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THE IMPORTANCE OF FLUORSPAR IN DEVELOPING FLUOROCHEMICAL INDUSTRY IN THE REPUBLIC OF SOUTH AFRICA, 2013

DIRECTORATE: MINERAL ECONOMICS

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Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

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Compiler: Mphonyana Modiselle
Mphonyana.Modiselle@dmr.gov.za

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Issued by and obtainable free of charge from
The Director: Mineral Economics, Trevenna Campus,
70 Mentjies Street, Sunnyside 0001, Private Bag X59, Arcadia 0007
Telephone (012) 444 3536/3537, Telefax (012) 341 4134
Website: http://www.dmr.gov.za

DEPARTMENT OF MINERAL RESOURCES

Director-General	Dr T Ramontja

MINERAL POLICY AND PROMOTION BRANCH

Deputy Director General	Mr M Mabuza
Chief Director: Mineral Promotion	Ms S Mohale

DIRECTORATE: MINERAL ECONOMICS

Director	Mr TR Masetlana
Deputy Director: Industrial Minerals	Ms N Dlambulo

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ABSTRACT

Fluorochemicals are chemical compounds that have a fluorine atom in their structure. They range from the simple fluorine gas (F_2) and hydrogen fluoride (HF) to more complex fluorinated organic compounds such as perfluorodecalin ($C_{10}F_{18}$). There is a large family of fluorochemicals, all based on the elemental gas fluorine. Almost all fluorochemicals are derived from the mineral fluorspar of which South Africa has the largest and richest sources (17 percent of world reserves).

HF is the first building block obtained from fluorspar for the production of fluorochemicals. HF is a valued source of fluorine and is a precursor to production of numerous products such as aluminium, pharmaceuticals, elastomers, semiconductors, fluorocarbons and fluoropolymers. The report focuses on fluoropolymers and fluorocarbons. Currently Pelchem is the only company in the country that beneficiates a small percentage of locally mined fluorspar into higher value fluorochemicals which, presents opportunities for this untapped market sector.

The South African government, in its Chemical Sector Development Strategy to address the considerable trade deficit in chemicals, has listed Fluorochemical Expansion Initiative (FEI) as a priority project amongst others. The initiative will also play an important role in fluorspar beneficiation, high tech research and development (R&D), attracting foreign direct investment, increasing exports of value added products, job creation and enterprise development.

South Africa has the largest single fluorspar reserves globally and exports most of its fluorspar mineral in an unbeneficiated form. However, the country can take advantage of the reserves to grow the chemical industry, especially on the focus to manufacture fluorochemicals that are critical in the production of agrochemicals, pharmaceuticals, semi-conductors for the electronics industry as well as domestic and industrial refrigeration and air-conditioning. Beneficiating fluorspar into fluorochemicals can add more value to domestic resources to provide for greater economic value and job creation as envisaged by the New Growth Path (NGP). Beneficiation is also aligned with the Industrial Policy Action Plan (IPAP), which was build on the National Industrial Policy Framework (NIPF) as well as the National Development Plan (NDP). The IPAP is necessary for industrialisation, localisation and inclusive growth. The NDP aims to eliminate poverty and reduce inequalities. The NIPF is a blueprint of South Africa's industrialisation process, which seeks to achieve Accelerated and Shared Growth Initiative of South Africa (ASGI-SA) goal of accelerating growth, poverty elimination, employment growth and further intensification of industrial economy.

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1. INTRODUCTION

Fluorspar is a fascinating and particularly important mineral, with a myriad of downstream applications that are integral to a variety of vital industrial processes. Its primary use is in the production of hydrogen fluoride (HF), the main consumption of which is driven by the need for gas for refrigeration. HF is also used in the production of aluminium fluoride. It is used to significantly lower the melting point of aluminium and therefore reduce costs in the production of aluminium in smelters. It is also used in the production of lithium batteries, fluorochemicals and in uranium enrichment.

Fluorochemicals are chemical compounds that have a fluorine atom in their structure; they range from the simple fluorine gas (F_2) and hydrogen fluoride (HF) to the more complex fluorinated organic compounds such as s such as perfluorodecalin ($C_{10}F_{18}$). There is a large family of fluorochemicals, all based on the elemental gas fluorine. Almost all fluorochemicals are derived from the mineral fluorspar of which South Africa has the largest and richest sources (17 percent of world reserves). The fluorochemicals sector has been challenged by stricter regulation and the phasing out of fluorinated compounds, especially certain ranges of fluorocarbons, due to their high global warming potential. As a general global driver, environmental issues are extremely relevant. The Montreal Protocol (to protect the ozone layer) affected the demand as it called for the phasing out of the use of a number of high fluorspar consuming chemicals, mainly the chlorofluorocarbons (CFCs) and next came the Kyoto Protocol (on climate change) which, affects a number of other fluorochemicals as well, mainly those with high global warming potential. More recently, the 2009 United Nations Climate Change Conference, commonly known as the Copenhagen Summit, discussed a framework for climate change mitigation beyond 2012.

While South Africa contains an abundance of mineral resources, this has not been entirely translated into a distinct competitive advantage for the country. Further downstream beneficiation has not fully reached its economic potential largely due to constraints within key value chains. More recently this has been intensified by diminishing mineral economic linkages in addition to decreased local content in backward linkages, a decline in technological capacity and skills in the mining and related sectors. Beneficiation entails the transformation of raw material, through the production process using local labour or capital resources, to a more finished product that has a higher value, and is marketable to a much wider range of consumers, both locally and internationally. There are opportunities in fluorocarbons and fluoropolymers space. Pelchem is currently the only company in the country that beneficiates a small percentage of locally mined fluorspar into higher value fluorochemicals as envisaged by Fluorochemical Expansion Initiative (FEI).

