Environmental and Economic considerations In Gas-To-Liquid Industry: the role of SASOL in gasification, 1970 – 2006

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The Iron Age came to an end, not because stones and rock supplies were eroded or completely exhausted. In a similar fashion worldwide utilisation of fossil fuels will not end because of complete erosion or depletion of resources, but rather because environmental degradation will compel the search for alternatives. (Miller, 2002) George Tyler Miller's observation expressed the rationale behind much of the research into alternative sources of energy to fuel the modern industrialised world economy. Apart from pressing environmental concerns, strategic geo-political developments also provided strong incentives for dedicated research. The OPEC virtual quadrupling of the price of oil in 1973/74, was described by Beenstock as "an unmitigated disaster." (Beenstock, 2007: 133) Some observers interpreted the oil price crises as the manifestation of Hotelling's Rule, which argued that the competitive price of exhaustible resources will increase over time at a rate equal to the relevant rate of discount. (Beenstock, 2007: 159) The higher oil price was therefore not exploitative, but in agreement with the inevitable logic of economics. The international impact of the oil crises paved the way for the report by the Independent Commission on International Development Issues (Brandt Report, 1980), which called for the creation of a New International Economic Order in which rich and poor countries would act in mutual benefit. The geo-political implications of the oil crises were impacting on the north/south economic relations debate, to which South Africa had been relatively marginal at that time. Politically South Africa was already experiencing heavy international criticism about domestic race policies, especially under the initiative of the Indian-led Non-aligned Movement members of the United Nations and the emerging newly independent African nations. Economic sanctions were not yet executed to the crippling effect of the late 1980's, but the South African fuel industry was nevertheless seeking access to more secure and economically viable sources of energy.

The one consequence of the oil crises was the new search for alternative sources of energy, compounded by the global awakening to the environmental catastrophe of global warming [*] imminently manifested. The energy conversion efficiency of oil to energy, is only 35%. Emissions are harmful: carbon monoxide, carbon dioxide, nitrogen oxide and sulphur oxide – all seriously damaging to the environment and adding to poisonous gasses in the atmosphere. Increasing global pressures on such emitting agents, have contributed to a convergence of research incentives by oil companies to find energy saving fuels as well as environmentally friendly production processes and consumer fuels. These initiatives also co-incided with the initiatives emanating from the World Commission on Environment and Development (The Brundtland Report: Brundtland, 1987). The Brundtland Report called for global environmental action on long term environmental issues, such as global warming. Actions from the recommendations of the report resulted in international agreements such as the Montreal and Kyoto Protocols, and Agenda 21.

This paper investigates the role of the South African Oil and Gas Corporation (SASOL) in the development of the gas-to-liquid (GTL) technology and the commercialisation of the environmentally beneficial gasification process and environmentally beneficial fuel. What was the role of SASOL in the development of new energy and environmentally conducive technologies and what was the impact on the performance of the corporation? What were the global forces driving the development of GTL technology and how were these reflected in the globalisation of Sasol's operations? This shows that a conscious business strategy pursued by Sasol demonstrated some similarities to those of big business (multi-national corporations) attempting to expand their operations into so-called emerging markets, although Sasol is seen to be a business seeking global penetration from an emerging market. Is there any difference between the strategy pursued by Sasol in its globalisation drive and that of other business groups expanding in the opposite direction?

Geo-political determinants of Sasol's operations: domestic, and international.

Sasol was formed in 1955 to advance the German Fischer-Tropsch process for the production of fuel from coal specifically adapted to the South African climate, quality of coal and stage of technological advancement. The production of diesel from coal had been implemented by the

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German army during the Second World War, but further sophistication in the United States of America in the Kellog Synfuel process required further adaptation to South African conditions. Sasol chemical engineers registered the unique Sasol Synthol process in 1953 and applied it without much adjustment until the 1970's. Despite the success in transforming the vast coal deposits of South Africa into synthetic fuel, production technology was expensive and highly subsidised by the South African government.[1] Sasol was regarded as a strategic industry to South Africa, since international sanctions had begun to exercise pressure on the country's access to international oil reserves. The fuel production at Sasol remained cost inefficient until late in the 1980's, but state subsidies protected the industry. (Verhoef 2003: 188, 196-199; Lambrechts, 1998:5)

The operational focus of Sasol was fundamentally influenced by the massive increase in international oil prices since the early 1970's. Two additional synthetic fuel production plants mere constructed to supplement initial production at SASOL 1 in Sasolburg. Simultaneous diversification in downstream chemical production opened the doors to the globalisation of Sasol research, technology and business operations. The diversification of Sasol operations commenced in the early 1980's, when the company was listed on the Johannesburg Securities Exchange and state control terminated. Sasol diversified operations into downstream chemicals production mining and related activities, oil refining and fuel marketing and the production of synthetic fuel. The research by chemical engineers in the synthetic fuel division of Sasol were ultimately responsible for the development of strategic technology that would develop a major political security and environmental advantage in the twenty first century.

The privatisation of Sasol and the political changes in South African domestic politics opened international markets to Sasol's commodities and intellectual property. During the last decade of the twentieth century, operating income increased by 19% per annum, total assets rose from R7,189 into R29,7m (an increase of 16,6%), while return on shareholders' funds rose from 22,8% to 24,4% per annum. (Verhoef 2003:193) During the closing decade of the twentieth century, Sasol diversified its production of downstream chemical production to the extent that the contribution of Sasol Chemicals to the corporation's total operating profit, increased from 20% in 1991 to 31,2% in 1995. (Sasol Annual Report; 1992; iv; 1996:9) In the following decade the synthetic fuel arm of the corporation's business again rose to prominence. Between 1991 and 1995 Sasol Synfuels' contribution to operating profits rose from 37% to 43,6%. Relatively speaking, this dominant position of synthetic fuels correlated with the initial niche specialisation of Sasol. Despite stronger growth in the production of chemicals, synthetic fuel production remained the core of Sasol operations. The initial foundation of the expansion for synthetic fuel production was the oil price increases of the 1970s, but especially the growing international antagonism towards South Africa following the student uprising in Soweto in 1976 and subsequent domestic political unrest, starting in the 1980s, but perpetuated into the late 1980s, resulting in the declaration of a state of emergency in 1986. Although Sasol supplied in only approximately 23% of domestic fuel demand, it represented a strategic cushion to an economy under growing isolation. Improved advanced synthol technology implemented in the two new Sasol plants at Secunda (Sasol 2 and Sasol 3), enabled the corporation to break even towards the end of the, 1990s, without state protection and at an oil price of US$ 13 p.b. (Sasol Annual Report, 1994: 15; 1995: 18) Sasol commenced with the manufacturing of unleaded petrol and the export of liquid petroleum gas to neighbouring countries. Fuel alcohol was exported to Brazil and towards the mid-1990s Sasol was exporting products to the value of R350 m. (Sasol Annual Report, 1995: 17; 1996: 15)

