

OVERVIEW OF SHELL GLOBAL SOLUTIONS' WORLDWIDE GASIFICATION DEVELOPMENTS

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Piet Zuideveld and Jan de Graaf, Shell Global Solutions International BV, the Netherlands

INTRODUCTION

Shell Global Solutions licenses two gasification technologies: the Shell Gasification Process (SGP) for liquid feedstock applications, and the Shell Coal Gasification Process (SCGP) for solids such as coal and petroleum coke. To date, 27 Shell-designed plants are in operation, incorporating 85 gasifiers – 36 in Asia, 28 in Europe and 21 in North and South America. The syngas produced is used for chemical manufacturing (typically oxo-alcohols, ammonia and urea), hydrogen production, and power generation, or for a combination of these.

Major recent projects now in operation using these Shell gasification technologies include the PER+ refinery upgrading project at Shell Pernis, Rotterdam, and the Nuon coal-fired power plant, Buggenum, both in the Netherlands.

Shell Global Solutions provides the technology for many new projects. This paper gives an overview of projects – either planned or in progress – and describes their significant features.

PROJECT OVERVIEW

Gasification of liquid residues

Ready for the future

Traditionally, crude-oil residues have been sold as a marine bunker fuel or used on site as a furnace fuel. However, there is continuous pressure to reduce both the emissions from refineries and the sulphur content of refinery products. Therefore, refiners are looking for alternative residue strategies for producing lighter, high-value products to help them remain competitive in a market where the demand for light oil products is steadily increasing.

The SGP can help refiners meet both legislative and business targets. By using this process, a refiner is able to produce cleaner products, reduce emissions and meet imminent tougher environmental legislation. When integrated with other upgrading technologies, the process can convert a wide range of low-value, heavy residues and asphaltenes into clean fuel for combined-cycle power generation and offers good prospects for attendant carbon dioxide sequestration schemes. Moreover, the quality of residue feed does not greatly affect the investment costs for the gasification technology, enabling refiners to use deeper conversion and heavier, cheaper crude oils.

Shell Nederland refinery, Pernis, Rotterdam, the Netherlands

The Pernis gasification plant was built in 1997 as part of a major refinery-upgrading project (the PER+ project). The new facilities included a world-scale hydrocracking unit, a gas-turbine-based power plant and a sulphur recovery unit. The Pernis gasification plant has three gasification trains designed to convert 1650 t/d of vacuum-flashed cracked residue into syngas. About two-thirds of this syngas is used to produce hydrogen for the hydrocracking unit (up to 285 t/d). The remainder is used for power production (up to 125 MW_e).

The gasification unit provides stable operation and high availability, and the refinery is producing cleaner products and meeting environmental legislation. One of the projects currently under development at the refinery is a project to export pure carbon dioxide.

Eni SpA, AGIP, Sannazzaro refinery, Italy

The project to install two gasifiers at the Sannazzaro refinery in Italy, each capable of treating 600 t/d of visbroken vacuum tar, has moved into the detailed engineering phase. Equipment requiring a long lead time has been ordered, and plant start-up is projected for 2005.

The main driver for this project is national legislation that enforces a reduction in emissions from power stations. This has resulted in a decline in demand for Sannazzaro refinery's residue stream. Syngas from the gasifier will be one of the fuels used by a new 1000-MW gas-syngas-based power plant being built near the refinery. Some hydrogen will be recovered from the syngas using membrane separation to meet other refinery needs.

Rafineria Gdańska SA, Gdansk, Poland

The Shell gasification plant at Gdansk refinery will be part of a larger upgrading project. The project will also include a Kellogg solvent de-asphalting unit, a Shell hydrocracking unit and facilities for hydrogen, steam and power generation. A consortium of companies, technology providers and engineering companies are working closely together to develop this project.

The gasification plant will have a capacity of about 1600 t/d and use asphaltenes as feedstock. Most of the syngas produced will be used to manufacture hydrogen for the hydrocracking unit, with the remainder being used to produce power for the refinery. A small amount of power will be exported. Steam production will be in line with the net demand of the integrated refinery complex.

The key strategic drivers for the Gdansk upgrading project are reducing refinery emissions, exporting high-sulphur fuel, and producing more higher-value products and better quality gasoline – all in line with European Union legislation and standards.

Over the last five years, Gdansk refinery has considered various process units and configurations. After various options had been evaluated, an integrated project in which Shell gasification technology plays an important part turned out to be the best fit with respect to the strategic drivers and return on investment.

Currently, the basis of design is being developed. The next phase will be the definition of the project leading to the final investment decision. The project is expected to start operation by mid-2006.

OPTI Canada Inc.–Nexen Petroleum Inc., Long Lake, Alberta, Canada

The Long Lake project involves the extraction of 70,000 bbl/d of bitumen from the Athabasca oil sands by steam-assisted gravity drainage (SAGD). OPTI's OrCrude™ primary upgrading process converts the raw bitumen into a partially upgraded product and a heavy asphaltene by-product. A distillate-hydrocracking unit upgrades the product further into a premium-quality, synthetic crude. The heavy asphaltene by-product will be the feed for a 3100-t/d Shell gasification unit.