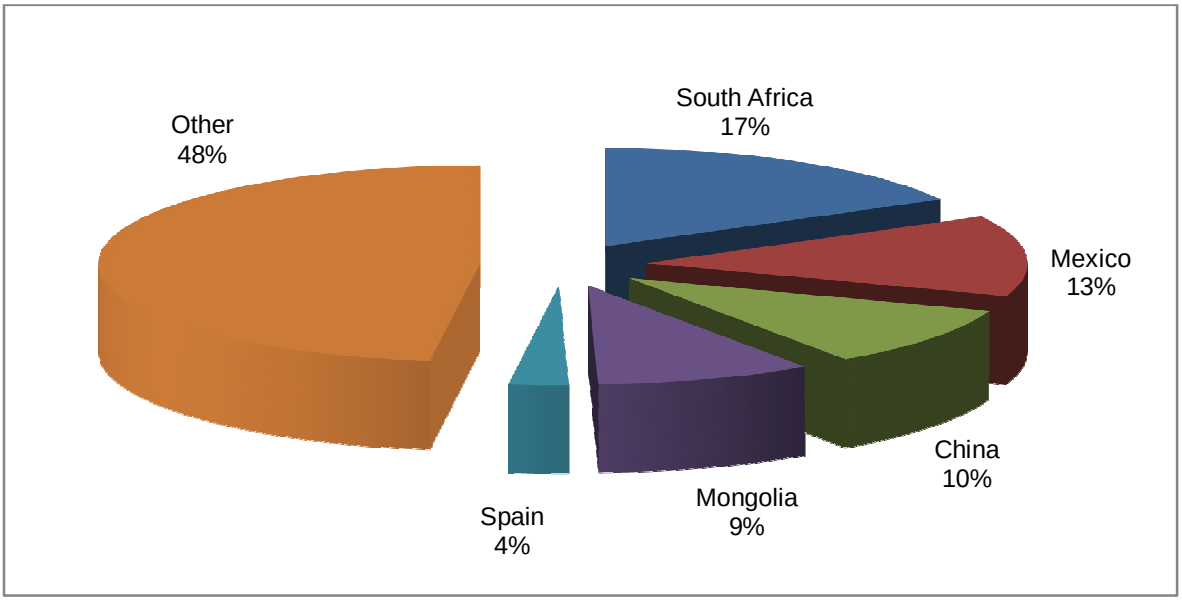
In March 2009, the South African Nuclear Energy Corporation Limited (Necsa) subsidiary, Pelchem, launched a Fluorochemical Expansion Initiative (FEI) with the ultimate goal of creating fluorine-based new business ventures and firms that will support economic growth and development in South Africa. The FEI is a priority project within government aiming to develop the chemical sector in South Africa. Earmarked chemical products include fluoropolymers, elastomers, pharmaceuticals and semiconductors. This initiative is aligned with the South African government's industrialisation programme, which seeks to enhance the quantity and quality of exports, promote creation of decent employment and diversification of the economy, including promotion of green economy.

2. GLOBAL FLUOROCHEMICALS

2.1. RESOURCES

Fluorspar is found in a wide range of geological environments across the globe. The primary economic source of fluorspar is vein deposits, where it occurs as the main mineral or with metallic ores such as lead, zinc, silver and barites in particular. Vein deposits are found around the world and include the El Hemman deposit in Morocco, the Rosiclane deposit in United States of America (USA), Osor deposit in Spain and recently exploited deposits in China. Replacement deposits are associated with intrusive igneous rocks, such as the Rio Verde deposit, San Luis districts deposit in Mexico and Vergenoeg deposit in South Africa. Stratiform deposits are typified by cave; such as Illinois deposit in the USA. The world's reserves of fluorspar are estimated at 240 Mt. South Africa is the single largest holder of these reserves (17%), followed by Mexico's 13%, China's 10% and Mongolia's 9% (Fig. 1).

FIGURE 1: WORLD FLUORSPAR RESERVES BY COUNTRY, 2012



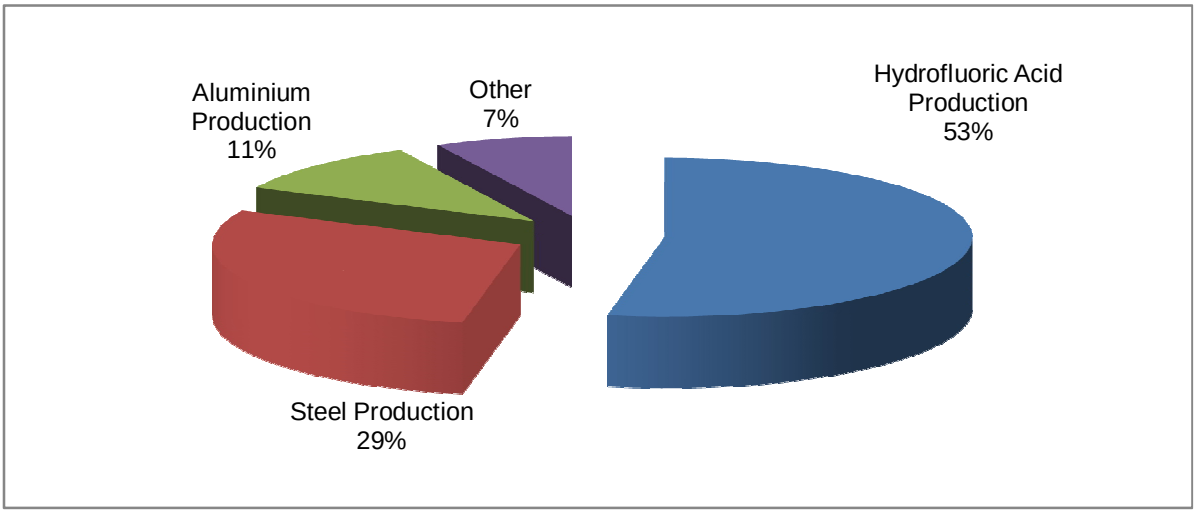
Source: USGS, 2012

2.2 USES

Commercial fluorspar is graded according to quality and specification into metallurgical grade (min. 80 percent CaF_2), ceramic grade (min. 80-96 percent CaF_2) and acid grade (min. 97 percent CaF_2). Approximately 60 to 65 percent of world fluorspar production is acidspar and commands a significantly higher price than metspar. There is limited potential for inter-substitution between acidspar and metspar, since metspar is sold in large lumps, whereas acidspar is sold as a fine powder for chemical conversion to downstream products. Given its critical role in the fluorochemical, aluminium and steel sector, both the US and European Union (EU) have identified future fluorspar supply as crucial for economic stability. Fluorspar global market value is estimated at approximately $2.0 billion and the downstream market value is estimated at $112 billion (including fluorochemicals).

