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# The need for indigenous fluorspar production in England

Open Report OR/08/027





BRITISH GEOLOGICAL SURVEY

OPEN REPORT OR/08/27

# The need for indigenous fluorspar production in England

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## *Keywords*

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## *Front cover*

INEOS Fluor's ZEPHEX plant, inhalers and non-stick pans.  
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Whilst due consideration has been given to comments received from all consultees, this report describes the views of the authors alone. References within this publication to any methodology, process, service, manufacturer or company do not constitute its endorsement or recommendation by MIRO or DEFRA. This publication is intended to inform the land-use planning debate. It is not a statement of planning policy or guidance; nor does it imply Government approval. Whilst every effort has been made to ensure the accuracy of the material in this report, the authors, British Geological Survey and cebr will not be liable for any loss or damages incurred through the use of this report.

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## Summary

This report is one of two outputs from a project entitled ‘The need for non-energy indigenous mineral production in England’ which received funding from the Sustainable Land-Won and Marine Dredged Aggregate Minerals Programme of the Aggregates Levy Sustainability Fund (ASLF) managed by the Mineral Industry Research Organisation. A separate report has also been prepared relating to ‘The need for indigenous aggregate production in England’.

The aim of this project was to analyse the real ‘need’ for non-energy indigenous mineral production in England. Specifically, this report contains information relating to the extraction and consumption of fluorspar. It describes the uses of fluorspar and its importance to the English economy and downstream industries which it supports.

Industrial minerals such as fluorspar are essential to a modern economy. They underpin manufacturing industry, construction and agriculture and also have important environmental and medical applications.

The principle aims of this study were to:

- Provide authoritative background information on what fluorspar is and the downstream industry which it supports;
- Review the economic benefits of the English fluorspar sector;
- Determine whether there is a continued ‘need’ for indigenous fluorspar production in England;
- To understand the economic impact of no indigenous fluorspar production and the consequences of importing all English requirements from overseas; and
- Consider the environmental impacts of indigenous fluorspar production.

Fluorspar extraction contributes to the English economy with an estimated gross value added (GVA) of over £4.5 million. It is also responsible for the employment of around 100 people. This consists of both the direct contribution of the industry and indirect benefits derived from the industry purchasing goods from its suppliers and employees of the industry demanding goods and services from other parts of the economy. In addition, the fluorspar industry provides a critical raw material to the chemicals industry. The down-stream fluorochemical sector is estimated to contribute more than £35 million to GVA and is associated with the employment of 507 people.

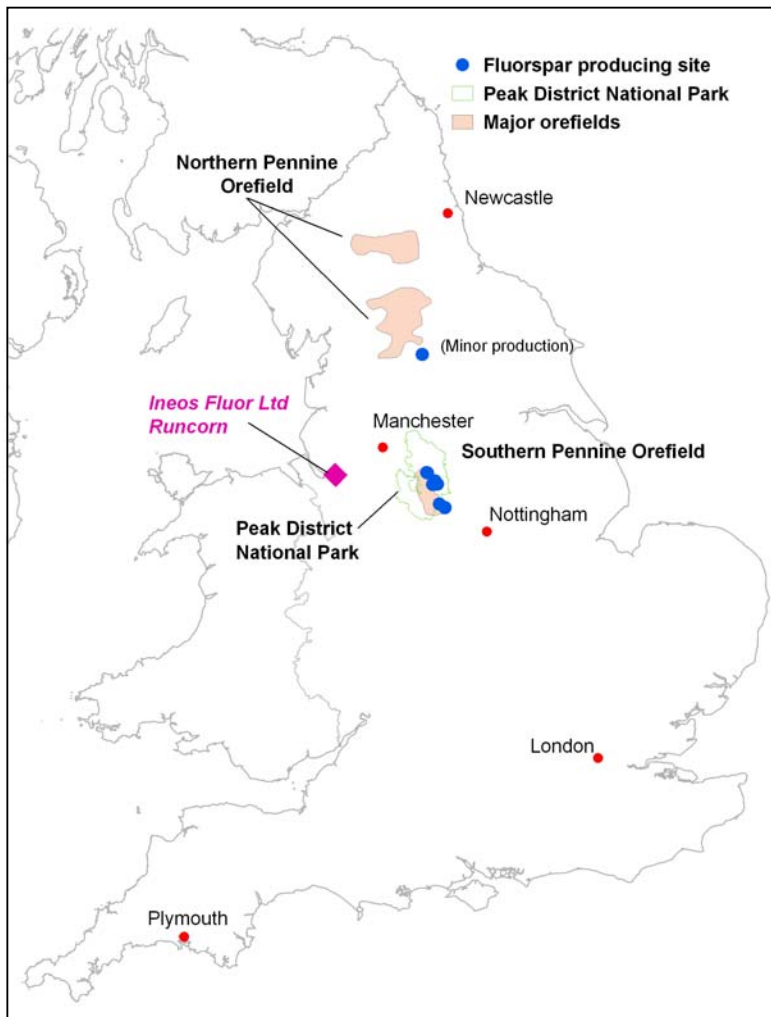
In comparison, the environmental cost of fluorspar extraction is difficult to measure. Fluorspar resources in England are concentrated in areas of attractive scenery, with all current production derived from the Peak District National Park.

Permitted reserves (those areas that have been given planning permission for mineral extraction) of fluorspar in England have reached critically low levels. Imports of fluorspar from overseas do not appear to offer a realistic long-term solution. This is because of the lack of availability of high quality fluorspar on the open market and the cost implications of importing fluorspar from overseas as demonstrated by the modelling exercises in this report and the demise of the French fluorochemical sector. Accordingly the English fluorochemical sector is highly dependent on indigenous fluorspar production.

# 1 Introduction to fluorspar

## 1.1 OCCURRENCE

Fluorspar is the commercial name for the mineral fluorite (calcium fluoride -  $\text{CaF}_2$ ), which, when pure contains 51.1% calcium and 48.9% fluorine. It is the most important and only UK source of the element fluorine (F). Fluorspar is found in a wide range of geological environments on every continent. In the UK fluorspar resources are restricted to two areas: the Southern and Northern Pennine orefields (Figure 1). The primary economic source of fluorspar is in vein deposits (minerals infilling cracks in the rock mass) where it occurs as the main mineral or with metallic ores, in particular lead, zinc and silver associated with barytes. Barytes and lead concentrates are by-products of fluorspar processing. The quality or grade of the fluorspar product determines its end-use. Commercial fluorspar is graded according to quality and specification into acid-grade (minimum 97 per cent  $\text{CaF}_2$ ), ceramic grade (85-95 per cent  $\text{CaF}_2$ ) and metallurgical grade (60–85 per cent  $\text{CaF}_2$ ).



**Figure 1** Principal fluorspar producing sites and the location of INEOS Fluor's Runcorn site

Source: BGS, 2006

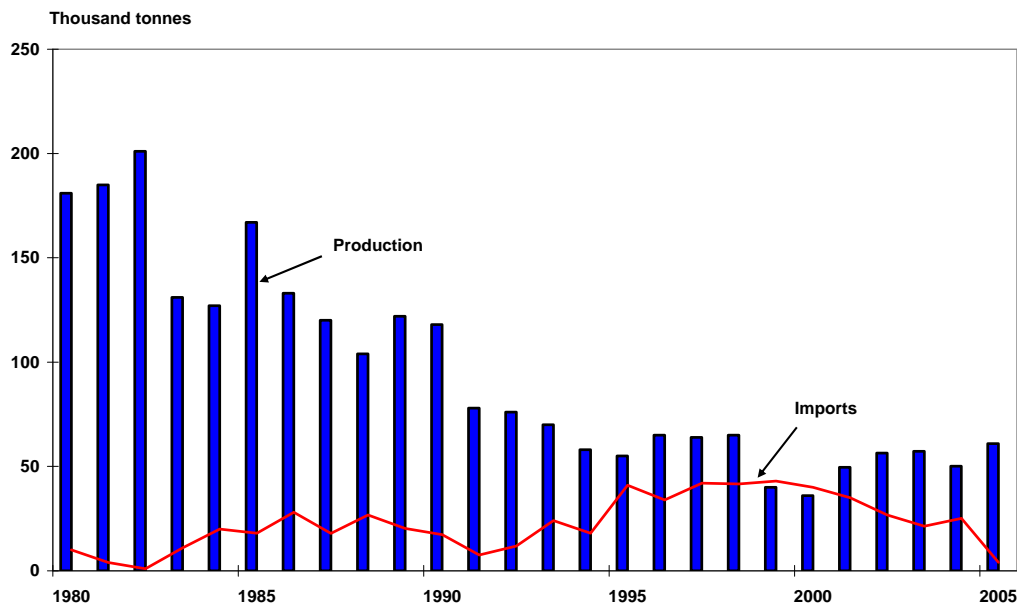


## 1.2 SUPPLY

Significant production of fluorspar in England began at the beginning of the 20th century with its use in steelmaking. Today steelmaking is a relatively minor use. Production increased with rising demand for fluorine-bearing chemicals, ultimately derived from fluorspar and peaked at 235 000 tonnes in 1975. Production has been on a downward trend since, because of a decline in demand by the chemical and steel sectors and the closure of some producers. All English output is of acid-grade fluorspar which is a critical raw material for the domestic chemicals industry. About 61 000 tonnes of acid-grade fluorspar were produced in the England in 2005 (Figure 2). There is no production of ceramic grade or metallurgical grade fluorspar in England.

