gas piped ashore from the South China Sea, to 12,500 barrels of high quality product per day. Around 50% of this output is converted to middle distillates, whereas the remaining 50% is high value speciality product. This includes detergent feedstocks, waxy raffinate for production of baseoils and low toxicity biodegradable drilling fluids. Other specialities produced by SMDS Malaysia are waxes of different grades. After a hydrogenation step the wax is produced by vacuum distillation. The wax is used for various purposes such as candles, hot melt adhesives, food packaging and cosmetics.

The SMDS plant at Bintulu, Malaysia

* Shareholders are Petronas, the Sarawak State Government, Diamond Gas Holdings (100% subsidiary of the Mitsubishi Corporation) and Shell International Gas

The key parameters which determine the economic viability of a new SMDS project are:

- **capital cost**
- **operating costs**
- **gas into plant price**
- **product revenues**
- **fiscal regime**

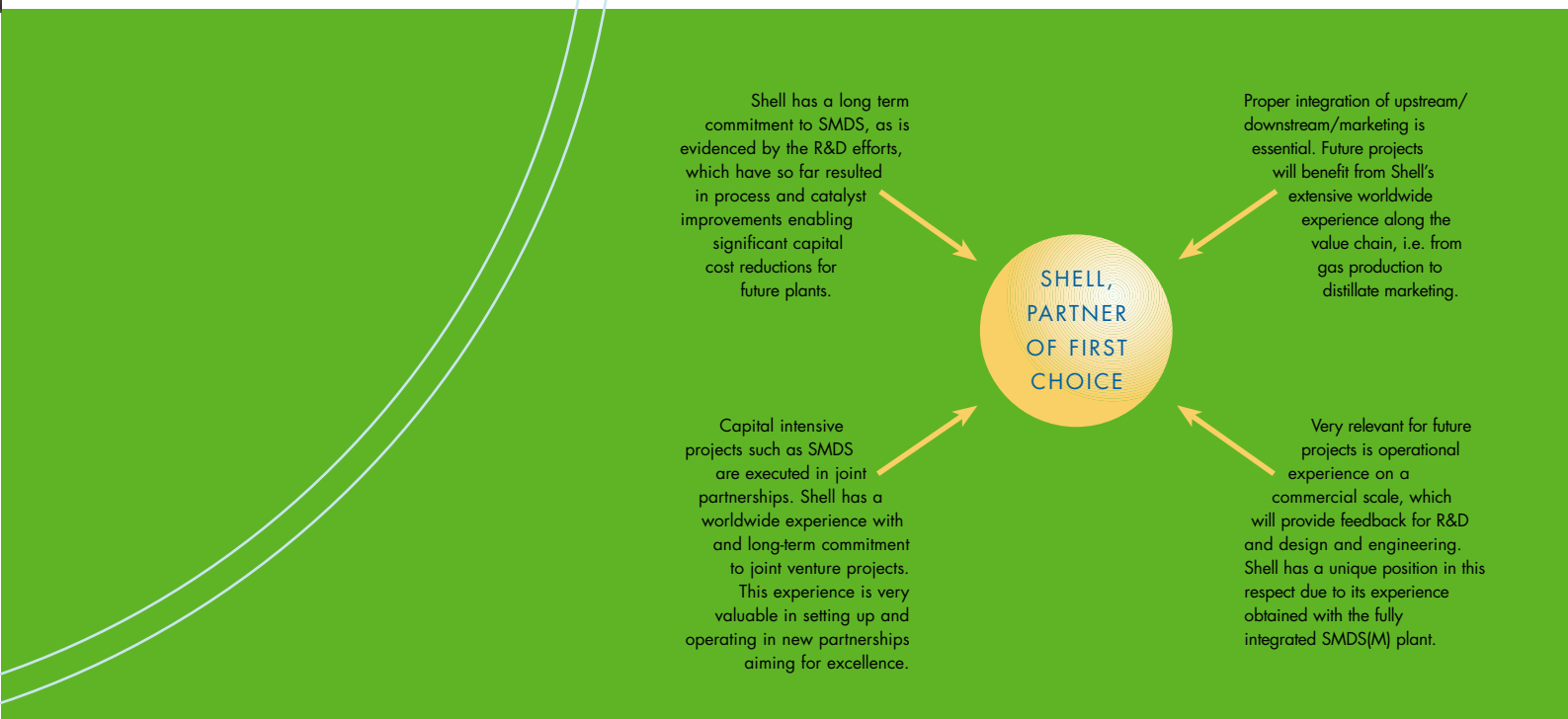
About half the products from the existing SMDS plant in Malaysia comprise of waxy raffinate, detergent feedstocks and waxes. Production capacities of these specialities are large compared to regional or world market demand. Future SMDS facilities will be designed to produce mainly middle distillates at large capacities. Economy of scale and technological innovation have substantially reduced the capital expenditure requirements (to below 25,000 US$/bpd). The final cost however will be site-specific, depending on available infrastructure and local manufacturing industry, and construction costs. At the moment the optimal size for future plants is considered to be around 70-75,000 bbl/day, i.e. some six times the size of the existing SMDS plant. Gas consumption is in the order of 700MMscf/day for an optimal size plant.