The geopolitical environment had changed rapidly by the late 1990s. In the first place the South African government under President F.W. de Klerk announced the commencement of negotiations towards the transition to a democratic government, co-inciding with the unbanning of all political parties and release of political prisoners. In South Africa the announcement of February 2, 1990 ushered in political transformation as well as international business and investor interest in the country. These political changes facilitated the global expansion of South African business interests, amongst which also SASOL. After signing the Uruguay Round of GATT negotiations in 1993, the South African government appointed the Liquid Fuels Industry Task Force (LFITF) to investigate the tariff protection awarded to SASOL since listing in 1979. Various mechanisms were devised, based on an agreed crude oil floor price which determined varying levels of tariff protection on synthetic fuels. The dramatic rise in international oil prices since late 1999 in actual fact meant that Sasol received no tariff protection since the last quarter of 1999 until 2002. (Sasol Annual Report, 2002: 25) The marketing of Ssol's synthetic fuel was highly regulated in South Africa – Sasol had to supply petrol to coastal retailers at the same price as to inland distributors. That was the inland basic landed cost (IBLC) plus transport cost from the coast to inland locations.

Sasol could also not operate its own service stations, but was permitted to sell its petrol only at designated sites, or at clearly identified blue pumps (Blue Pump agreement) at the service stations of other petroleum companies. Finally speculation about the deregulation of the domestic fuel industry convinced the management of Sasol that the company would perform far better without any protection or restriction. In December 1999 Sasol officially announced that it would terminate the "Blue Pump" Agreement as well as the agreement to supply fuel to other oil companies in South Africa, in five years time. Sasol welcomed the new approach by government to deregulate the liquid fuels industry. In a statement Sasol announced; "Such an approach will afford al participants in the industry, particularly the small players and previously disadvantaged groups, the opportunity to grow and transform in order to become more competitive." (Engineering News, 17-25/6/98; The Star Business Report, 10/12/98; Business Day, 10/12/98) A confluence of the impacts of the domestic political transition, global market transformation and international trade deregulation, thus impacted on the business strategy of Sasol towards the beginning of the twenty-first century.

A conscious business strategy towards the globalization of operations emerged at Sasol at the beginning of the new millennium. The chairman, mr Paul Kruger stated in the Chairman's statement, in 1999 that, "Sasol has clearly signaled that it is becoming more of an international player and events in the rest of the world are therefore of greater importance to it". (Sasol Annual Report, 1999: 6) The new business strategy for a privatised and non-tariff-protected and subsidy free Sasol was two fold: first the corporation would develop new international business and joint ventures in collaboration with international marketing companies, by means whereof Sasol would diversify its operations into established former markets of Sasol, but also to seek and develop new markets offshore. This aspect of its new vision was firmly directed at the distribution of the existing product base. The second dimension of the business strategy of Sasol was premised on the pioneering technology, developed in Sasol, which afforded the corporation a competitive advantage in the international synthetic fuel industry. The strategy was to develop its ground breaking Slurry Phase Distillate (SPD) technology as the driving force or engine of significant future global growth. (Chemical Marketing Reporter, 1996: 9) The global positioning of Sasol was inevitable: businesses built around natural resources are usually global, because they serve international customers in advanced markets, they seek alternative sources of resources due to the saturation or cost of domestic materials, and because such "…companies move up the value chain, selling branded products or offering solutions to niche markets." (Khanna and Palepu, 2006:67)

The strategic direction of Sasol was taking shape within the international debate on sustainable development and environmental protection. The initial announcement by Sasol of its intention to advance its SPD technology internationally, was made in May 1996 at the Fourth World Forum or chemicals, in Paris. The conference addressed the theme of sustainable development, with specific emphasis on the need for new fuels and fuel production processes, together with the development of materials which minimize waste and pollution particularly in areas such as transport and construction. (Chemical Marketing Reporter, 1996: 10) International concern about sustainable development and the environmental problems facing the planet, constituted the framework of research and technological development within which Sasol corporate business development would take shape. The Report of the World Commission on Environment and Development (Brundtland, 1987) defined the parameters of the growing global shift towards international environmental action. The report approached environmental and development issues as common concerns, within a holistic perspective and placed great emphasis on the urgency for increased co-operation with industry to address such concerns. The consequence of the Brundtland Report was most visible in the signing of the Montreal and later Kyoto Protocols. The direct link between economic growth and environmental protection emerged as a prerequisite for future business development and planning. Apart from growing international consensus on climate change and global warming, big business in the chemical industry also signed the Stockholm Convention[2] (convention held May 2001; entered into force 17/05/2004) as well as the Rotterdam Convention[3] (signed 10/09/98; entered into effect 24/2/2004 http://www.pic.int/home.phb?type=sid=16) Sasol was a signatory to both of the latter conventions. This signified the growing integration of environmental considerations with business development, globally as well as in the South African business environment. Since the Brundtland Report the global environmentalism has gained impressive momentum, to the extent that a series of international agreements such as the Montreal and Kyoto Protocols and Agenda 21 were agreed, which enshrined the concept of environmentally sustainable development further. Article 2(i) of the Kyoto Protocol stated that "Each Party … in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development, shall:

(a) Implement and/or further elaborate policies and measures in accordance with its national circumstances such as:

(i) Enhancement of energy efficiency in relevant sectors of the national economy;

(iv) Research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and of advances and innovative environmentally sound technologies: "…These protocols of international consensus constituted the frame work in which much of the development of synthetic fuel technology would emerge as a vital contributor to the implementation of the goals of the Kyoto Protocol, as well as an incentive to expansion of global business opportunities.