Within the UK fluorspar production is confined to England, with the Southern Pennine Orefield (mainly within the Peak District National Park), historically being the principal source of supply. The only other significant source has been the Northern Pennine Orefield in Durham, however mining ceased here in 1999. World production of fluorspar was around 5.1 million tonnes in 2005 and China is the dominant producer accounting for more than 50% of world production. Chinese production increased by 11 per cent between 2005 and 2006 and has increased by 13 per cent over the last five years (Hetherington *et al.* 2008).

Prior to the mid-1980s, the UK was a net exporter of fluorspar but subsequently became a net importer as it became less competitive. Because of quality considerations UK imports of acid-grade fluorspar are now from Spain. Imports of metallurgical grade fluorspar are chiefly from Mexico and China.



**Figure 2** UK production and imports of fluorspar, 1980-2005 (imports include both acid-grade and metallurgical grade)

Source: UK Minerals Yearbook, 2006

## 1.3 STRUCTURE OF THE INDUSTRY

Glebe Mines Ltd, is the only producer of marketable fluorspar in the UK. The company, and its predecessors, have supplied the English fluorine chemical industry for 68 years. Over the last 35 years there have been a number of other ventures to produce fluorspar, both in the Southern

and Northern Pennine orefields, however none have proved sustainable. Glebe Mines operates the Cavendish Mill, near Stoney Middleton in the Peak District National Park. Fluorspar ore to supply the Mill is mainly derived from Glebe’s own operations, but smaller ‘tributer’ producers also supply some ore.

The main consumer of fluorspar in England is the hydrofluoric acid (HF) and fluorochemicals producer INEOS Fluor. INEOS Fluor (acquired from ICI in 2001) is a global manufacturer of fluorochemicals, with its main manufacturing facility at Runcorn in Cheshire (Figure 1). The site at Runcorn produces a range of fluorochemicals and uses, for the most part, only fluorspar produced in England. In 2007, in a strategic move, INEOS Fluor acquired Glebe Mines Ltd and secured supply to the UK’s only viable source of acid-grade fluorspar (INEOS Fluor, 2007a). The international chemical company Rhodia, also manufactured fluorochemicals at its Avonmouth site. Since closure of its HF plant in 2004, it has had to source HF from other suppliers, including INEOS Fluor. However, Rhodia recently announced closure of its operation stating that the site was no longer economically viable due to difficult market conditions (Rhodia, 2007).

#### 1.4 RESERVES

Permitted reserves (minerals that have been given planning permission for mineral extraction) of fluorspar ore within the main producer’s control were about 1.8 million tonnes at the end of 2005. These reserves have since been depleted and with no addition to the reserve base current permitted reserves of fluorspar stand at around 630 000 tonnes (Dec. 2007), equivalent to some 1.5 years supply for the operation at Cavendish Mill at a rate of ore usage of 420 000 t/y (Hodgkinson and Lee, 2008). Further, more than half of this reserve comprises tailings material that has already been processed and because of its characteristics it cannot be processed again on its own at Cavendish Mill. It must be mixed with fluorspar extracted from the ground and consequently its value as a reserve is restricted by the availability of new fluorspar ore with which to blend it.

#### 1.5 CONSUMPTION

UK consumption of fluorspar is shown in the Table 1. Acid-grade fluorspar is believed to account for almost all of the fluorspar consumed. A very minor amount (less than 10 tonnes) is used in steelmaking and comprises imported metallurgical fluorspar (HM Revenue & Customs).

Domestic sales	61 000 tonnes
Imports	4 051 tonnes
<b>Total UK consumption</b>	<b>64 000 tonnes</b>

**Table 1** UK Consumption of fluorspar in 2005 (imports include both acid-grade and metallurgical grade)

*Source: HM Revenue & Customs*

#### 1.6 USES

All output of English acid-grade fluorspar is used in the manufacture of HF, which in addition to being an important product in its own right, is required for manufacturing a range of fluorine-bearing chemicals (fluorochemicals). Demand for fluorspar in England is principally driven by demand for HF and associated fluorocarbon production. Historically this was for chlorofluorocarbon (CFC) production, widely used in aerosols and refrigeration. CFC production

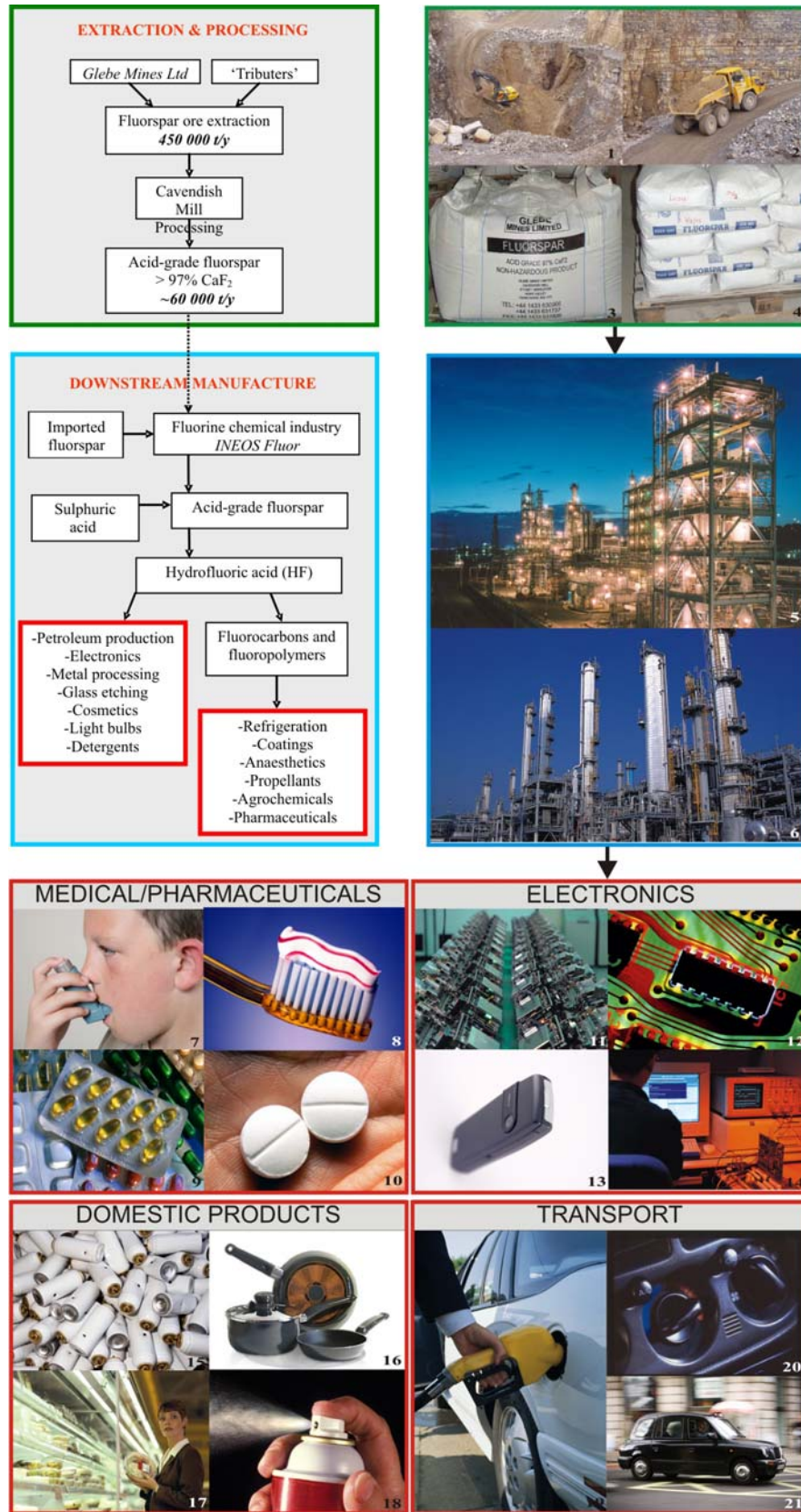
was banned in developed countries from 1996 because of its ozone depleting effects. CFCs were replaced by hydrochlorofluorocarbons (HCFCs) although these still have some ozone depleting effects. Consequently manufacturers developed hydrofluorocarbons (HFCs) which are chlorine-free and have no ozone depleting effect.