ENVIRONMENTAL ASPECTS

Worldwide, the quality of air is a matter of increasing concern, especially in large cities, where people are exposed to emissions caused by traffic and industry. Blending SMDS middle distillates with today's standard gasoil can lead to significant reductions in emissions.

The SMDS process itself has minimal impact on the local environment. Waste water leaving the plant is treated to allow its discharge as surface water. A bio-degradable residue and spent catalyst are the only solid wastes. The catalyst is very robust and only needs replacement once every five years. The spent catalyst is sent back to its manufacturer where the components are regenerated. The emissions of the SMDS process into the atmosphere are free of SO_x and particulate matter.

Environmental concerns have also led to significant efforts to phase out flaring of associated gas. Gas conversion is seen as a possible solution to extinguishing the flares, leading to a growing interest in the SMDS process.

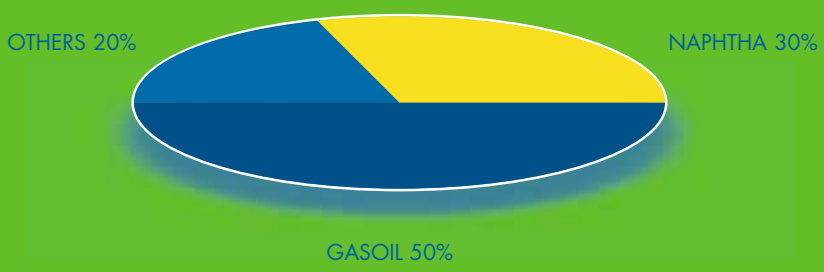


PRODUCTS

A new large scale SMDS will produce mainly middle distillates: naphtha, gasoil and optionally kerosene. The SMDS process provides considerable flexibility with regard to the product slate. Since products manufactured by SMDS are completely paraffinic and virtually free from nitrogen and sulphur, the middle distillates produced are crystal-clear odourless liquids. They have excellent combustion properties.

Cleanliness of the natural gas is transferred into the SMDS products. The liquids are crystal clear, odourless and virtually free of sulphur

TYPICAL PRODUCT DISTRIBUTION



NAPHTHA

The naphtha or C_5-C_8 fraction produced from the SMDS process is highly paraffinic. This makes it an ideal cracker feedstock for ethylene manufacture. The paraffinic nature and the purity of the SMDS naphtha results in about 10 per cent higher ethylene yields compared to petroleum-derived naphtha feedstock.

GASOIL

High cetane, low density and negligible sulphur and polyaromatics make SMDS gasoil a valuable component in gasoil blends. SMDS gasoil has successfully been used in a number of countries around the world, amongst others in California to upgrade refinery stock to CARB[1] specification.

OTHER PRODUCTS

SMDS product slate includes Liquefied Petroleum Gas (LPG). SMDS technology also offers the opportunity to segregate chemical compounds, such as solvents and waxes. Likewise part of the product stream can be used to manufacture high quality lubricant feedstock. However, the market for these types of component tends to be small, even on the basis of a single large scale SMDS project. Therefore, opportunities for these specialities need to be reviewed cautiously and on a case by case basis.

A by-product of the Fischer-Tropsch reaction is water, produced in volumes equal to the middle distillates. In areas with water scarcity, this may be used for irrigation purposes.

Finally, the base SMDS design aims to produce liquids only, on a 'stand-alone' basis. However, the technology can be configured to co-produce electricity and/or steam (for sea water desalination) at relatively low costs, should this be desirable.

[1] California Air Resource Board

EXPLANATORY NOTE

This brochure reviews the scope of the natural gas and power related businesses of the Royal Dutch/Shell Group of Companies (Shell). It describes the energy solutions that Shell offers to our customers, co-venturers and the communities with whom we work. Shell has five core business sectors, encompassing:

Exploration and Production searches for, finds and produces oil and gas. Builds the infrastructure needed to deliver hydrocarbons to market.

Gas & Power commercialises natural gas, supplies liquefied natural gas, develops markets and infrastructures, markets and trades natural gas and electricity, develops power plants and converts Gas to Liquids.

Oil Products sells and markets transportation fuels, lubricants and speciality products. Refines, supplies, trades and ships crude oil and petroleum products. Provides consultancy services to third parties based on Shell technology and experience gained in Shell operations.

Chemicals produces and sells base chemicals, petrochemical building blocks and polyolefins globally.

Renewables generates 'green' electricity and provides renewable energy solutions. Develops and operates wind farms, manufactures and markets solar systems and grows sustainably managed forests.

Other activities other business activities include: Shell Hydrogen, Shell Trading and Shell Consumer.

These business sections operate globally and are supported by Shell service companies in London and The Hague, and Shell's research laboratories. Shell's global presence, local knowledge and worldwide pool of expertise and skilled people are available to meet our customers' needs in gas and power.

SHELL'S BUSINESS PRINCIPLES

Shell Companies operate under a code of conduct called the Statement of General Business Principles. These principles govern the way we operate and provide, for our employees and for the outside world, an ethical framework which is both mandatory and transparent. This statement has been a public document for the last 20 years.

The Group publishes 'The Shell Report' which provides information on its economic, environmental and social performances set out against the Group's Business Principles.

A fisherman offshore from the SMDS plant, Bintulu, Malaysia

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