<u>Sasol's innovation in gas-to-fuel-technology.</u>

The grip of OPEC on oil prices and production levels in the 1970s and early 1980s stimulated the search for alternative sources of fuel and alternative technology to utilize the new raw materials. Natural gas emerged as a valuable feedstock for the production of synthetic fuel. The global need for less carbon-intensive fuels and cleaner urban air provided additional incentives in the post-Brundtland era of environmentalism, for research to develop appropriate technology. Although oil prices have returned to 1972 levels by 1998, current prices contribute significantly to the affordability of new technology. (Beenstock, 2007:135) Some commentators even envisage a future global economy powered almost exclusively on alternative fuel, such as gas (Fleisch, Sills, Briscoe, 2002:2) Whereas the crisis dimension of the oil price hikes of the early 1970s may have subsided, the affordability of new technology based on the conversion of alternative feedstocks, remain problematic.

Sasol's decision to privatise or list in 1979, included that the company wanted to improve profitability by reducing its dependence on international oil prices. This was a conscious business decision. The first step was to improve the Fisher-Tropsch reactor technology use to produce oil from coal. In 1981 a programme was commenced to improve the existing adapted technology applied in Sasol 1 in Sasolburg. This new research was based on earlier research which had been undertaken in Brownsville, Texas, by Dobie Keith of Hydrocarbon Research Inc during the 1940s. Worldwide anxiety escalated about the possibility that crude oil reserves might run out. (Collins, 2007:118) Researchers under the leadership of Keith investigated the methodology to convert natural gas to fuel by using a fluid flatbed (FFB) reactor. This research was not completed, but was shelved as the price of natural gas rose and vast new oil reserves were found in the Middle East late in the 1940s. Sasol engineers continued this investigation for the purpose of improving the efficiency of its own synthetic fuel reactor. In 1981 Sasol management authorised the designing of an FFB demonstration reactor and in 1987 the new reactor was installed in Sasolburg. The demonstration reactor was called Sasol Advanced Synthol (SAS) reactor and was easier to operate, cheaper to run and more efficient in producing clean gas. The SAS reactors were installed at Sasol 2 and Sasol 3 in Secunda in 1992 and by 1996 all synthol reactors at Secunda were replaced by SAS reactors. (Collins, 2007: 123) This technology improved efficiency had reduced production costs at the time that Sasol was informed by government that tariff subsidies would be phased out. Sasol spent US$1 billion on this development which reduced its operational costs by the equivalent of US$1 a barrel of crude oil. (Collins, 2007:129) Sasol's profitability was therefore enhanced by technological developments and contributed to free Sasol further from world oil prices.

The Sasol business strategy was closely linked to the development of new technology. Sasol experimented with the use of its advanced Fischer-Tropsch SAS technology had been performed for the production of diesel. Most of the hydro-carbon molecules produced in the SAS reactors, were straight-chain carbons which ignite faster. (Van Dyk, Keyser, Coertzen, 2004:1) Sasol then developed its new SPD technology: slurry phase distillate technology. (Sasol Annual Report, 1997:51; Annual Report, 2000:58). The Arge reactors used in the manufacturing of petrol, was producing more petrol than diesel. The demand for diesel was growing and Sasol management supported ongoing research to improve the older reactors. In May 1993 the SPD technology was developed. It was based on a five metre diameter slurry bed reactor, incorporating the shell of the SAS reactor pioneered earlier by Sasol. (Verhoef, 2005:205) Sasol had been operating the Sasol-Lurgi fixed bed gasification process for more than fifty years (Van Dyk, Keyser, Coertzen 2004:2) using coal as feedstock. Subsequently, SPD technology was developed in 1993 to use the Sasol-Lurgi process to manufacture diesel from gas, as opposed to the manufacturing of diesel from crude oil. The synthetic gas (CO+H) produced in the Sasol-Lurgi process produce more than 30 million tons of synthetic gas per annum. By 2004 the production of synthetic gas by the 97 gasifiers used by Sasol had risen by almost 15% (Van Dyk, Keyser, Coertzen, 2004:3) "The Sasol process starts with the Gasification plant where coal is converted to crude gas under pressure and at high temperature in the presence of steam and oxygen … the purified synthesis feed gas is made available for conversion into long chain hydrocarbons with SAS or Sasol Slurry Phase Fischer-Tropsch proprietary technologies." (Van Dyk, Keyser, Coetzen, 2004:3) This gasification process then produces a variety of co-products, but the most important application is the use of synthesis feed gas at a lower temperature than in the case of the SAS reactors, to produce high-quality diesel. This production process is the most efficient in the world. Sasol plants in South Africa produce 3,2 million m^3/synthesis gas per hour in its 97 gasfiers, while the Dakota Gas Company in the USA operates only 14 similar gasifiers, the Schwarze Pumpe in Germany only 7 and even less in the Czech Republic. (Van Dyk, Keyser, Coertzen, 2004:5) The significance of the more efficient gasification process developed by Sasol, was that Sasol technology was applied to produce the world's purest diesel: five-meter diameter slurry bed reactors were built, incorporating the shell of the SAS reactor pioneered a few years earlier, to be fed by the gasifiers that had served the three retired Synthol reactors in Sasolburg. Construction was completed in May 1993 and the new plant produced diesel that contained almost no sulphur aromatics. Sasol's diesel had achieved a major environmental advantage over other conventional diesel products, since governments in primarily developed countries were expected to impose an even more stringer set environmental demands on vehicle emissions. (Sasol Annual Report, 2000:56-57) The SlPD process offered a major competitive advantage to Sasol, which would lead to further applications.