Globally fluorocarbons have two main applications: 1. foam blowing a technique for treating plastics to improve their insulation properties and 2. in cooling, freezing or other heat transfer processes including domestic and industrial refrigeration and air conditioning.

Fluorocarbons are also used as a feedstock for fluoropolymer production, which is generally increasing in use globally. Fluoropolymers are used for a wide variety of coatings due to their unusual properties such as fire resistance, resistance to chemical attack, insulation and a low resistance to movement. Consequently they are used for insulating wires and cables, in non-stick cookware e.g. Teflon<sup>®</sup> and for waterproofing textiles e.g. GORE-TEX<sup>®</sup> (Eurofluor, 2007).

HF is a critical chemical for the electronics industry in the manufacture of semi-conductors. Semi-conductors are used in a range of labour saving consumer devices such as computers, mobile phones, washing machines and refrigerators. They are also essential components in the electronic systems in cars, aeroplanes and trains. HF is required for the processing of many important metals, including aluminium, stainless steel and uranium for nuclear fuel. Aluminium is widely used in the transport sector, valued for its strength, lightness and corrosion resistance. HF is used during the processing of crude oil to produce fuel which burns more efficiently with lower emissions (Eurofluor, 2007).

Fluorine derived from fluorspar has a range of pharmaceutical and medical applications. Fluoride compounds are used in antibiotics and anaesthetics and in arthritis, HIV and anti-malarial drugs. Fluorine rich gases are used as the propellant in inhalers for treating asthma. Most toothpaste contains fluoride which strengthens tooth enamel, helping to prevent decay (British Dental Health Foundation, 2008). HF is also used in the production of efficient crop protection chemicals, helping to increase the reactivity and selectivity of both insecticides and herbicides and reduce their environmental impact. HF is used in a wide range of consumer products including detergents for laundry and dishwashing applications. HF is used to treat crystal glass to give a sparkling finish and to produce light bulbs with a 'pearl' or 'frosted' appearance (Eurofluor, 2007). Some of the diverse uses of fluorspar are summarised in Figure 3.



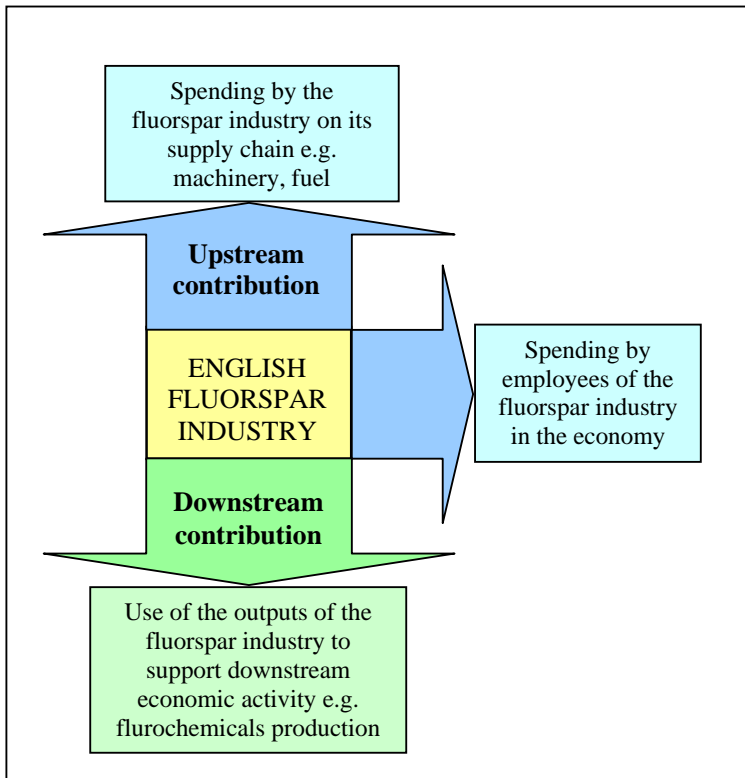
**Figure 3** The dependence of downstream manufacturing on fluorspar and the wide range of everyday products ultimately derived from this raw material

Photo copyright: Glebe Mines Ltd 1,2; INEOS Fluor 5,7,16,17,20; BGS©NERC 3,4; TongRo Images 6,11,14; Ingam Publishing 8, 9, 10,12,13,18; PhotoAlto 15; Jupiter Images 19,21

## 2 Economic benefits of fluorspar

### 2.1 CONTRIBUTION TO ECONOMIC OUTPUT

The most obvious contribution made by any sector to the economic output of England is its 'direct contribution'. Wealth is created and employment is sustained as a result of customers purchasing mineral products. However, the contribution of any sector to the economy extends beyond this due to links between different industries, as shown in Figure 4. The overall benefit to the economy is considerably greater due to these 'indirect contributions'.



**Figure 4** Links between the fluorspar industry and other sectors of the economy

Source: *cebr*

As Figure 4 illustrates, the 'indirect' contributions of the fluorspar industry can be divided into three components:

- **The upstream contribution** - the fluorspar industry requires various inputs in order to operate. These include a wide range of goods and services such as fuel, transport, machinery and consultancy services. Acquiring these inputs generates economic activity and employment in these supplying industries.
- **Employee spend contribution** - the part of the wages and salaries that employees of the fluorspar industry spend on consumer goods and services, rather than save, also supports economic activity and employment in other sectors.
- **The downstream contribution** - fluorspar is an important input into many downstream industries which, in turn, generate economic activity and employment. Most notable among these is the important role played by fluorochemicals in many consumer products.

There is a difference between the first two of these links (in blue) and the third (in green). If the English fluorspar industry did not exist the contributions of these first two links to the economy would be lost in their entirety. Although, over time, suppliers would be expected to supply different industries and employees to find new jobs, however, these would be expected to be less productive or less remunerative.

With most sectors it is not the case that the entirety of the downstream activity would be lost because generally they use more than one raw material. Therefore, the level of this activity cannot simply be added to the upstream and employee spend contributions. However, in the case of fluorspar, there would be very significant impacts on the downstream fluorochemical industries detailed in Section 1.6.

## **2.2 MEASURES OF ECONOMIC CONTRIBUTION**

Gross output, or turnover, represents the total value of sales produced by an industry within a period of time. However, economic benefit is often measured in terms of ‘Gross Value Added’ (GVA) which is defined as gross output minus the value of goods and services used to produce that output. Therefore, the GVA generated by an industry is approximately the sum of remuneration of employees and profit generated by that industry. The GVA of an industry can be thought of as its contribution to national Gross Domestic Product (GDP).

## **2.3 DIRECT BENEFITS OF THE FLUORSPAR INDUSTRY**

According to the most recent set of accounts compiled by Glebe Mines Ltd, the turnover of the fluorspar sector is almost exactly £8 million. It is estimated that fluorspar production has directly contributed between £3 million to £3.25 million to the English economy in terms of GVA, in recent years (Table 2). This represents a small proportion of the total English GVA, however, it does represent a more significant component of the local and regional economies where fluorspar is extracted.

The main fluorspar producer (Glebe Mines Ltd) in England directly employs 65 people (INEOS Fluor, 2007b). This excludes contractors, with additional employment associated with the small-scale producers (‘tributors’) which provide fluorspar ore to Glebe. It is estimated that fluorspar accounts for 10 per cent of the employment in the ward in which Glebe Mines’ operation is based and fluorspar production is estimated to account for 0.18 per cent of total employment in the Derbyshire Dales local authority. Whilst these numbers are modest, the available jobs require a wide range of skills and, are mainly located in rural areas, providing employment diversity in contrast to agriculture and tourism. Employees at the mine are relatively well paid and the employment is non-seasonal compared with other opportunities in these areas.

## **2.4 INDIRECT BENEFITS OF THE FLUORSPAR INDUSTRY**

Due to the size of the fluorspar sector it is difficult to immediately trace the effects of indirect contribution using National Accounts data. Estimates of the size of indirect contribution can be derived from National Accounts data and input-output tables using the broader classification ‘Mining of Chemicals and Fertilisers’ of which fluorspar extraction is one part. These can then be scaled down to reflect the value of the fluorspar extraction within the larger sector. Input-output tables (ONS, 2007) analyse the pattern of spending relationships between different parts of the economy, i.e. how much sector A spends on the outputs produced by sector B. The expenditure contribution can then be traced into GVA and employment.

### 2.4.1 Upstream contribution of the fluorspar industry

The upstream contribution of the fluorspar industry to the economy is as a result of purchasing goods and services from its suppliers. It has been estimated that the English fluorspar industry spent approximately £3 million with its suppliers in 2005, generating around £1.3 million in GVA (Table 2).