HF is by far the largest market for global fluorspar supply, accounting for 53 percent of total world production (Fig. 2). Metal fluxes are also a major market for fluorspar outside the HF sector, with 29 percent of fluorspar total output consumed in production of steel (using metspar) and 11 percent used in aluminium production - using acidspar (Fig. 2).

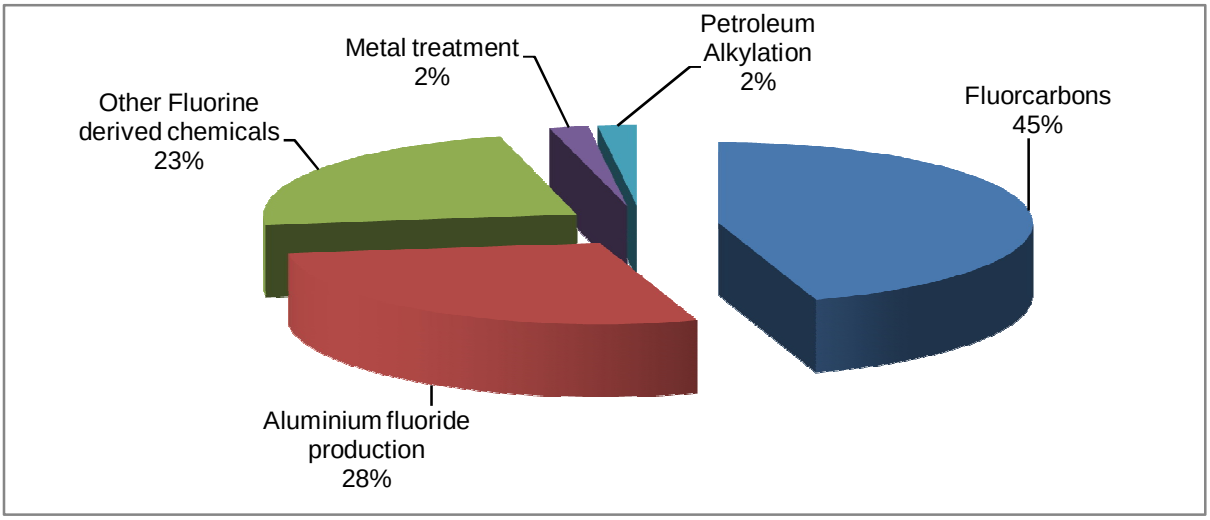
FIGURE 2: WORLD FLUORSPAR MARKETS, 2012



Source: IHS Inc. 2011 (formerly known as SRI Consulting)

This intermediate HF market serves numerous downstream chemical sectors, the largest being fluorocarbons with 45 percent of the market (Fig. 3). The second largest use of HF is in the production of aluminium fluoride (AlF_3), which is the feedstock for synthetic cryolite (a flux used in aluminium production) (Fig. 3). The fluorine containing chemicals are used as refrigerants (replacing CFCs), non-stick coatings, medical propellants, anaesthetics and in the production process of electronics, computer chips, printed circuit boards and thermal insulation (Fig. 4)

FIGURE 3: WORLD HYDROFLUORIC ACID MARKETS, 2012



Source: IHS Inc. 2011 (formerly known as SRI Consulting)

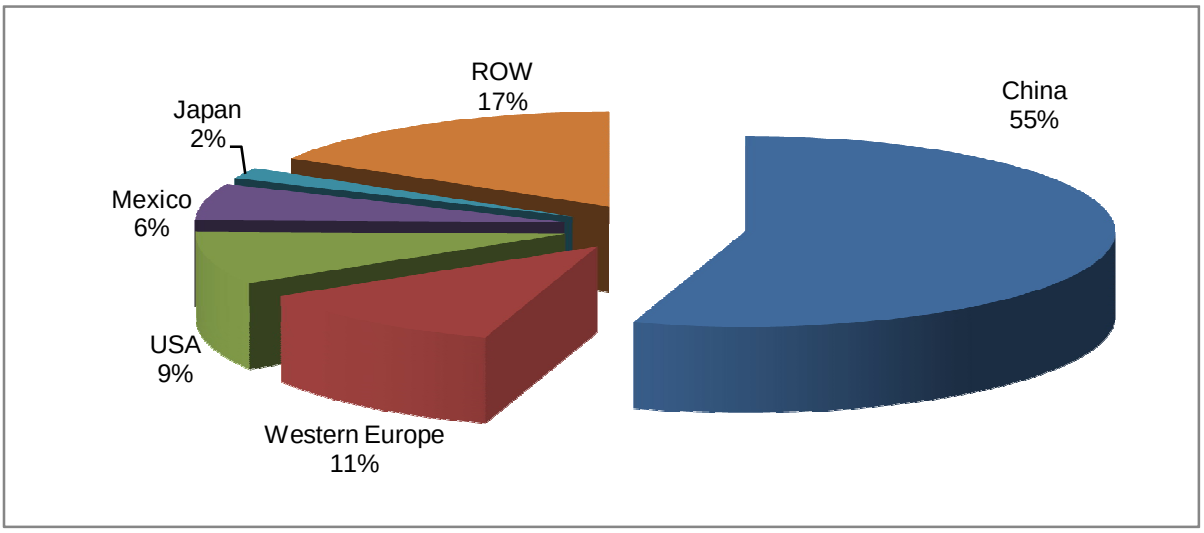
FIGURE 4: FLUOROCHEMICAL USES

Source: Freedonia Group, 2009 Report

2.3 SUPPLY AND DEMAND

Total world production of fluorspar was estimated at 6.85 Mt in 2012. China and Mexico dominate the world fluorspar production accounting for approximately 61 percent and 18 percent respectively. Other fluorspar producing countries include Mongolia (6 percent), South Africa (3 percent), Spain and Russia at 2 percent each (Fig. 5). Although South Africa currently has the largest reserves of fluorspar, the country does not dominate world production.