This important technological development was eventually transferred to further application in the gas-to-liquid technology. Worldwide oil companies were searching for new fuels and new production processes, together with the development of materials which minimise waste and pollution. (Chemical Marketing Report, 1996:9) The key to the exploitation of this technological advantage lay in accessing the source of feedstocks for the application thereof - that is gas. The source of the natural gas deposits lie outside the developed world – gas resources are already utilised domestically in the developed economies, leaving the use of so-called "stranded" or remote natural gas resources as the only solution to the problem of access to feed stocks to oil companies (Taylor, 2007:51-53) The Sasol adaptation of the Fischer-Tropsch process, by means whereof methane gas is converted into synthesis gas, offered a unique advantage to Sasol in the search for environmentally conducive fuel. Methane gas is one of six gasses targeted under the Kyoto

Protocol. Sasol's adaptation of the Fischer-Tropsch process using a cobalt-based catalyst in its slurry phase reactor, offered an internationally leading technology. (Taylor, 2007: 35; Wilhelm, Simbeck, Karp, Dickenson, 2001:145-146) The main problem in the application of this innovation, lay in the high cost. Fleisch (et al) argued that the chemical conversion process' cost was expensive and therefore inhibitive for the development as a serious alternative to oil. (Fleisch, et.al, 2002:3-8) The Sasol cobalt-based catalyst and SPD reactor has been widely acclaimed for improving the economics for producing Fischer-Tropsch diesel fuel. (Norton, et al, 1998:4-5). The most efficient way to reform methane (natural gas) into diesel and for hydro cracking wax into diesel was required to advance the Sasol innovative SPD process commercially. Sasol decided on the auto thermal reforming process (ATR) as the most suitable and efficient method to reform methane gas. (Wilhelm, et.al, 2001:145; Fleisch et. al 2002:6-8) This method involved the heating of methane gas in the presence of oxygen and a catalyst. It was most competitive with the iron and cobalt-based SPD process developed by Sasol. This technology (ATR) had been developed in Denmark by the Haldor Tropsϕse company. Sasol purchased this technology license for application in its gas installations. (Sasol Annual Report, 2002:50) Fleisch, et.al, 2002:4) Sasol then entered into a joint venture with Chevron Texaco, to perform the process of hydro cracking wax into diesel. (Engineering News Round, 242 (24); 22; Pump Industry analyst July 1999:2) Oil and Gas Journal, 98(51): 46) The Sasol Chevron joint-venture started the search for commercially efficient applications of GTL technology on a global scale.

Commercialisation of GTL technology.

The development of an improved Fischer Tropsch process to produce fuel from coal inspired further research to improve the efficiency of the technology and eventually provided the platform from which Sasol could venture into the global fuel markets. The improved Sasol SPD process thus offered an opportunity for the global development of GTL installations in order to promote lower volumes of greenhouse gas emissions. The joint venture with Chevron resulted in the establishment of Sasol Chevron as the operating vehicle for international application of the Sasol SPD process and Chevron technology. Sasol then embarked on exploration exercises to identify gas resources for the production of the new clean-burning, low-sulphur synthetic faction of diesel. Sasol Chevron Ltd was launched as the exclusive vehicle for application of Sasol's SPD technology. The joint-venture would seek third-party and parent gas reserves worldwide, it would establish GTL plants and market GTL products.

The new joint-venture between Sasol Synfuels International and Chevron Texaco (Sasol Chevron Ltd; based in London) proceeded almost immediately with plans to implement the new technology on natural gas fields at Ras Laffran in Qatar. A joint-venture was signed with Qatar General Petroleum Corporation and Phillips Petroleum of the USA for the construction of a new-generation plant to produce 20 000 barrels of fuel per day, applying the Sasol SPD process. (Sasol Annual Report, 2000:47; Sasol Press Release: http://www.sasol.com, 16/04/02) While Qatar aimed to become the world leader in GTL projects (European Chemical News, 2002:54) with six major GTL projects planned since 2000, Sasol Chevron offered groundbreaking technology to reduce the cost of such new plants. The Sasol Chevron technology was licensed and sold to potential licensors as a bundle GTL products. The bundle consisted of an ATR process provided by Haldor Topsøe (from Lyngby, Denmark) for syngas production, the Sasol SPD process for Fischer Tropsch, and Chevron's isocracking or Isodewaxing processes for fuels or lube based oil. (Oil and Gas Journal, 2000:47) This technology had been perfected since 1995 to reduce establishment capital costs by 20% to build a GTL plant.

The joint-venture offered Sasol partnership with a strong USA based oil corporation to venture into the global fuel arena. Sasol had produced fuel from coal for more than fifty years but for a limited cost-intensive domestic market. The newly developed pioneering technology paved the way for global application given two major developments: growing international concern about environmental changes and adverse effects of prolonged oil consumption as the primary source of fuel, and the rising oil price under the control of a politically potentially threatening dispensation to first world economies. Sasol Chevron Ltd therefore explained the strategy of the enterprise as first to commercialise the SPD technology, eg. outside South Africa in Nigeria, and then to refine the technology to drive down capital and operating costs. Sasol Chevron set out to identify new prime sites for such GTL plants and value added opportunities to generate early revenue. In the second phase of the joint-venture Sasol Chevron set out to improve technology further and to invest in high return projects, Capital costs of $20 000 bpd was the set target in order to be competitive with existing refineries (which produced fuel at a cost of $13 000 bpd. Cost efficiency drives were supported by cleaner international fuel regulations and the worldwide trend for dieselisation of the transport industry. (Fleisch et al, 2002:6; Wilhelm, 2001: 145, 147)