Multiplier component	Turnover /spend (£m)	GVA generated (£m)	Employment generated (number of jobs)
Direct	8.0	3.0 – 3.25	60
Spending on upstream suppliers	3.0	1.3	33
Spending by employees	0.6	0.3	7
<b>Total</b>	<b>11.6</b>	<b>4.6–4.85</b>	<b>100</b>

**Table 2** Direct and indirect economic contribution of the English fluorspar sector

Source: *cebr*

### 2.4.2 Employee spend contribution of the fluorspar industry

Direct employees of the English fluorspar industry support economic activity as a result of spending of their salaries. This creates a demand for goods and services from other parts of the economy. It has been estimated that spending by employees of the English fluorspar industry totalled £0.6 million in 2005, generating around £0.3 million in GVA (Table 2).

Combining the effects of spending on upstream supplies and spending by employees with the direct contribution discussed above indicates that English fluorspar extraction is responsible for generating between £4.6 million and £4.85 million of GVA and for sustaining at least 100 jobs (Table 2).

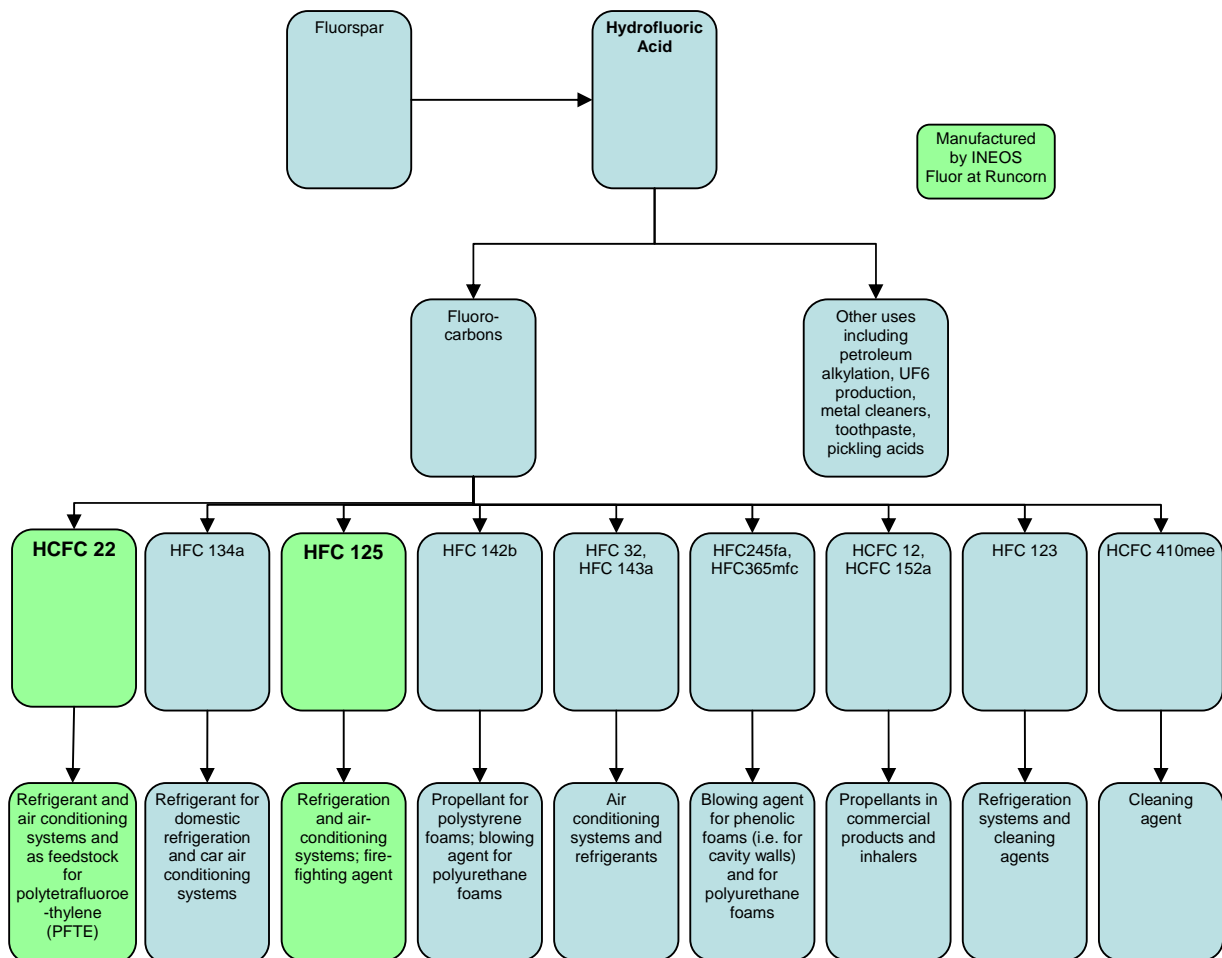
## 2.5 DOWNSTREAM CONTRIBUTION – FLUOROCHEMICALS

Fluorspar is a vital feedstock for the production of HF. In turn, HF is used for the manufacture of a wide range of products. Within the England, a particularly important use of HF is as an input for the fluorine chemicals industry, which uses it to produce fluorocarbons. Figure 5 illustrates the value chain for the fluorspar and the fluorine chemicals industry. It also indicates those components which are manufactured by INEOS Fluor at its Runcorn site. All of the fluorspar mined by Glebe Mines is used by INEOS Fluor to manufacture hydrofluoric acid at its installation in Runcorn. In turn, some of the HF produced is directly exported by INEOS Fluor (approximately 29 per cent) while the remainder of the HF is used in the production of a variety of fluorocarbons. The fluorochemicals industry is heavily dependent upon supplies of fluorspar from the fluorspar industry. Without these, they would be unable to produce their own outputs.

In its operations at Runcorn, INEOS Fluor employs 250 people, accounting for approximately 6 per cent of the employment in the ward in which the Runcorn facility is based. The operation has a turnover of £100 million. Based on the ratio of employment to GVA in the ‘Manufacture of other inorganic basic chemicals sector’, it can be estimated that the GVA associated with INEOS Fluor’s Runcorn operations is £24 million.

These findings are more significant when placed in the context of the local and regional economy:

- Manufacture of ‘basic inorganic chemicals’ (including fluorocarbon manufacture by INEOS Fluor) is the sector responsible for the greatest employment in the ward. It accounts for five times more employment than any other sector in the ward.
- INEOS Fluor’s Runcorn operations account for approximately 0.38 per cent of the entire GVA of the Halton and Warrington area.
- Fluorocarbon manufacture accounts for 0.6 per cent of the entire chemicals sector employment in the North West which, of one hundred sectors, is the eighteenth largest employer in the region. The chemicals sector in the North West is responsible for broadly the same amount of employment as the real estate sector and twice as much as the insurance and pension fund industry.



**Figure 5** Uses of fluorspar and the English fluorocarbon industry

Source: *cebr*

## 2.6 INDIRECT BENEFITS OF INEOS FLUOR’S ACTIVITIES

As with the Glebe Mines the economic contribution resulting from the spending on upstream suppliers (other than Glebe Mines) and the spending by INEOS Fluor’s employees has been estimated. Input-output tables were used to undertake this analysis, deploying the same methodology as the input-output table analysis used to examine these effects for Glebe Mines (Table 3).



It is estimated that the spending on upstream suppliers by INEOS Fluor is approximately £24.5 million. In this value, we exclude the company's expenditure on fluorspar as the economic contribution of this sector has already been assessed. It is estimated that this spending results in £9.4 million of GVA being generated and is associated with the employment of 204 people.

We further estimate that the employees of INEOS Fluor spend approximately £4.5 million per annum. This is estimated to result in a further £2.3 million of GVA being generated and the employment of 53 people.

<b>Multiplier component</b>	<b>Turnover /spend (£m)</b>	<b>GVA generated (£m)</b>	<b>Employment generated (number of jobs)</b>
Direct	100	24	250
Spending on upstream suppliers	24.5	9.4	204
Spending by employees	4.5	2.3	53
<b>Total</b>	<b>129</b>	<b>35.7</b>	<b>507</b>

**Table 3** Direct and indirect economic contribution of INEOS Fluor activities

*Source: cebr*

Combining these different forecasts together suggests that the economic contribution (GVA) made by the downstream user of fluorspar i.e. INEOS Fluor to the English economy is estimated to be £35.7 million of GVA, associated with the employment of 507 people.

## 2.7 SUMMARY OF ECONOMIC CONTRIBUTION

The economic contribution of the fluorspar industry extends beyond the direct wealth and employment generated by customers purchasing fluorspar. The Gross Value Added (GVA) of the industry is just one part of the overall contribution made by fluorspar to the English economy. Indirect benefits are also achieved through the interaction between fluorspar and other industries, and by their employees spending their wages and salaries.

Table 4 provides a summary of both the direct and indirect contributions of the industry, together with details of how the indirect contribution is comprised in terms of upstream, employee spend and downstream contributions.