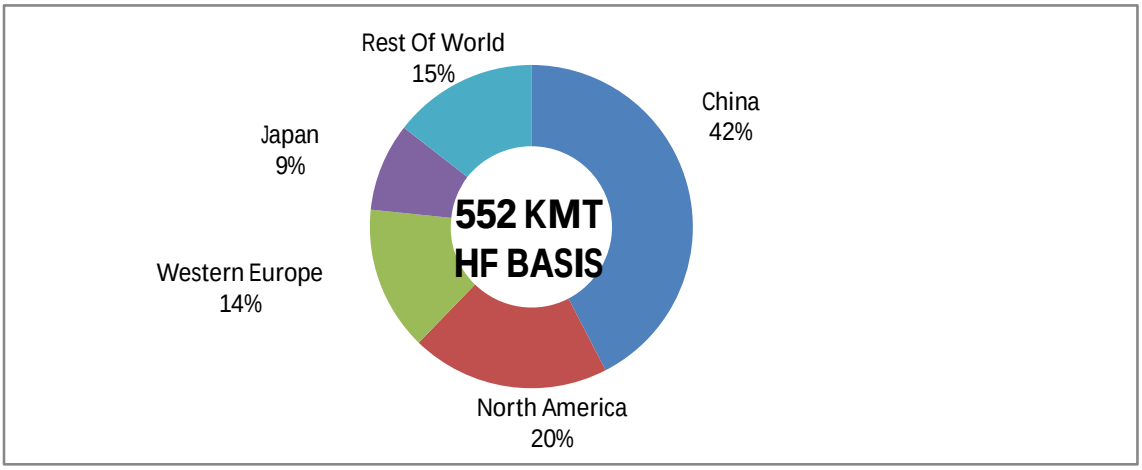
FIGURE 5: WORLD FLUORSPAR PRODUCTION, 2012



Source: USGS, 2012

Fluorspar demand is driven by uses in fluorocarbon applications, which include consumer goods such as fridges, freezers and air conditioners as well as steel and aluminium fluoride production. China consumed 42 percent of world fluorspar demand, followed by North America's 20 percent, Europe's 14 percent and Japan's 9 percent (Fig. 6). South Africa's local industries demand is minimal.

FIGURE 6: WORLD FLUORSPAR DEMAND BY COUNTRY, 2012

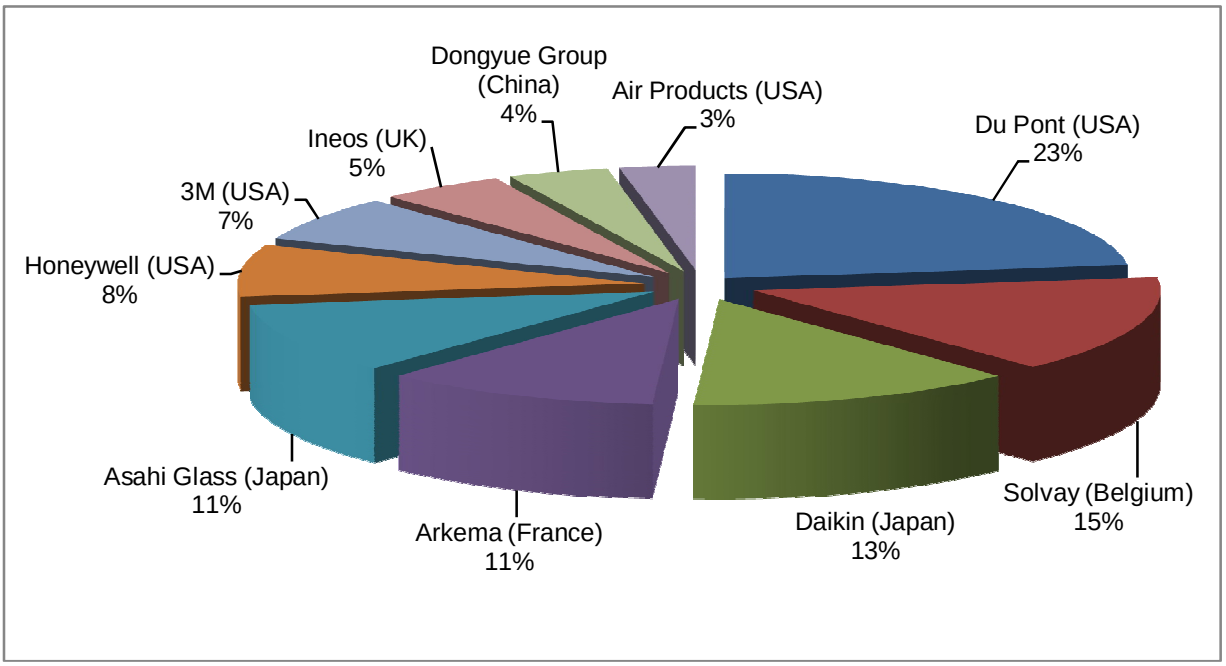


Source: IHS Inc. 2011 (formerly known as SRI Consulting)

Note: ROW – Rest of World

The global fluorochemical industry is estimated at $16 billion and, its major markets are refrigerants (fluorocarbons), aluminium fluoride and fluoropolymers (plastic- Teflon). Both aluminium fluoride and fluorocarbon markets have stalled throughout 2013, leading to a slowdown in HF production and a subsequent slump in acidspar demand. Although fluoropolymers production has increased as a proportion of the total market, the industry's inherent links to economic growth have caused demand to slide. The industry is also facing a possibility of further environmental restrictions owing to the chemicals with high global warming potential. The global fluorochemicals industry is fairly concentrated in relatively few players due to difficult technology and logistical barriers to entry, including economic scale, high cost of capital investments, steep research and developments costs and evolving environmental regulations. Global players are located in the United States of America, Western Europe and Asia Pacific regions. Figure 7 below shows the top 10 global fluorochemical producers.

FIGURE 7: KEY FLUOROCHEMICAL PLAYERS, 2011



Source: Freedonia, 2009 Report

2.4 ENVIRONMENTAL AND REGULATORY CONSIDERATION

The Montreal Protocol on substances that deplete the ozone layer (1989) and Kyoto Protocol (1997) has sought (and, largely, achieved) a standardized global approach to the treatment of chemicals likely to harm the environment and, have set a precedent, which is being followed by those seeking to limit ozone depleting and greenhouse gas emissions.