The second initiative of Sasol Chevron was the building of a 34,000 bpdl GTL plant on a site adjacent to the Escavros River in Nigeria to convert gas into diesel. (22.300 bpd ultra-clean diesel, 10800 bpd, naphta and 1000 bpd liquid petrol gas). The exact technology bundle of Sasol Chevron as applied in Qatar would be used. The project was officially recognised by the Nigerian government in September 2000 and targeted production by 2005. (Fleisch et al 2002; 6:8; Wilhelm, et al 2001:145; Asian Chemical News, 2003: 16/6/2003) The initial focus of Sasol Chevron was on Nigeria and Qatar, Sasol further entered into an agreement with the government in Mozambique to transport natural gas by means of a 865 kilometre pipeline from Mozambique to Secunda (at the Sasol 2 and Sasol 3 plants in Mpumalanga) to use gas as primary feedstock in the production of synthetic fuel. The Sasol Mozambique Natural Gas Project commenced with the import of natural gas from Mozambique since 26 March 2004.Reserves were sufficient to guarantee delivery for 17 years. (DME, 2005: vii; Sasol Annual Report, 2004:36; 2002:43)

The high cost involved in establishing GTL plants, served as a major brake on the implementation of GTL projects. The cost deterrent had led to the shelving of the development of the natural gas field found by Shell in 1971 at North Field, of the coast of Qatar. The Sasol SPD cobalt-based catalyst, improved reactor technology reduced cost in the area of large scale air separation dramatically. (Wall Street Journal, 2005:A1) Belussi et al had indicated in 2004 already that the cost breakdown for a GTL plant has made up approximately 60% of investment costs for the syngas section, 25% for the Fischer Tropsch section and 15% for the waxes hydro-cracking section. (Belussi et al, 2004:3 Oil & Gas Journal, 2000:46) Initial investment cost was calculated at US$30 per barrel, but by 2004 further research and development had brought it down to US$20 per boe. (Belussi, 2004:3; Wall Street Journal, 2005: A1) The improved technology efficiency convinced the Qatar government to permit the commercial extraction of gas. The original agreement between Sasol Chevron Ltd and Qatar Petroleum in 2001 was later renegotiated in 2004 to provide for increased capacity at the Ras Laffran plant. Planning was amended in 2004 to increase capacity from 34 000 bpd to 65,000 bpd in 2009 and eventually 130 000 bpd by 2010. (Chemical Week, 31/3/04:20; Financial Times, 2007:27; Greene,1999:40)

The economy of scale of GTL plants has been fully recognised. A recent study by Boerrigter (2006) indicated that production below 20 000 bpd would cause the total capital investment costs to rise rapidly and thus renders such installations unattractive and not economically feasible. (Boerrigter, 2006:14-15) Boerrigter calculated the main equipment costs at 100 units of total investment costs, another 100 units of cost for auxiliary costs (buildings, site improvements, utility and service facilities, storage and distribution, as well as the purchase of land. Owners' cost (indirect costs for R&D, engineering, construction, contractors' fees and contingencies, working capital and start-up costs) would add another 40 units to total investment costs. (Boerrigter, 2006 14) These costs could only be justified if the international oil price is above $20 per barrel, which has been the case since 2005. Analysts have calculated the cost of production of one barrel GTL diesel at approximately US$14, which then satisfies the investment in GTL production. It was calculated that at world oil prices at a level of US$25 per barrel, GTL diesel production delivered a return of approximately 19% on investment. (Wall Street Journal, 2005: A1) Greene calculated that even if associated concern sales of stranded natural gas reserves, sold at a slight premium, and an international oil price in excess of $30 bpd, then GTL fuel could still sell at $17 barrel and post a 15% rate of return. (Greene, 1999:16)

These beneficial cost developments justified the construction of three large GTL projects. These included the ORYX-1 plant, at Ras Laffran, Qatar, built by Sasol-Chevron. The scale of this development is currently 34 000 bpd, with a projected increase in production by 2010. The second is the PEARL plant of Shell in Qatar, at a scale of 70 000 bpd. The third is the Escravos plant in Nigeria, in collaboration with the National Nigerian Petroleum Corporation and Chevron Nigeria Ltd. This plant will also produce 34 000 bpd when production commences in 2009. Sasol Chevron is also in negotiations with the National Petroleum Company of Iran with the intention to develop a GTL project at Bandar Assaluyeh. Negotiations are also conducted with the government of Australia to develop a GTL plant off the Australian west coast at the Burrup Peninsula. (Sasol Annual Report, 2005:13; Sasol Chevron consultancy, 2001:17; Financial Times, 2007:27)

The advantages of the development of GTL technology is significant, because it offers both environmental benefits and important efficiency gains. Combustion engines are 30-50% more efficient than sport ignition (petrol) engines and GTL fuel (primarily diesel) gives more kilometres per litre of fuel and reduced exhaust gas emissions. GTL fuel is already the most greenhouse efficient fuel. Incorporating this technological development as part of the Sasol business strategy, contributed significantly to the globalisation of Sasol's business and its operations outside the South African market.

The Sasol proprietary SPD cobalt reactor process integrated into the Sasol Chevron GTL technology, is responsible for the cost efficient operations at the Sasol Chevron GTL plants. The GTL plants converts natural gas into high quality GTL diesel (70-80% of production), GTL naphta (20-30% of production) and a small volume liquefied petroleum gas. (LPG) (Adegoke, 2006: 27 – 32) Naphta is a feedstock for steam cracking in the production of ethylene which is the basic building block in the petrochemical industry's production of plastic polyethylene and other derivatives. The GTL fuel enhances fuel efficiency in auto motive transport, because of the following characteristics:

- GTL fuel consists almost entirely of paraffins, which have a higher hydrogen-carbon (H/C) ratio and therefore a lower density (0.78kg/1 compared to 0.82-0.85kg/l of ordinary petrol from crude oil)
- Low aromatic content, approximately less than 1%.
- GTL fuel has a high energy content, since its gross heating value of 46.1 MJ/kg is 4-5% higher than conventional diesel.
- GTL fuel has a high cetane number in excess of 70, while retaining good cold flow properties ((CFPP of less than 10°C).
- GTL fuel has a very low sulphur content of less than 5 ppm.
- GTL fuel contains essentially zero oxygenates, because the SPD process involves a hydro-processing step that removes polar molecules.
- GTL fuel has a negligible metals corrosivity – too small to be considered significant (Was tested on carbon steel, aluminium alloy, copper alloy)
- GTL fuel is "readily biodegradable". A compound is considered "readily biodegradable" when it achieves 60% biodegradation within 28 days – GTL fuel was tested in two ecotoxicity tests (Activated Sludge Respiration Inhibition (ASRI) test and the Pseudomonas Putida Growth Inhibition Test). These confirmed that GTL fuel is non-toxic to bacteria in concentrations of up to 100,000 ppm. This is above the solubility limit of the product in

water and means therefore that, should GTL fuel land in sewage works, it would not jeopardize the efficiency of waste water treatment systems.