2005	GVA £million	Employment
<i>Fluorspar industry:</i>		
Direct	3.0	60
Indirect:		
Upstream	1.3	33
Employee spend	0.3	7
<b>Sub-total</b>	<b>4.6</b>	<b>100</b>
<i>Downstream industry:</i>		
Direct	24	250
Indirect:		
Upstream	9.4	204
Employee spend	2.3	53
<b>Sub-total</b>	<b>35.7</b>	<b>507</b>

**Table 4** Summary of economic contribution of the English fluorspar industry

Source: cebr

### 3 Are significant imports a realistic option?

This question has two elements, firstly is the required material available on the open market and can it be practically imported into England? Secondly, what are the cost implications of importing material from overseas?

#### 3.1 THE SUPPLY CHAIN FOR IMPORTING FLUORSPAR

Importing fluorspar from overseas requires a supply chain with several elements that need to fit together if it is to be successful. Firstly, there needs to be sufficient material available on the open-market to meet demand. The main fluorspar producing countries are China, Mexico, Russia and Spain (Hetherington *et al*, 2008). The global availability of fluorspar has changed significantly over recent years and it is becoming increasingly difficult to procure high-quality material on the open-market. China, the world's largest fluorspar producer and exporter reduced its export quota for fluorspar by 50 per cent between 2001 and 2005 due to a greater focus on domestic use of the mineral, thus reducing supply to the world market (Hodgkinson and Lee, 2008). Reduced supply from the world's largest producer has also placed upward pressure on spot market prices. In addition HF exported from China is subject to 15 per cent export tax. European fluorspar, mainly from Spain and Germany, is not available in sufficient quantities according to INEOS Fluor. South African fluorspar is relatively high in phosphorus, iron and arsenic and INEOS Fluor do not believe it is available in sufficient quantities to meet their demands. Raw material sourced from Mexico, if available, also contains relatively high arsenic levels. Arsenic removal technology would require significant capital investment and time to establish (INEOS Fluor, 2007b). Accordingly the industry has serious doubts regarding the suitability or reliability of imports to meet English demand.

Transportation is an important consideration for importing any bulk commodity such as fluorspar from abroad. Fluorspar is generally marketed as Free On Board, whereby producers are only responsible for delivering the commodity to the main form of transport (e.g. a ship), whereupon the purchaser must arrange freight charges, insurance etc. At the port of origin there will also be costs associated with loading the material onto ships. Next there are the economic costs associated with transporting the material by ship and unloading the fluorspar at the receiving port. The cost of international ship hire is currently at unprecedented levels. Finally, there are the issues associated with distributing the fluorspar from the receiving port or wharf to the end-use customers, in England primarily INEOS Fluor. In some instances, the costs associated with this final distribution could be lower if the receiving port is closer to the end market. Conversely, they could also be higher if the distance is greater.

#### 3.2 ECONOMIC CONSEQUENCES OF IMPORTS

Assuming, however, that sufficient quantity of fluorspar can be sourced from the spot market, we have examined the impact of the increase in costs that INEOS Fluor would face on two (sets of) products: HCFC-22 and the set of blended refrigerants that make use of HFC-125. Collectively, INEOS Fluor employs 70 people in the production of these two products at its Runcorn site.

'Market models' were used to examine how the raw material cost change alters the market and financial position of the companies operating within it. Appendix 1 provides full details of the underlying structure of the models.

It was necessary to look at specific fluorocarbon products in the modelling as the cost and demand characteristics between different products within the industry can differ significantly. Consequently the impact of ceasing indigenous production could also differ considerably.

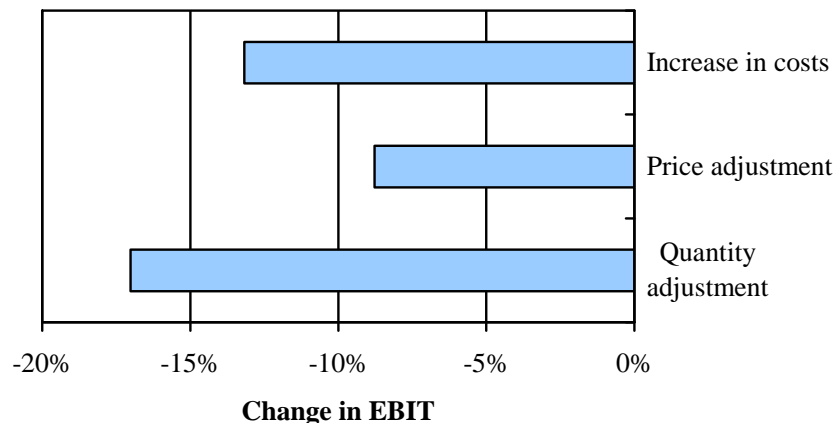
### 3.2.1 Model 1 – HCFC-22

HCFC-22 is extensively used in the production of polytetrafluoroethylene (PTFE), commonly known as Teflon® and used in non-stick pans and for waterproofing textiles.

In the modelling of this product it was assumed that one of two companies serving the European market, i.e. INEOS Fluor, experience an increase in the price of raw materials (fluorspar) of just over 10 per cent, equivalent to the short term increase that INEOS Fluor estimate they would face in the event that indigenous fluorspar production ceased and it was necessary to import this raw material instead.

This ten per cent increase assumes that, if indigenous production were to cease, sufficient quantity of fluorspar of the requisite grades would be available on the spot market to meet INEOS Fluor demand. As such, it takes account of current spot market prices. However, as discussed previously the amount of fluorspar available on the spot market is quite limited. If it was not possible to source the fluorspar from the spot market, the implication would be a considerably more significant increase in cost and, at least in the short/medium term, a risk of interrupted supply. As such, this analysis should be considered as representing the ‘best-case’ scenario from the perspective of INEOS Fluor.

The model indicates that the increase in raw material costs would cause INEOS Fluor’s profits for this product to fall. This can be partly offset by INEOS Fluor increasing product prices and passing these onto their customers. However, the level of price increases is limited by competition from the other company supplying the market which is not assumed to face higher raw material costs. These higher prices, plus greater costs, also reduce the overall tonnage of HCFC-22 supplied to the market and proportion of that quantity supplied by INEOS Fluor. The impact of an increase in raw material costs on predicted Earnings Before Interest and Tax (EBIT) in the production of HCFC-22 is shown below (Figure 6).



**Figure 6** Diagram illustrating the estimated cumulative impact on INEOS Fluor EBIT from the production of HCFC-22 were indigenous fluorspar production to cease

Source: cebr

Figure 6 shows that the initial impact on EBIT from the increase in costs (holding everything else constant) is between ten and fifteen per cent. Part of this increase in costs can be passed through into higher prices which reduces the expected EBIT impact to between five and ten per

cent. However, because of this increase in price, coupled with the fact that the higher costs of the company cause them to cut back on production, there is also a reduction in the output of the company. The final result is that the model suggests that the profitability of the company in relation to sales of this product would decline by around 17 per cent as a result of the increase in fluorspar costs.

In addition the model suggests that the impact of ceasing indigenous production of fluorspar is likely to result in quite significant changes in the market, and in INEOS Fluor’s financial position (Table 5). As well as the fall in the profit levels relating to this product of around 17 per cent, the loss of competitiveness is estimated to result in a fall in the quantity of HCFC-22 supplied by INEOS of more than 6 per cent and a corresponding loss of market share of almost 5 percentage points. Downstream consumers of HCFC-22 are also adversely impacted as a proportion (33 per cent) of the increase in costs is estimated to be passed on in the form of higher prices.

Parameter change	Change (%)
Increase in final product price	1.6
Implied cost pass through rate i.e. percentage of additional cost that are passed through in higher prices	33
Change in output of INEOS	-6.6
Change in INEOS Fluor market share	-4.7

**Table 5** Changes in the market in the manufacture of HCFC-22

Source: *cebr*

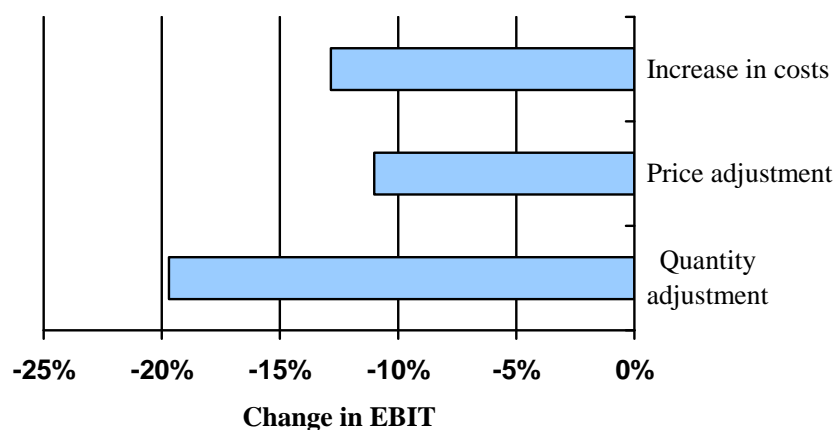
The above analysis assumes that there is no entry or exit into the European market for HCFC-22 as a result of the change in costs that INEOS Fluor would experience if indigenous fluorspar production were to cease. The most likely source of such entry would be from Chinese manufacturers moving into the European market. On the basis of the cost data provided by INEOS Fluor, it would appear that their costs of HCFC-22 production, even following the cessation of indigenous fluorspar production, would remain slightly lower than the costs that would be incurred by Chinese manufacturers supplying the European market, given the transport costs these suppliers would face. This would suggest that entry by these manufacturers would be unlikely to occur. However, these effects are all predicated on the basis of INEOS Fluor being able to successfully procure fluorspar of the requisite grade from the open market at prevailing market prices. If this can be achieved, then the modelling suggests that no new market entry is likely. However, if sufficient supplies of fluorspar cannot be acquired (or can only be acquired at substantially greater cost than is assumed in this modelling exercise) then there is a substantial risk of new market entry. The modelling suggests that the high fixed costs of production of HCFC-22, coupled with the relatively low levels of quantity demanded, means that the European market is unlikely to be able to sustain more than two suppliers. Consequently, if new market entry does occur then it is likely that INEOS Fluor’s production of HCFC-22 would no longer be profitable and hence the operation would have to close.