The Montréal Protocol is an international treaty that eliminates the production and consumption of ozone depleting chemicals such as chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform. In the early 1990's, these substances were replaced with fluorinated gases (F-gases) which consist of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). Some of these F-gases however, have an extremely high global warming potential and are emitted at an increasing rate. For example, the refrigerant R134a (tetrafluoroethane) is a single HFC compound used in motor vehicle air-conditioners, which has no ozone depletion effect but has a global warming potential (GWP)[**] of 1300. The Kyoto Protocol, on the other hand, is an international treaty of the United Nation Framework Convention on Climate Change (UNFCCC). This treaty aims to stabilize the concentrations of four greenhouse gases (carbon dioxide, methane, nitrous oxide and sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons).

Chlorofluorocarbons (CFCs) are the original refrigerants and propellants. Hydrochlorofluorcarbons (HCFCs) have lower ozone destruction potential, and their use is being dramatically reduced (curtailed) owing to ozone depletion. Hydrofluorcarbons (HFCs) are the best current option for refrigerants, with no Cl and no ozone destruction potential. However, they have very high GWP, e.g. HFC-152a-GWP is 122. Hydrofluoroolefins (HFOs) are the refrigerant and propellants of the future. They have no Cl, no ozone destruction potential and a much lower GWP, e.g. HFO-1234ze-GWP is 6.

The US Environmental Protection Agency (EPA) approved two hydrofluoroolefin (HFO) compounds as replacements for chlorofluorocarbons-HFO 1234ze and HFO 1234yr. HFO 1234ze, developed by Honeywell International Inc, has been approved for the use as a foam blowing agent. HFO 1234ze has a very low global warming potential (GWP), is non flammable and can replace existing high-GWP blowing agents such as hydrofluorocarbons (HFC) 134a and 152a. In the developed markets, HF is facing erratic demand due to environmental legislations and the subsequent phase-out of hydrochlorofluorocarbon (HCFC) including HCFC-141b in the USA and Europe in the near future. Most producers are introducing HFC substitutes, which consume more HF and are expensive and a decline in market share is expected due to other cheaper replacement such as carbon dioxide for foam blowing.

Asia was the only region, showing an increase in HF capacity. In the USA, production of HCFC-142b and HCFC-22 was stopped until 2010, with complete ban to be in place by 2020. Production of all other HCFCs would be halted by 2015 and banned by 2030. In Europe, especially Germany, the phase out schedules are even faster. The European Commission passed a legislation to bring down emissions of fluorinated gases into the atmosphere by at least 25 percent. The legislation forms part of the commission's endeavour to reduce green house emissions as required by the Kyoto Protocol on climate change.

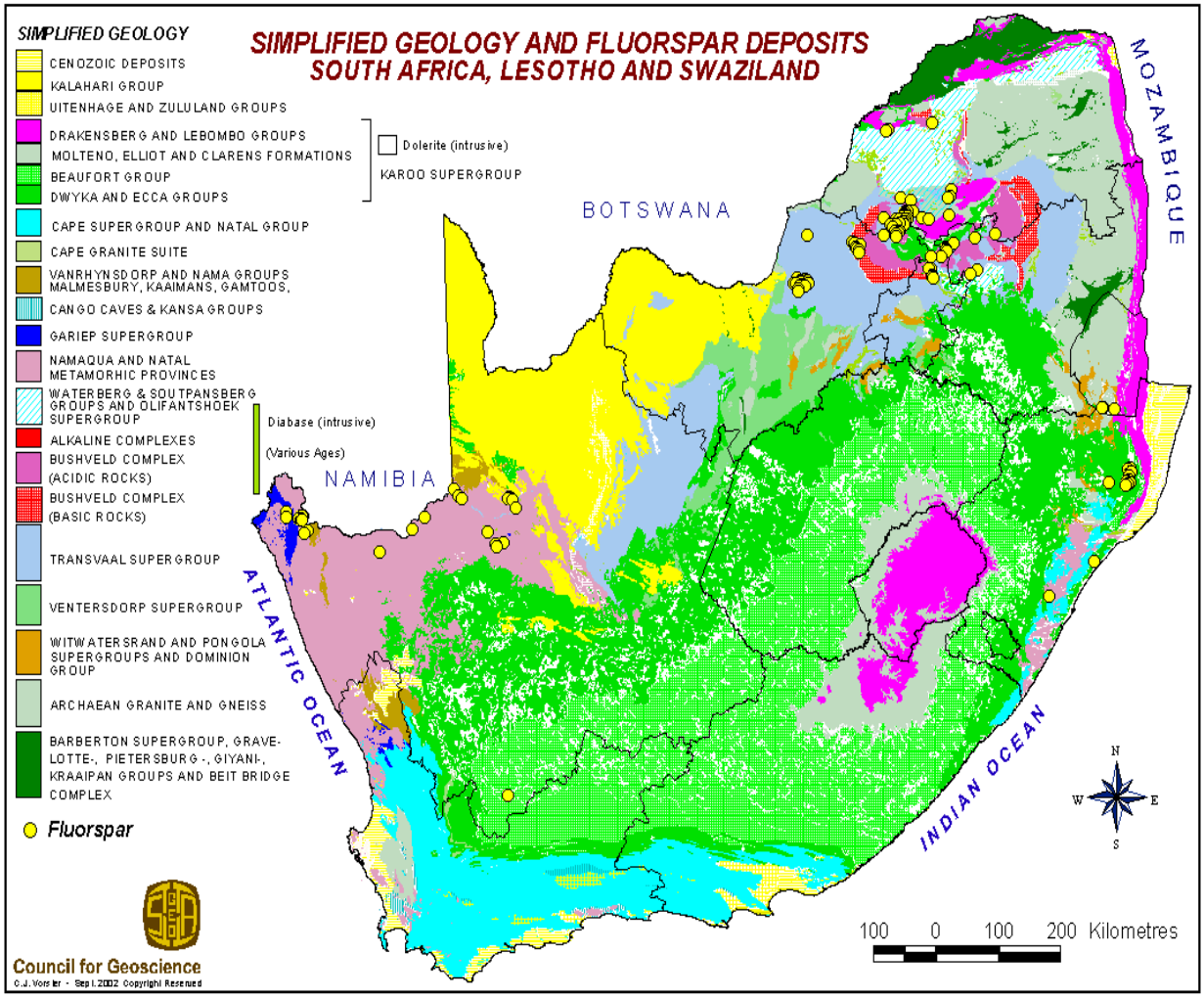
[**] *GWP is a measurement of how much effect the given compound will have on global warming in relation to CO_2, where CO_2 has a GWP of 1.*