The three main processes will be fully integrated at the Long Lake project. The gasification plant will produce the hydrogen for the hydrocracking unit and steam to drive the SAGD extraction process.

The basic engineering of the project has been finished, and hazard and operability (HAZOP) analyses are in progress to help support the final investment decision, which is expected in late 2003. With economic prospects still as favourable as those reported during last year's gasification conference, the project is expected to commence construction in early 2004.

Gasification of coal

Nuon, Buggenum, the Netherlands

Since 1998, the Buggenum coal gasification plant has been operating as a commercial power station with a high level of availability. The plant uses up to 2000 t/d of coal to produce 4×10^6 Nm³ of syngas. The syngas is used to fuel an integrated gasification combined cycle power plant with a capacity of 253 MW_e. Technical and operational feedback are being used to improve the SCGP design further for future projects.

To meet new reduced carbon dioxide emission levels, the Dutch government and companies using coal-fired power plants have agreed to reduce carbon dioxide emissions, starting in 2008, by a partial switch from coal to biomass fuel. The Buggenum plant aims to use up to 40% biomass as a co-feedstock with coal. A test run of 60 t/d of biomass mixed with coal has been successful.

The use of biomass for producing power is expected to play an important role in future renewable energy-supply systems. Although research and results from the test run indicate that biomass as a co-feedstock is promising, the success of this project depends on many scientific, technical, economic and societal variables. After capital costs, there are several other factors that need consideration: the availability of biomass; future emission constraints; and competition from other renewable-energy-based technologies.

Shuanghuan Chemical Company, Yingcheng, Hubei, People's Republic of China (PRC)

The Yingcheng project will be the first Shell coal gasification plant to come on stream in China. The project is a 900-t/d coal gasification plant for the Shuanghuan Chemical Company and will replace the existing oil gasification plant that uses heavy-oil feedstock.

The engineering of the plant by the China Whuhan Chemical Engineering Company is well under way and plant construction has also started. Start-up is planned for the second half of 2004.

Liuzhou Chemical Industry Corporation, Liuzhou, Guangxi, PRC

When it comes on line, the gasification plant for Liuzhou Chemical Industry will be able to handle 1200 t/d of coal, producing 2.1×10^6 Nm³ of syngas. The new plant will replace the company's existing, old and environmentally unfriendly gasification plant. The syngas will be used to manufacture ammonia-based fertilisers and oxo-alcohols. The project has reached the detailed engineering phase, with the gasifier internals being ordered from Babcock Borsig Espana in Spain. Syngas production is expected to start in 2005.

Sinopec-Shell, Yueyang, Hunan, PRC

The coal gasification project in Yueyang, Hunan, is a 50:50 joint venture between China Petroleum and Chemical Corporation (Sinopec) and Shell that comprises gasification and air separation plants. Shell coal gasification technology will be used to convert coal into syngas at a

processing capacity of 2000 t/d. The syngas will replace the current naphtha-based feedstock for the fertiliser plant owned by Sinopec Baling Branch Company, Yueyang, China. The project will reduce feedstock costs for the Baling Branch Company and considerably improve its competitiveness.

The Sinopec Lanzhou Design Institute has begun to implement the gasification project, and start-up is planned for the end of 2005.

Sinopec, Zhijiang, Hubei, and Anqing, Anhui, PRC

Sinopec has two more coal gasification projects planned in Hubei and Anhui provinces. These will be similar in design and capacity to the Hunan project and will produce syngas for manufacturing fertiliser.

For both projects, the Sinopec Lanzhou Design Institute will use Shell Global Solutions' basic design to manage engineering, procurement and construction. Shell Global Solutions' consultants will provide technical services and work with Sinopec to ensure that project experience and lessons learned from the Hunan project are applied.

Currently, licensing agreements for three more coal gasification projects in China have been signed: one for Dahua Chemicals in Dalian, Liaoning Province; and two in Yunnan Province, for Yuntianhua Chemicals and Yunzhanhua Chemicals respectively. The Yunnan projects will be for gasifiers that can handle 2000 t/d of coal. The syngas product will be the feed for new fertiliser plants. The start-up of these plants is expected to be in 2006.

With three more licence agreements signed, Shell Global Solutions is now providing technology for eight coal gasification projects in China. Each project will process coal to syngas for chemical manufacturing – mainly ammonia-based fertilisers and oxo-alcohols.

These coal gasification developments are very important for the local Chinese economy. In China, many fertiliser companies use fuel oil or naphtha as feedstock. But, as fuel-oil prices have increased dramatically over the last decade, Chinese fertiliser companies are looking for alternative feedstocks to help improve their margins. Coal is plentiful in China and often locally available, which leads to reduced feedstock and transport costs that will significantly improve the competitiveness of fertiliser manufacturers.

With this in mind, the main drivers for the Chinese coal gasification projects are obvious. Firstly, companies want to produce low-cost feedstock – syngas – to reduce the cost of fertiliser manufacture and compete with imported fertilisers. Secondly, they are looking for cleaner fuel technology to replace existing, old and environmentally unfriendly facilities – both requirements can be met by SCGP.