### 3.2.2 Model 2 – blended refrigerant using HFC-125

HFC-125 is used as one component in a blend of chemicals needed to produce refrigerants. To simplify the modelling, the four different refrigerants made using HFC-125 have been treated as being within one market.

In an identical way as for HCFC-22, a model has been used to predict what the outcome might be in the event that domestic production of fluorspar ceased. INEOS Fluor’s estimates suggest this would cause its marginal costs of production to increase by between four and nine per cent (depending on the precise blend of refrigerant being considered). This model used a marginal cost increase of 7 per cent.

The model suggests that the increase in marginal cost causes INEOS Fluor’s EBIT from the production of HFC-125 to fall by a further twelve per cent. This is a slightly smaller magnitude than for HCFC-22, reflecting the slightly smaller proportion of costs that are accounted for by fluorspar for manufacture of these products. However, the impact of change in the market price is much less effective in reducing this negative impact: the larger number of firms who do not face the same cost increase places a stronger constraint on the extent to which prices in the market can increase. Consequently, losses relating to this product are estimated to be 11 per cent greater than in the status quo, even after the price adjustment. Finally, the relative loss in competitiveness from the cost increase means that the impact of the quantity adjustment is much more severe. In total, the model predicts that INEOS Fluor would suffer a reduction in earnings for this product as a result of the cessation of the indigenous production of fluorspar of around 20 per cent (Figure 7).



**Figure 7** Diagram illustrating the estimated cumulative impact on INEOS Fluor EBIT from the production of blended refrigerants were indigenous fluorspar production to cease

Source: cebr

A further reduction in earnings of this magnitude could be expected to result in closure of the operation and the associated loss in employment of approximately 39 people.

Table 6 re-emphasises the point regarding the difficulty of cost pass through in the market. This results from the fact that INEOS would be the only supplier affected by the increase in costs. The model suggests that despite an estimated 7 per cent increase in costs, competitive pressures would prevent the final price rise being more than 1 per cent.

Parameter change	Change (%)
Increase in final product price	0.8
Implied cost pass through rate i.e. percentage of additional cost that are passed through in higher prices	14.2
Change in output of INEOS	-21.2
Change in INEOS Fluor market share	-2.6

**Table 6** Changes in the market in the manufacture of HFC-125

Source: cebr

### 3.3 POSSIBLE WIDER RAMIFICATIONS OF CESSATION OF INDIGENOUS FLUORSPAR PRODUCTION

The modelling discussed above has focussed on specific products manufactured by INEOS Fluor at its Runcorn operation. However, internal analysis by INEOS Fluor strongly indicates that, because of the highly integrated nature of its operations, a decision to terminate production of HCFC-22 at Runcorn would have far reaching knock-on implications for INEOS Fluor and other businesses in the INEOS Group.

In the case of HCFC-22 the results suggest that the impact of the cessation of indigenous fluorspar production in England would, even in a best case scenario, result in the output supplied, market share and profitability of INEOS Fluor's manufacture of HCFC-22 declining. However, these results are predicated on the spot market for fluorspar being able to provide sufficient quantities of fluorspar at the requisite grade. If this was not to happen, then the consequences would be more severe. INEOS Fluor consider there is a significant risk that the ultimate implications of cessation of indigenous fluorspar production would be the termination of HCFC-22 manufacture at Runcorn. If this were to happen there are knock-on implications for the following other aspects of INEOS Group operations (Figure 8):

- *Hydrofluoric acid manufacture*
- *Chloroform production from the chloromethane plant*
- *Chlorine cell rooms*
- *Anhydrous caustic soda plant*
- *Perchlorylene and trichloroethylene (Per/Tri) site*

Each of these is explored below in turn.

While the majority of the hydrofluoric acid produced from fluorspar at Ineos's Runcorn site is used for onward production of hydrofluorocarbons, approximately 29 per cent of the hydrofluoric acid produced is directly sold within the UK to industries which are critical to UK fuel and nuclear power independence. If INEOS Fluor was to no longer be able to source fluorspar from indigenous sources then this would threaten its supply of HF to these customers. Although in the short term it would need to honour existing contracts, this would probably have to be done at a loss.

In the longer term, INEOS Fluor considers that the most likely consequence of cessation of indigenous fluorspar production would be the closure of its HF manufacture plant. As well as the job losses that this would cause in Runcorn, and the cost increases it would necessitate for the downstream users of hydrofluoric acid, it would also raise issues regarding the independence of key 'strategic' aspects of UK industry as well as safety concerns regarding the long distance transport of a hazardous materials like HF.

As well as requiring HF, the manufacture of HCFC-22 requires chloroform. All of the chloroform required is sourced from INEOS Chlor's *chloromethanes plant*. This chloromethanes plant is responsible for the production of approximately 60 000 tonnes of chloroform. Approximately fifty per cent is sold to INEOS Fluor. Internal assessments undertaken by INEOS suggest that were HCFC-22 to no longer be produced then there is a substantial risk of a 'domino effect' and the closure of the chloromethane plant.

In turn, closure of the chloromethane plant could have further repercussions. The chloromethane plant requires the production of chlorine. This is co-produced in *chlorine cell rooms* with sodium hydroxide (caustic soda). The chlorine required for INEOS's chloromethane plant is derived from INEOS's three cell rooms. Analysis by INEOS Fluor suggests that if the chloromethanes plant were closed then the loss in demand for chlorine would likely necessitate the closure of at least one of these three cell rooms. This would result in the loss of sales of the caustic soda co-produced at the same time as the chlorine.

If a cell room was to close, causing a reduction in caustic soda production, then this would have a further knock-on impact on to INEOS's *anhydrous caustic soda plant* and its *Per/Tri plant*.

The anhydrous caustic soda plant is responsible for converting caustic soda liquor into 'pearls' of solid caustic soda which can be transported overseas more easily. If less caustic soda was to be produced then the necessity for export vanishes and the requirement for an anhydrous caustic soda plant is reduced.