- Engine performance and fuel consumption is superior to performance achieved using conventional diesel. If the standard compression ignition engine is adopted to exploit the benefits of GTL fuel's higher octane and other charateristics mentioned above, performance is expected to improve even further.
- Exhaust emissions of GTL fuel exhibited substantially lower hydrocarbon, carbon monoxide, oxides of nitrogen and particular matter. Global concern has risen particularly about the emission of aromatic hydrocarbons and poly-aromatic hydrocarbons because of their carcinogenic effects and about oxides of sulphur in regions where acid rain is a problem. Hydrocarbon emissions from GTL fuel combustion was proven to be between 40 and 60% lower than for conventional diesel. (Sasol Chevron Consulting, 2001:8-15; Green, 1999: 18-33)

Although favourable environmental factors place the global use of GTL fuel in a strong commanding position, cost still act against universal use. The Sasol Chevron Oryx GTL plant, that was intended to commence production in June 2006, met with technical problems in ancillary equipment and postponed full normal operational production to the middle of 2008. The cost of the Qatar GTL plant to Sasol Chevron was US$850m and escalated to $1bn. The Shell initiative in Qatar also experienced cost increases from initial estimates of US$5 bn to US$18 bn (for a 140 000 bpd plant) In 2007 Exxon Mobil scrapped plans to build an enormous GTL plant in Qatar. (Engineering News, 2006: Financial Times, 2007:27) Cost efficiency has in the meantime improved with the dramatic increase in the international oil price well in excess of US$90 bpd. Economies of scale remain the main solution to establishment cost. Sasol Chevron as a joint-venture has therefore embarked on the exploration of opportunities to create an installed GTL capacity of 500 000 bpd by 2013. Sasol Synfuels International would take up about 260 000 bpd. In South Africa Sasol Synfuels has an installed capacity of 160 000 bpd already (Sasol Annual Report, 2005:24-25) The demand for GTL fuel rose internationally as oil prices rise, natural gas markets tighten and environmental regulations on cleaner fuels have come into play. (In South Africa the sale of leaded fuel by oil refineries was prohibited since the beginning of 2006. Engineering news, 2006) A major region of expansion is the environmentally sensitive Australian local market, where a GTL plant producing 60 000 bpd is under investigation. Financial Times, 2007:27)

Sasol business strategy: expanding from an emerging market.

The Sasol business strategy that focused on global expansion, has proven to be implemented at the right time. Initiatives by the new government encouraged the formulation of a business strategy that would enable Sasol to access global markets as a strategic move. Internationally environmental concerns and growing geo-political security concerns favoured the commercialisation of GTL technology In 2006 the South African government threatened to tax Sasol on the windfall profits made following the rise in the OPEC manipulated international oil price. The Minister of Finance unexpectedly announced in his budget speech in February 2006 that government was investigating windfall profits made by the synthetic fuel industry in South Africa. (Financial Mail, 2006; Business Day, 2006) This development issued a signal to Sasol that it should actively pursue the opportunities of the global economy. Sasol's SPD process technology was registered proprietary technology, which the company planned to use in order to enable Sasol to produce more than 50% of its liquid fuels outside South Africa within ten years. (Greene, 1999:17; Sasol Annual Report, 2005:25) In Australia the government has also introduced an alternative fuel policy to encourage the use of environmentally friendly fuels. That policy had not yet introduced a tax-neutral dispensation that would actively encourage the use of the most efficient, environmentally and greenhouse beneficial fuels across the board. (Sasol Chevron Consulting, 2001: 23 – 24) Sasol had made submissions to that effect to the Australian tax authority hoping that the company would be able to export its expertise and propriety technology to gas fields in Australia soon. The production of GTL diesel could also benefit from rapidly increasing USA security concerns to strengthen the demand for alternative fuel sources. (Greene,1999: 34- 35). Another potential source of demand for GTL fuel has recently been identified in a study by Adegoke. This study argued that steam generation in the air separation unit and in the syngas generation phase of GTL processing, could simultaneously generate steam which could be utilised for the generation of electricity. (Adegoke, 2006: 27 – 30) This new possibility could potentially offer multiple advantages to developing nations in Africa requiring basic infrastructure, such as electricity supply.

In assessing the forces behind the massive research and development investment by Sasol, the business strategy of the company as a potential global player from an emerging market base, needs to be considered. Sasol started operations as a strategic concern for the South African government. The costs of research and initial production, were highly subsidised by the state, but the commercialisation of operations in the late 1970s was driven by management's insistence on privatisation. The result was the listing of Sasol on the JSE in 1979. The decision by Sasol to privatise and restructure its business operations to take advantage of its most valuable asset, that was the production of synthetic fuel and all the further research and development and subsequent technological innovation, was a conscious business strategy. (Verhoef,2003:205-210) Given the opportunities of globalisation, Sasol could only take full advantage of the opportunities offered in global markets if the company could establish partnerships with global concerns in related business operations on the basis of its technological innovation. To Sasol that provided the impetus towards further internationally leading technological innovation within the context of environmental concerns about gas emissions, fossil fuels and sustainability of fuel production.