Gasification of waste coal

Coal-to-clean fuels and power

Waste Management and Processors Inc. (WMPI), Gilberton, USA

WMPI has selected the Shell coal gasification technology for its coal-to-clean fuels and power co-production project at Gilberton, USA. The project also includes gas treatment and cleaning systems; Fischer-Tropsch synthesis technology to convert cleaned syngas into synthetic hydrocarbon liquids; and a gas-turbine combined-cycle plant to produce power and steam.

The Gilberton project will be the first commercial-scale application of waste coal gasification in the USA and will process about 4700 t/d of anthracite culm (40% ash) into 6×10^6 Nm³ of syngas and about 40 MW_e. The project will help to free land occupied by piles of coal waste and turn the waste coal into high-value distillate fuels.

Partial oxidation of natural gas

The second generation of Shell Middle Distillate Synthesis (SMDS) plants

The first fully integrated application of the gas-to-liquids SMDS process was the 12,500-bbl/d, commercial-scale plant at Bintulu, Malaysia, which started up in 1993. Since then, there have been important improvements in equipment engineering and catalyst performance and these have led to the development of a second generation of large-scale SMDS plants. The process schemes for these plants are similar to those of the Bintulu plant. Most of the required syngas feed will be produced in a Shell gasification plant, with the balance – about 15% – coming from a steam methane reformer. This combined arrangement delivers the 2:1 ratio of hydrogen and carbon monoxide favoured by the subsequent Fischer-Tropsch synthesis.

A special feature of these new gasification plants will be their large scale that typically requires 14,000 t/d of oxygen for a 70,000-bbl/d plant.

Preparatory work is moving ahead and is most advanced for two projects in the Middle East.

CONCLUSION

This overview illustrates that the SGP and SCGP are mature technologies that are being increasingly applied in many plants worldwide (see Table 1). Environmental legislation and better fertiliser plant and refinery economics continue to drive markets, so there is an on-going demand for these technologies.

With feedstock options ranging from biomass to pet-coke, coal and coal wastes and heavy residues such as asphaltenes from Canadian tar sands, Shell's gasification technologies provide an answer to future commercial challenges. The development of new technologies such as coal-to-clean fuels is expected to widen the use of Shell's gasification technologies further.

Shell Global Solutions aims to work closely with other parties to provide customers worldwide with efficient integrated solutions tailored to their needs in which gasification plays its key role. This can be done successfully using operational feedback from recently completed projects.

Table 1: Recent projects using Shell Global Solutions' gasification technologies.

| Owner | Location | Feedstock | Input (t/d) | Syngas output (10 ⁶ Nm ³ /d) | End product | Start-up date |
|-------------------------------------|----------------------------|-----------------|-------------|--|------------------------|---------------|
| Nuon | Buggenum, the Netherlands | Coal | 2000 | 4.0 | Power | 1994 |
| Shell Nederland Raffinaderij | Rotterdam, the Netherlands | Cracked residue | 1650 | 4.7 | Hydrogen/ power/ steam | 1997 |
| Lanzhou Chemical | Lanzhou, PRC | Vacuum residue | 700 | 2.1 | Chemicals | 1998 |
| Chemopetrol (revamp) | Litvinov, Czech Republic | Cracked residue | 1250 | 3.6 | Chemicals/ hydrogen | 2001 |
| Lucky Goldstar | Naju, Korea | Vacuum residue | 225 | 0.7 | Chemicals | 2001 |
| Shuanghuan Chemical | Yingcheng, Hubei, PRC | Coal | 900 | 1.3 | Chemicals | 2004 |
| Eni SpA | Sannazzaro, Italy | Cracked residue | 1200 | 3.4 | Power/ hydrogen | 2005 |
| Liuzhou Chemical | Liuzhou, Guangxi, PRC | Coal | 1200 | 2.1 | Chemicals | 2005 |
| Sinopec-Shell | Yueyang, Hunan, PRC | Coal | 2000 | 3.4 | Chemicals | 2005 |
| Sinopec | Zhijiang, Hubei, PRC | Coal | 2000 | 3.4 | Chemicals | 2005 |
| Sinopec | Anqing, Anhui, PRC | Coal | 2000 | 3.4 | Chemicals | 2005 |
| Opti/Nexen | Alberta, Canada | Asphalt | 3100 | 7.5 | Steam/hydrogen | 2006 |
| Dahua Chemicals | Dalian, Liaoning, PRC | Coal | 1000 | 1.5 | Chemicals | 2006 |
| Yuntianhua Chemicals | Anning, Yunnan, PRC | Coal | 2000 | 3.4 | Chemicals | 2006 |
| Yunzhanhua Chemicals | Qujing, Yunnan, PRC | Coal | 2000 | 3.4 | Chemicals | 2006 |
| Rafineria Gdańska SA | Gdansk, Poland | Asphalt | 1600 | 4.7 | Hydrogen/power | 2006 |
| WMPI | Pennsylvania, USA | Waste coal | 4000 | 6.0 | Synthetic hydrocarbon | 2007 |