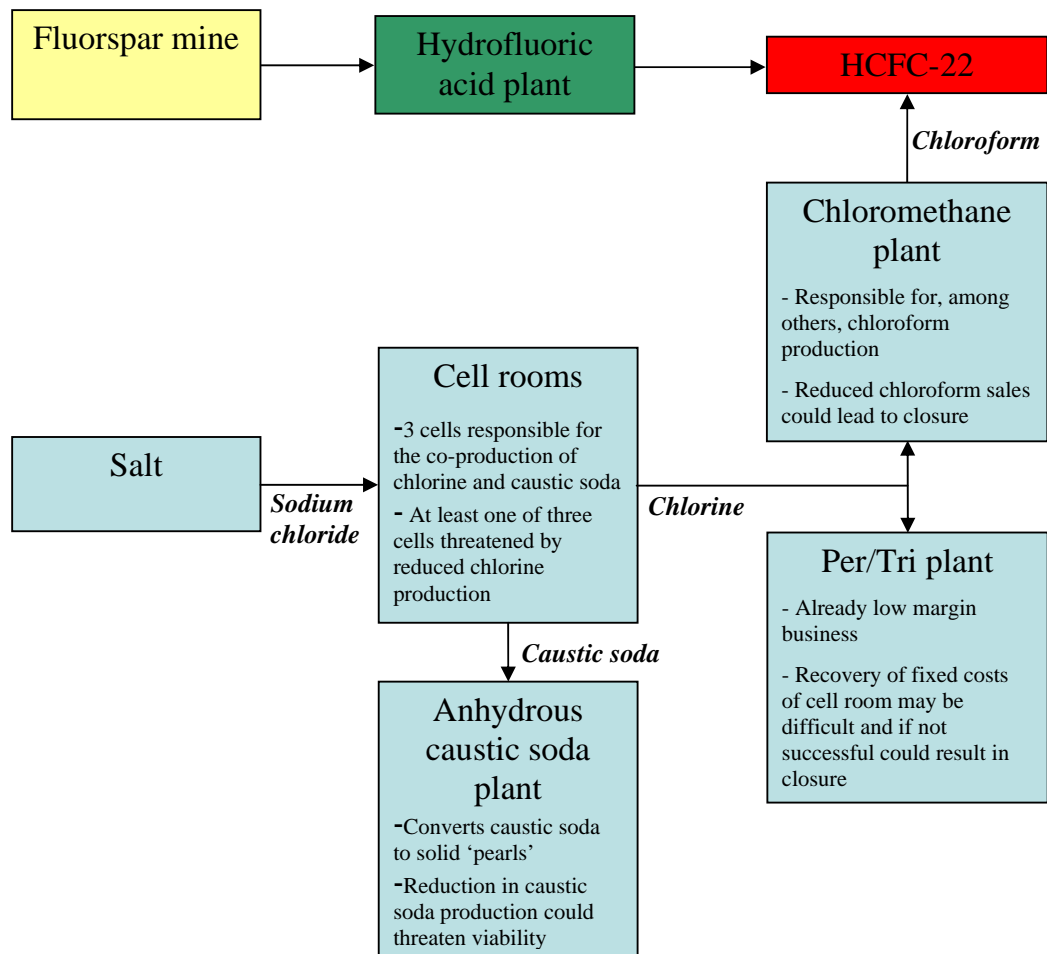
The Per/Tri plant is responsible for the co-production of perchlorethylene and trichloroethylene, using the chlorine derived from the cell rooms. The closure of the chloromethane plant would, however, require all of the fixed costs of the cell rooms to be recovered through sales of perchlorethylene and trichloroethylene. Historically, however, perchlorethylene and trichloroethylene sales have yielded the lowest return on chlorine of all derivatives based in Runcorn, with the fixed costs of the cell rooms instead primarily recovered through the chlorine sold on to the chloromethanes plant. INEOS estimates suggest this may necessitate the closure of the Per/Tri site and a second cell room.

Finally, lower production of chlorine and hence lower production of caustic soda would reduce demand for the basic raw material required for this production, salt (sodium chloride) in the form of brine.

In total, the analysis undertaken by INEOS suggest that at least further a 450 jobs within INEOS, and more in companies that contract with INEOS, could be lost if the cessation of indigenous fluorspar production was to lead to the closure of the HCFC-22 plant.

It should be stressed that the analysis underpinning these potential wider impacts has been undertaken internally by INEOS. It has been outside the scope of this project to undertake independent economic modelling to consider these wider implications.





**Figure 8** The potential wider ramifications that might be associated with the cessation of indigenous fluorspar extraction

Source: cebr

The following case study detailing the demise of the French fluorochemical sector provides an illustration of the dependence this industry has on indigenous production of its primary raw material fluorspar.

## CASE STUDY – THE EXPERIENCE OF FRANCE

France was once a globally significant fluorospar producer, supporting an important downstream fluorochemical industry. France's fluorospar production peaked in 2001 at 123 000 tonnes, when it was the second largest producer in Europe and the seventh largest in the world, accounting for around 3 per cent of global production.

France's fluorospar was sourced almost entirely from a single company the Société Générale de Recherches et d'Exploitations Minières (Sorgerem), who operated three mines (Burg, Montroc and Le Moulinal) in the Tarn region of south-west France (USGS, 2005). Sorgerem had been active in the region since 1971 and the mines had been worked for more than 60 years (Alcan, 2005). However, following a gradual decline in production Sorgerem announced that the mines contained insufficient fluorospar reserves to sustain their business and exploration had been unsuccessful in defining any new significant fluorospar deposits in the region (Alcan, 2007). Subsequently the 200 000 tonne per year fluorospar operations closed in June 2006, with the loss of around 80 jobs and significantly France lost its only indigenous producer of acid-grade fluorospar.



The competitiveness of France's downstream fluorochemical industry was highly dependent on indigenous fluorospar production, which moderated the cost of raw materials and ensured security of supply. Less than a year later the Arkema Group, the major chemical producer, announced the unexpected closure of its fluorochemical operations at its plant in Pierre-Bénite, France, with the loss of around 226 jobs (Industrial Minerals, 2007).

The Pierre-Bénite plant activities were highly dependent on hydrofluoric acid, the basis for the manufacture of its refrigerant fluids and fluoropolymers (Arkema, 2007). Following the closure of France's only fluorospar producer the company was forced to source fluorospar from abroad, mainly South Africa.

The company's main explanation for the plant closure was lack of access to indigenously produced fluorospar and the rising costs of imported material.

Arkema concluded that 'Its (the plants) profitability is affected in particular by highly adverse economic conditions linked to the sharp increase in cost of access to fluorospar, the main raw material for hydrofluoric acid...' (Arkema, 2007).

The French circumstances closely mirror the current situation in England, with almost all of France's fluorospar being sourced from a single producer under threat.

## 4 Environmental impacts of the fluorspar industry

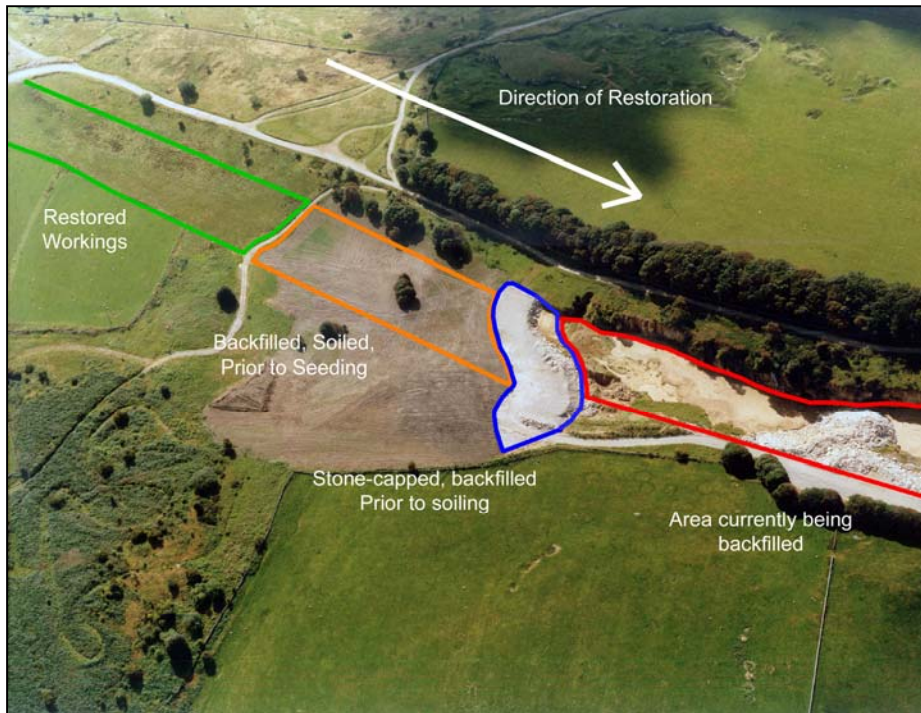
Fluorspar resources in Britain are found exclusively in mineralised veins and related deposits in Carboniferous limestones. These limestones tend to form attractive scenery with considerable ecological significance and amenity value. The veins are linear in form and can extend over considerable distances, often in elevated and/or highly visible locations. Almost all permitted reserves in the Southern Pennine Orefield lie within the Peak District National Park. The fluorspar industry thus operates in a very sensitive area (Figure 9). The now defunct operations in the Northern Pennine Orefield lie exclusively within the North Pennines Area of Outstanding Natural Beauty (AONB).



**Figure 9** Peak District National Park scenery

*Photo copyright: BGS©NERC*

Surface working of fluorspar and other vein minerals, especially to significant depths, raises issues of surface limestone storage and possible sale as aggregate. Some sites are located in places where limestone working would not normally be permitted. Both the Peak District National Park Authority and the industry are seeking to minimise any associated production of limestone. Fluorspar is different from most of the other industrial minerals produced in England in that deposits are more difficult to identify and evaluate. In addition, individual deposits tend to be relatively small and isolated. Consequently a continuous programme to identify and evaluate new deposits and progress them through the planning process is required to maintain an adequate reserve base. Vein mineral workings represent a temporary land-use and the scale of the operations is relatively small. Operations tend to have a short life when compared with other industrial mineral workings and due to their limited extent are often easier to integrate back in to the landscape (Figure 10). Most sites can typically be restored close to original ground level, to a high ecological standard and restoration is undertaken progressively wherever possible.