3. SOUTH AFRICA

3.1 OCCURENCES

Fluorspar is found in a wide range of geological environments across the globe. The primary economic source of fluorspar is vein deposits, where it occurs as the main mineral or with metallic ores such as lead, zinc, silver and barites in particular. South Africa is the single largest holder of fluorspar reserves in the world with most of these resources found in the Bushveld Complex – currently mined by Vergenoeg, jointly owned by Spanish company called Minerales y Productos Derivados SA (Minersa) with 85 percent share and MEDU Capital (15) (Fig. 8). Fluorspar deposits are also found in the Malmani subgroup of the Transvaal Supergroup, in the south western part of Marico District, south of Zeerust, currently mined by Witkop owned by Fluormin (63%) and Sallies (37%).

FIGURE 8: FLUORSPAR DEPOSITS IN SOUTH AFRICA



Source: Council for Geoscience

3.2 SUPPLY AND DEMAND

Vergenoeg mine is the current active fluorspar producer (170 kt in 2012) in South Africa. Witkop mine has been on care and maintenance since October 2012, due to the current economic environment and falling fluorspar prices below its production costs owing to low fluorspar grade. Buffalo mine was closed in October 2008, with no plans to recommence operations in the near future. Production decreased by 3 percent from 2002-2012, owing to several operational challenges, which included water shortages, power supply challenges, lower ore grades as well as maintenance shutdowns (Fig. 9).

FIGURE 9: SOUTH AFRICA'S PRODUCTION AND SALES OF FLUORSPAR, 2002 – 2012

Source: DMR, Mineral Economics

The fluorspar industry in South Africa is export-orientated with around 95 percent being exported and, the remaining 5 percent is beneficiated to crude and pure HF and other fluorochemical products. Although South Africa supplies 5 percent of the fluoride source for the $16 billion global fluorochemical industry, it earns less than 0.5 percent of its value. This is due to low levels of fluorspar beneficiation in the country. There is however a potential to expand fluorochemical beneficiation as the country has a number of large industries such as automotive manufacturing, agriculture, petrochemicals and mining. The stringent environmental protection legislations regarding the use of chlorofluorocarbons (CFCs) were deemed as the main cause for sluggish fluorspar demand. Growth of fluorspar is dependent on the use of HFCs as an alternative to CFCs. Further prospects of non-ozone depleting refrigerants represent another major factor that may influence fluorspar growth.

As a result of international public scare concerning the depleting ozone layer, the Montreal Protocol was signed by South Africa in 1987. The global phasing out of CFCs due to Montreal Protocol resulted in African Explosive & Chemical Incorporated (AECI) closing down most of its South African CFC operations in 1995. This, resulted in its hydrogen fluoride (HF) plant being uneconomical to serve its local users of HF.

3.3 OPPORTUNITIES OF BENEFICIATION

Fluorspar is one of the many mineral resources that are abundant in South Africa on which the country has never truly capitalised. Despite, South Africa accounting for 17 percent of world's reserves, the country currently beneficiates less than 5 percent of its fluorspar total production into higher value fluorochemical products. This presents an opportunity for manufacturers to venture into the downstream value addition market on raw materials. South Africa has the opportunity to challenge the market by providing an alternative stream of beneficiated supply.

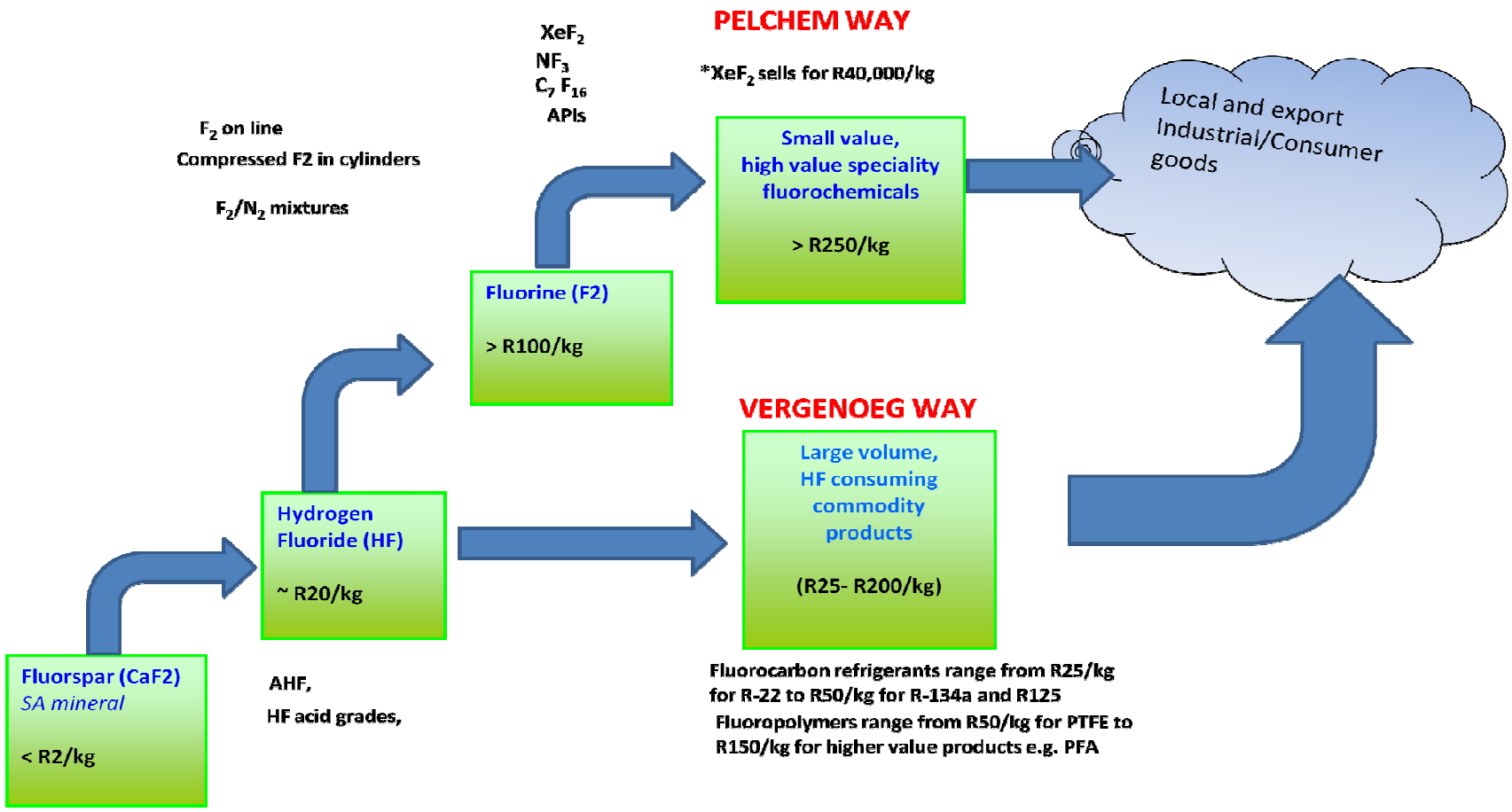
Despite there being barriers to entry to the fluorochemical industry in terms of the technology involved, the potential for further downstream beneficiation presents attractive opportunities for new entrants in the market. There has been reluctance to invest in the technology and infrastructure required for fluorspar beneficiation owing to several factors, including: skills shortage and the length of time it takes to develop fluorochemical facilities. The challenge facing the industry is to strike a balance between innovation and commercialisation of that innovation. The value of fluorochemicals generally increases with the complexity of the molecules, the cost of reagents and the difficulty of processing steps required producing the compounds.