The most critical challenge to management teams of large corporations, according to Khanna et al in North America, Europe and Japan is globalisation. (Khanna et al, 2006:63) Although much of the studies by the authors are concerned with the operations of multinational corporations outward from the designated regions into so-called emerging markets, exactly the same forces applied to the diversified conglomerate that Sasol had developed into, attempting to expand business operations globally. The business of Sasol was a hybrid of the concerns of developed countries' multinationals seeking to move into the fast growing emerging markets and emerging giants seeking to expand from emerging markets. Sasol sought to expand from a partially emerging market and was entering into other emerging markets itself. The explorations for natural gas into Mozambique and Nigeria presented similar risks of having to deal with 'institutional voids' (Khanna et al,2006:63-64, 73) The Sasol strategy was to strengthen its own business position through joint-ventures, for example with Chevron, when entering the markets of Nigeria and Qatar. Sasol offered the 'security' of leading technology in synthetic fuel production and utilised the established size and reputation of Chevron to secure its global operations in exporting its innovative technology. The two dimensions of Sasol's successful business strategy were the restructuring of its business operations into focused business entities specialising in particular areas of the chemical and fuels industry (as discussed in Verhoef, 2003) and secondly, globalising operations on the strength of new technology. The latter was strongly conditioned by international environmental concerns, referred to above. Sasol had established an international 'brand' with its proprietary Fishcer-Tropsch synthetic fuel-from-coal process (first adapted in the SAS and later the SPD processes) and used that advantage to expand globally. This was the exact same distinctive strategy applied by Western, Japanese and South Korean companies that appeared "…to hold near insurmountable advantages over businesses in newly industrializing countries." These concerns introduced "… brand names, efficient innovation processes and management systems and sophisticated technologies, but also had access to vast reservoirs of finance and talent." (Khanna and Palepu,2006: 62) The success of the Sasol brand was confirmed by the secondary listing of the company on the New York Stock Exchange on April 9, 2003. The share opened at US$10.90 and rose to $45 later that year (Sargeant,2006) Sasol was therefore successful in tapping into international financial markets by attracting the interests of international investors in its operations and business performance. (Khanna and Palepu, 2006: 63) Sasol thus displayed characteristics comparable to business strategies of multinational corporations in developed countries seeking to expand their operations in emerging markets of the developing world.

In strengthening the Sasol brand as a responsible international role player in the synthetic fuels industry, the company joined the international environmental actions to enhance environmental responsible behaviour, to promote environmentally friendly and sustainable fuel production and promote overall human health and safety. Part of delivering the distinctive Sasol brand internationally, was to do so as an environmentally responsible company. Whereas business groups in emerging markets "…created value by developing a common group brand that stand for world-class quality and customer service.." (Khanna and Palepu,1999:129), Sasol was creating that notion of a world-class environmentally responsible oil company. This constituted a strategic component of Sasol's business strategy. (Sasol SD Report,2007: 3) For Sasol to succeed globally, especially in the GTL-industry, it was imperative that production was focused on the global tier. This meant that products offered domestically and globally had to comply with equally high standards of quality. (Khanna and Palepu, 2006:65) This requirement was especially important as far as the adherence to international standards of GHG emission and bio-degradability is concerned. Although some of the products of Sasol Chemicals (detergents, waxes, etc) were more targeted on the glocal and local markets, GTL fuel had to comply with international standards of efficiency and environmental sustainability. To illustrate the superiority of the new Sasol-Chevron GTL diesel, the Sasol-Chevron Challenge was held,[4] demonstrating the world-class nature of the product.

Operations at Sasol's various divisions in South Africa and in other parts of the world, were all systematically aligned with international environmental sustainability requirements. Global growth was premised on compliance with international sustainability benchmarks and related environmental concerns. In this respect Sasol set an impressive example in South Africa as well as in Africa. In 1994 Sasol signed the Responsible Care programme and participated since in the Sustainability Reporting Guidelines of the Global Reporting Initiative (GRI). (Sasol Annual Report,2001:88; 2005:57) Since 1996 Sasol issued an annual review of its compliance with various environmental standards. Since 2002 a separate Sustainable Development Report was published in the public domain. Sasol had committed itself voluntarily to international sustainability standards because compliance was accepted as "…an important part of our strategic commitment to sustainable development." (Sasol SD Report,2007:9) Since 2000 Sasol subscribed to the international ISO 14001 environmental management system and subjected each business division to the gradual compliance with the ISO certification process. Seven businesses received ISO 14001 certificates in 2000 – which was interpreted as a major achievement, since two of the successful entities were mines: the Wonderwater coal mine was the first strip mine and the Bosjespruit mine (also coal) was the first underground colliery to receive ISO certification. (Sasol SD Report, 2000: 64 – 66) Massive capital expenditure was made since 2000 to reduce emissions of process chlorine, sulphur dioxide and hydrogen sulphide. Extensive emission management programmes were implemented at the Sasolburg synthetic fuel plant and the Natref refinery, leading to reductions of up to 20%. (Sasol SD Report, 2003:68) The introduction of natural gas as feedstock for the manufacturing of synthetic fuel in 2004 reduced hydrogen sulphide emissions almost completely, sulphur oxide by 17% and carbon dioxide by 47%. (Sasol SD Report, 2003:69) By 2005 more explicit emission targets were formulated: to reduce the emission of volatile organic components (VOCs) by 50% on the 2005 baseline by 2015 as well as to reduce GHG emissions by 10% by July 2015. (Sasol SD Report, 2005:56)

The endeavours to comply with international environmental best practice met with a fair degree of success towards the end of 2007.

Table 1. Sasol Group Performance on environmental targets, 2005 2007.

Emission type	2005	2006	2007
Total greenhouse gas emissions (CO_2 equivalent)	72 015	72 975	70 922
Hydrogen sulphide (H_2S kilotonnes)	89	78	74
Nitrogen oxide (NO_x kilotonnes)	163	160	162
Sulphur oxide (SO_x kilotonnes)	222	223	219
Hazardous waste (kilotonnes)	272	254	138
Non-hazardous waste (kilotonnes)	846	910	1003
Water (1 000m 3)	146 515	142 722	140 469

Source: SASOL Sustainability Report, 2007 : 4.