**Figure 10** Progressive restoration of fluorspar workings in the Peak District. Note the area to the left of the image which has been restored close to the original ground level

*Photo copyright: Glebe Mines Ltd*

There are permitted resources of fluorspar which can be worked by underground mining, and there is potential for further deposits to be identified at depth. However, given the greater costs of underground operations, higher ore grades are generally required to sustain this method of production. Accordingly, continued production of fluorspar from relatively low cost surface operations is necessary in order to offset the higher cost of working fluorspar underground. Furthermore, the combination of high grade ore from underground operations and lower grade ore from surface workings allows blending of different ore grades to maximise recovery of the resource and provide the appropriate specification to the processing plant.

It is possible that operators of small-scale, short-term fluorspar workings in environmentally acceptable locations may discover more extensive resources that are capable of further excavation, either laterally or in depth. Extensions to operations may then have the effect of increasing the scale of the activity and prolong development longer than was originally intended. This may, sometimes, be less environmentally acceptable than when permission was first granted. There are also a number of planning permissions for vein minerals in the Peak District National Park which were granted many years ago with operating and restoration conditions that are inadequate by modern standards. The reactivation of some of these would have significant environmental effects. However, the industry has sought to consolidate old permissions to remove any ambiguity on how they are worked. This has resulted in modern conditions of working and, importantly, restoration conditions to be agreed where formerly there was none.

## 5 Conclusions

- All English output is of acid-grade fluorspar. This is a critical raw material for the domestic chemicals industry.
- A single company, Glebe Mines Ltd, is the only producer of marketable fluorspar in the UK, from their operations in the Peak District National Park.
- All of the fluorspar produced in England is used by the hydrofluoric acid (HF) and fluorochemicals producer INEOS Fluor with its main manufacturing facility at Runcorn in Cheshire. HF and fluorochemicals are essential components in many everyday products including pharmaceuticals, refrigerants, petroleum, crop protection agents, detergents, crystal glass, light bulbs and ceramics.
- In 2007, in a strategic move, INEOS Fluor acquired Glebe Mines Ltd and secured supply to the UK's only viable source of acid-grade fluorspar.
- The gross value added (GVA) of the English fluorspar sector is between £4.6 million and £4.85 million and is responsible for sustaining at least 100 jobs. This consists of both the direct contribution of the industry and indirect benefits derived from the industry purchasing goods from its suppliers and employees of the industry demanding goods and services from other parts of the economy.
- This represents a significant proportion of local economic activity offering non-seasonal, relatively well-paid, professional and skilled employment in a rural area.
- Of greater importance is the economic contribution made by downstream consumers of indigenously produced fluorspar. INEOS Fluor employs 250 people, with an estimated GVA contribution of £24 million. INEOS Fluor's Runcorn operations account for approximately six per cent of employment in the ward that it is based. Combining this with the indirect contribution of INEOS Fluor's Runcorn operation it is estimated that the total contribution made by the downstream user of fluorspar to the English economy is £35.7 million of GVA, associated with the employment of 507 people.
- Permitted reserves of fluorspar in England have reached critically low levels.
- Fluorspar resources in England are concentrated in areas of attractive scenery or national parks, thus the fluorspar industry operates in very environmentally sensitive areas.
- It is unlikely that sufficient quantity of fluorspar (at the appropriate grade) would be available on the spot market to meet INEOS Fluor's requirements.
- If sufficient quantity of fluorspar could be sourced from the spot market at the very least, this would lead to an increase in costs.
- INEOS Fluor compete in an international market and the modelling undertaken as part of this study suggests that the cost increase associated with sourcing fluorspar from the overseas would lead to a significant deterioration in INEOS Fluor's market position (for two products analysed) and a fall in profits. This could be expected to result in the cessation of production of certain products and the closure of associated operations.
- Internal analysis by INEOS Fluor strongly suggest that, because of the highly integrated nature of its operations at its Runcorn site, a decision to terminate production of the HCFC-22 product at Runcorn would have far reaching knock-on implications for INEOS Fluor and

other businesses in the INEOS Group, collectively, responsible for the employment of more than 450 people.

- Moreover, in the case of HF manufacture, the outputs from this production are sold to some of the UK's key strategic industries including the nuclear and petroleum sectors. Were UK production of HF to cease then these 'strategic industries' would face increased costs while it would also raise concerns regarding both the 'independence' of these sectors as well as safety implications of transporting such a hazardous material over long distances.
- France provides an illustration of the dependence the fluorochemical sector has on indigenous fluorspar production to remain competitive. Less than a year after France ceased indigenous fluorspar production a major chemical producer announced the closure of its fluorochemical operations.
- Imports of fluorspar from overseas do not appear to offer a realistic long-term solution due to the cost implications of importing fluorspar from overseas as demonstrated by the modelling exercises and the lack of availability of high quality fluorspar on the open market. Accordingly the English fluorochemical sector is highly dependent on indigenous fluorspar production.

# Appendix 1

## **THE IMPACT OF INCREASING FLUORSPAR PRICES ON THE FLUORO-CHEMICAL INDUSTRY IN THE UK**

The essence of the model is that it assumes that the market is not perfectly competitive (in which case the price of a chemical product would be equal to the marginal cost of its production) but, rather, oligopolistic i.e. there are a relatively small number of firms. It then makes use of the Cournot oligopoly framework; which represents the ‘standard’ approach to considering oligopolistic markets.

The key inputs that have been used for the modelling were provided by Ineos Fluor, but are not reproduced here to protect the Company’s confidentiality. These included details on marginal costs of production, fixed to variable costs proportions, market share details and prices.

Using these assumptions, the model does a reasonable job at predicting current market outcomes. The model predicted European sales of the product HCFC-22 to within 11% of actual market quantity, that this quantity would be shared between 2 firms equally and predicted prices that were slightly higher than those seen in the market at present. For the product HFC-125 the model accurately predicted the number of firms in the market, predicted prices which were slightly lower and output that was slightly higher than the actual observed. It did less well at predicting the European market share of Ineos Fluor for this particular product, but overall it was considered that it accurately captured the main features of the market.

The market models were then ‘shocked’ by a restriction in the supply of indigenous fluorspar, causing the price to rise for Ineos Fluor only. The model results are shown in sections 3.2.1 and 3.2.2.

### **Cournot modelling**

The market modelling exercise uses a Cournot framework to consider an impact of a cost shock on the market for two particular fluorochemical products. In undertaking this analysis, a number of assumptions are made about the behaviour of firms in the marketplace and the nature of competition. The key assumptions are the following:

- firms aim to maximise profits;
- the ‘strategic variable’ chosen by companies is the amount of the products they supply, rather than price that they set (firms can only ever choose one of price or quantity, the other determined by the demand curve);
- the market for the fluorochemical products is a European market which would imply, *inter alia*, that the price for these products is the same across the continent with no regional differences;
- the output that firms produce is homogeneous;
- firms have a cost structure which consists of a fixed costs incurred by all firms in the market and a constant marginal cost;
- the model assumes that all firms have the same constant marginal cost;
- there is a constant, linear relationship between demand and price.

The modelling results should be seen as stylised representations of the likely ‘typical’ impact on the market(s) for these products of a cost shock in the upstream price for fluorspar.



With these assumptions made, the mathematical underpinnings of the model are as follows.

The relationship between price and output (Q) is given by the following, downward sloping demand curve:

$$P(Q) = a - bQ \quad \text{Equation 1}$$

The cost curve for each firm  $i$  ( $i=1 \dots n$ ) is given as:

$$C_i = F_i + c_i q_i \quad \text{Equation 2}$$

Firm's profits,  $\Pi_i$  are given by the product of the quantity they sell and the price they sell them at, less the cost of production.

Using equation 1, and noting that  $Q = \sum_i^n q_i$  this can be seen as being:

$$\Pi_i = q_i P(Q) - (c_i q_i + F_i) \quad \text{Equation 3}$$

Assuming that firm's choose quantities to maximise profits, this profit function can be differentiated with respect to  $q_i$  to yield the profit maximising condition of:

$$P(Q) - c_i - b q_i = 0 \quad \text{Equation 4}$$

All firms have the same profit maximising condition, so it is also the case that:

$$NP(Q) - \sum_{i=1}^n c_i - bQ = 0 \quad \text{Equation 5}$$

Dividing by N, letting  $c^*$  be the average of all marginal costs, i.e.

$$c^* = \left( \sum_{i=1}^n c_i \right) / N$$

and rearranging gives:

$$P(Q) - (bQ)/N = c^* \quad \text{Equation 6}$$

Substituting equation 1 into equation 6 and rearranging gives:

$$Q = \frac{\left( \frac{N}{N+1} \right) (a - c^*)}{b} \quad \text{Equation 7}$$

Substituting this back into equation 1 and re-arranging gives:

$$P = \left( \frac{1}{n+1} \right) a + \left( \frac{n}{n+1} \right) c^* \quad \text{Equation 8}$$



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