The expected benefits for the country include:

- increased exports and an improvement on chemical trade deficit;
- stimulate the use of HF and fluorine in other mineral beneficiation initiatives;
- foreign direct investments and international collaboration in business and technology;
- growth and development of high level skills and technology;
- increase the beneficiation of key raw materials and minerals
- create skilled and semi skilled jobs with opportunities to establish various support industries and downstream businesses;
- secure source of key raw materials and skills for the country for potential strategic programs.

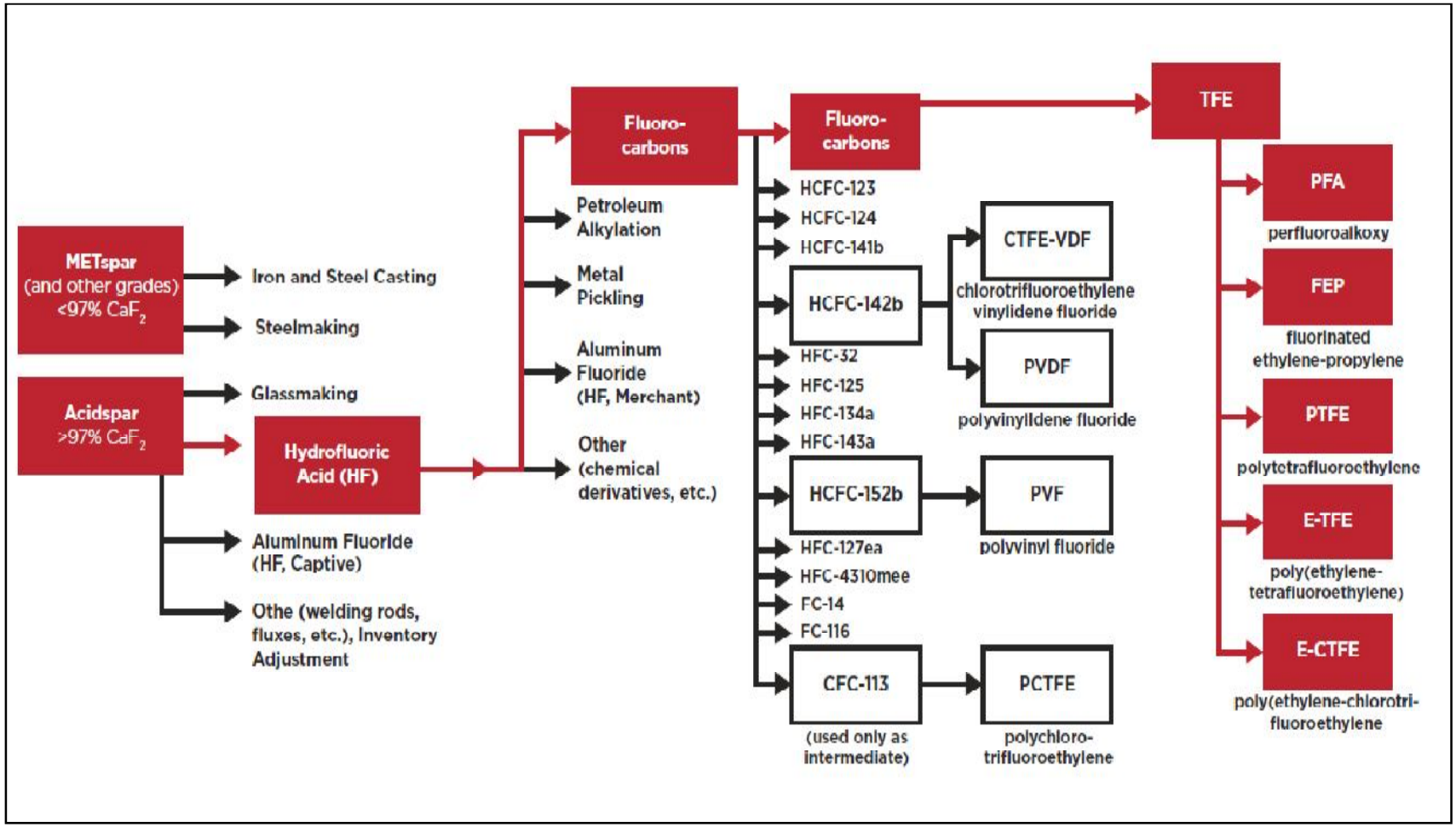
The general trend with regard to fluorochemical price per category is shown in Figure 10 and 11 below:

FIGURE 10: FLUORSPAR VALUE CHAIN: BUILDING BLOCKS FOR SOUTH AFRICAN HUB



Source: Pelchem 2011

FIGURE 11: WORLD FLUORSPAR VALUE CHAIN



Source: SRI Consulting, adapted by Industrial Minerals

4. DEVELOPMENTS AND PROJECTS IN THE INDUSTRY

The Fluorochemical Expansion Initiative (FEI)

- In March 2009, South African Nuclear Energy Corporation Limited (Necsa) subsidiary Pelchem launched a Fluorochemical Expansion Initiative (FEI).
- The ultimate goal is to create fluorine-based new business ventures and firms that will support economic growth and development in South Africa.
- The FEI is a priority project within government to develop the chemical sector in South Africa.
- The FEI is driven by the Department of Science & Technology (DST) and the Department of Trade & Industry (the dti) and, is aimed at developing South Africa's fluorochemical Industry through increased local beneficiation of the country's fluorspar reserves.
- Earmarked chemical products include fluoropolymers, elastomers, pharmaceuticals and semiconductors.
- Pelchem is currently the only company in the country that beneficiates a small percentage of locally mined fluorspar into fluorochemicals.

Research on potential opportunities in downstream fluorochemicals

- In response to Department of Mineral Resources' (DMR) Minerals Beneficiation Programme, the Industrial Policy Support Fund (IPSF), administered by the Industrial Development Corporation (IDC) on behalf of the dti is pursuing the commissioning of an investigation into the commercial viability of the potential downstream opportunities of fluorocarbons and fluoropolymers in South Africa.
- Beneficiation of current fluorspar resources is expected to promote industrial development, investment, competitiveness, employment creation and diversification of the industrial base of the economy.

Sephaku Fluoride Ltd (SepFluor)

- Development of two primary fluorspar deposits at its Nokeng project- Outwash Fan and Plattekop from which it is planning to produce 180 kt/pa.
- The Sephaku project will largely feed that company's planned beneficiation facility, comprising plants for the production of sulphuric acid (93 kt/pa), anhydrous hydrogen fluoride (60 kt/pa) and aluminium fluoride (60 kt/pa).
- Nokeng project was granted environmental authorization by Gauteng Department of Agriculture and Rural Development (GDARD) in April 2013
- Nokeng project's Integrated Water Use License Application (IWULA) was authorized by the Department of Water affairs (DWA) in July 2013.
- The SAMREC (South African Code of Reporting of Exploration Results, Mineral Resources and Mineral Reserves), Mineral Reserve estimate for Nokeng project is estimated at 13.2 Mt at a grade of 29.5 percent.
- The company made pre-payment of R23 million to Eskom to secure construction of required power line to the project site.
- During the construction, an independent economic impact study estimated that the project would contribute R660.5 million to Gross Domestic Product (GDP) per region and create 2145 employment opportunities.

- Notification for Construction has been issued to GDARD and, receipt of the notification was acknowledged by GDARD (September 2013)
- The engineering, procurement and construction (EPC) Contractor for the Project has been appointed and the agreement was signed in November 2013.
- The Detail Design and Engineering Phase of the Project formally kicked off in March 2014.
- Parallel to the Detail Design & Engineering Phase, Project Valuation is updated in line with revised economic parameters and the Project Funding effort is accelerated to ensure the start of Construction earliest in the 4th Quarter of 2014.
- Production Ramp-Up is planned for the 4th Quarter of 2016.

SA Fluorite Pty Ltd - **Doornhoek project**

- South African-based fluorspar developer with a promising deposit.
- Central African Mining & Exploration Co. plc (CAMEC), subsidiary of ferrochrome giant Eurasian Natural Resources Corp (ENRC) owns 51 percent interest in the Doornhoek fluorspar property in South Africa.
- The project contains in excess 50 Mt fluorspar at an average grade exceeding 20 percent CaF_2.
- The anticipated production target is 275 kt per annum.
- A preliminary economic assessment of the project "PEA" (Scoping study) was completed.
- Metallurgical test work at Mintek is underway and environmental studies are ongoing and, production is expected by 2017.
- There are currently limited employment opportunities (approximately 15 people currently employed excluding contractors) but this is expected to increase to about 300 or more once production starts.

5. OUTLOOK

According to Roskill Information Services, fluorspar demand is expected to grow in the next ten years due to increasing consumption in chemicals industry, despite environmental legislation and more limited economic growth predominant in some of the major developing countries. The global fluorochemicals industry is expected to grow by 5 percent per year and to rise to $21.5 billion by 2018. With South Africa, having the largest reserves of fluorspar the country is well positioned to take the maximum advantage of the current huge demand in Africa, as a regional industrial powerhouse. South Africa has insufficient demand for world class sized fluorochemical hub, however with a growing economy, existing local demand and increasing localisation through local beneficiation of fluorochemical products, the country market has a great potential for growth especially when exploited together with the African market.

The regulations for fluorspar industry have become stricter in recent years. The general regulations are mainly focused on environment and safety production. More aggressive regulations are restraining fluorochemical consumption, especially in area of fluorocarbons in developed countries, particularly in combination with slower manufacturing growth and higher market penetration of fluorochemical-using consumer goods. Fluoropolymers and fluorochemicals provide a stable and growing source of fluorspar demand. South Africa currently imports all its fluoropolymers and fluorochemicals requirements. Whilst South Africa has had

successes in the establishment of its existing fluorochemical industry (Pelchem's FEI), significant effort needs to be made in accelerating development and growth in skills, technologies, manufacturing capacities, mineral beneficiation and improving the trade deficit in the chemical sector and reliance on imports.

The South African government at national and provincial level has created incentives and enabling environment to meet its economic growth and job creation targets through manufacturing in addition to mining and services. The government's commitment and support for the vision to create global competitive fluorspar beneficiation industry cluster in South Africa will create opportunities to challenge the export market. The Industrial Development Corporation (IDC) has successfully created advanced manufacturing operations in South Africa and, has identified fluorspar as a strategic investment opportunity. In addition, adequate funding mechanisms need to be developed to ensure that maximum benefit is drawn from fluorspar value addition and that South Africa extracts maximum value from the exploitation of its fluorspar resources. Higher levels of local fluorspar beneficiation are expected to create 1 000 jobs and raise export revenue by R1 billion.

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