These statistics indicate sustained but slow progress on sustainability indices by Sasol. Sasol had set itself the target of inclusion in the Dow Jones Sustainability Index (DJSI). In 2003 Sasol's rating was 70%, in 2005 73% and in 2007 again 70%. That rating again failed to secure Sasol inclusion in the top 10% of the DJSI in 2007. (Sasol SD Report, 2007:8) In subjecting the group to perpetual scrutiny in order to gain DJSI inclusion, Sasol showed genuine commitment to the Global Reporting Initiatives' (GRI) Sustainability Reporting Guidelines (SRG). In 2007 Sasol's Sustainable Development Report complied with the G3 guidelines for sustainability reporting. (Sasol SD Report,2007:9) Although the Sustainable Development Report of Sasol reported on all aspects of Group operations, the relevance to the analysis of Sasol's global performance in GTL production, is that globalisation of operations would be blocked unless compliance across the board of its oil and gas operations could not be confirmed. Environmental compliance had become an integral part of business strategy and a prerequisite for global expansion.

The extensive research and development activities of Sasol facilitated the global expansion of its operations in a dynamic three-way interaction: adaptation of the Fischer-Tropsch process enabled the coal-to-liquid petroleum production process. This was required to meet domestic South African needs. That specific technology was then improved and sophisticated to enhance efficiency and productivity in production as well as application. The third dimension was added by growing international pressures towards environmental sustainability and development, to which Sasol as a company in an emerging market could either respond to or ignore. If the company desired to expand into the global market, then its business strategy had to take the global environmental forces into account. The growth of Sasol illustrates the dynamic interaction between internal business strategy, domestic socio-economic forces and global geo-political forces. By 2007 Sasol had operations in 33 countries, of which more than half were directly benefiting from GTL operations.

Conclusion.

The development of new GTL technology by scientists and engineers at Sasol was a response to a number of forces affecting South Africa and therefore the companies conducting business within it. It was simultaneously a response to international forces on environmental matters, which gained prominence and intensity towards the late 1980s. Sasol was an initial response to the need to find an alternative source of fuel for South Africa during years of political isolation and marginalisation. Later on innovation in fuel technology was imperative to respond to issues of production efficiency and global environmental pressures opposing extensive use of fossil fuels. A third dimension of innovation was the need to expand operations outside the confines of the South African market. The government provided a protected environment to Sasol to conduct research and market the fuel it produced from coal. Perpetual government subsidisation of the Sasol operations until the late 1970s guaranteed a protected market and therefore created the risk of uncompetitive behaviour. Sasol management insisted on privatisation and thus accepted the challenge of operating in an environment where market forces would impact directly on its operations. Competitiveness in operations and leadership in technology were the key elements of the chosen business strategy of Sasol. The changes in the geo-political environment of Sasol in the early 1990s justified the conscious business strategy change implemented by the company: the decision to expand globally using the competitive advantage of its synthetic fuel technology. The development of innovative technology by Sasol (reference is made to the SAS and SPD processes and later to the application of SPD to GTL) offered the company the opportunity to sell that technology to gain access to global synthetic fuel markets. The driving forces behind the technological developments at Sasol were both to improve production efficiency and to respond to international environmental pressures. Finally improved business efficiency made globalisation of operations imperative. Environmental concerns equally contributed to a search for improved technology, which in the long run also contributed to better business by the corporation. The improved operations of Sasol were not the outcome of the expansion of its operations into global markets, which thus created a 'global scope' to its business, but by the technological innovation, in response to environmental pressures. World-class innovative synthetic fuel technology was driven by Sasol's business strategy and by environmental concerns. The successful emergence of Sasol as a global leader in synthetic fuel technology as well as a global player in the synthetic fuel market, had nevertheless commenced under state protection and subsidization. As an infant industry it established itself well in the domestic market, but took a conscious business decision to move out of the protected environment and compete internationally using its technology.

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[1] The protection afforded to Sasol consisted of an allowance paid to Sasol for every litre of fuel manufactured from local raw materials (coal). After 1979 the oil price rose substantially to a level in January 1985, when the payment of the subsidy was suspended. Another protection mechanism was introduced in 1989, for 70% of Sasol's petrol and 30% of its diesel production. This was based on an internationally desired floor price for crude oil. Should the floor price of crude oil drop below the protection level fixed in the agreed $/barrel price, Sasol would be compensated 0,78 US ants/litre for every dollar the dollar price settled below the protected level. – Lambrechts, 1998: 60-63; Engineering News, 19-25/6/98: "Everything you wanted to know about South Africa's energy policy, but were afraid to ask Minister Maduna."; The Star: Business Report, 10/12/98: "Sasol terminate supply pact."; Business Day, 10/12/98: "Sasol to end supply deals."
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[2] The Stockholm Convention (May 2001/2004) was an agreement to eliminate or reduce releases of 12 persistent organic pollutants (pops). The convention also sets up a system to identify additional chemicals that are hazardous and attempts to channel resources into the cleaning up of existing stockpiles and dumps. (http://www.pops.int; http://www.unido.org/doc/29684)

[3] The Rotterdam convention was adopted on 10 September 1998 and entered into force on 24 February 2004. The convention was an agreement on Prior Informal Consent Procedure for certain hazardous chemicals and Pesticides in International Trade. The convention promotes the shared responsibility and co-operative efforts amongst parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from damage. The convention sets out to promote the sound use of those chemicals by introducing a legally binding obligation on signatories to provide Prior Informal Consent (PIC) for the trade in those chemicals. The convention covers pesticides and industrial chemicals that have been banned or severely restricted for health

or environmental reasons by the parties concerned. An exchange of information on a wide range of chemicals is encouraged. (http://www.pic.int/home/php

[4] The Sasol-Chevron Challenge was a rally in a Toyota Hilux Raider four wheel drive vehicle "The African Renaissance" using GTL diesel on the 11,000 km journey between the GTL plant in Sasolburg and the ORYX GTL plant in Dohar, Qatar in 46 days. The aim was to demonstrate GTL diesel's ability to deliver higher performance with less emissions in one of the toughest motoring environments in the world. Only one of the five vehicles supported by Toyota used GTL diesel. The end of the rally coincided with the inauguration of the GTL plant in Doha, Qatar, in June 2006, without changing the oil on the vehicle. (http://www.sasol.com. Accessed 2007/12/04; Sasol Sustainable Development Report, 2006:2)

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