British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

The Economic Importance of Minerals to the UK

Office of the Deputy Prime Minister
Creating sustainable communities

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Preface

This report was produced by the British Geological Survey for the Office of the Deputy Prime Minister (Minerals and Waste Planning Division). It forms one of a number of reports, leaflets and mineral profiles prepared under the Joint ODPM-BGS Minerals Programme that, among other objectives, seeks to present factual and authoritative data on the extent, availability, production, trade and use of minerals that are of economic importance to the UK. Much of this information is made available on the BGS minerals website: www.mineralsUK.com.

The report has been written in such a way as to be suitable for a wide non-economist audience and has avoided too much detail and economic theory. Its production contributes to a better understanding of the economic and social issues associated with the production and use of minerals and their contribution to sustainable economic development.

Acknowledgements

The authors would like to thank Dr Brian Marker and Bill Mackenzie of the Minerals and Waste Planning Division of the Office of the Deputy Prime Minister for their support and constructive comments during the preparation of this report. The authors would also like to thank their colleagues for their assistance and advice, in particular Gus Gunn, Adrian Minks for graphic design, Janice Hillier for statistical support and Becky White for report preparation.

BRITISH GEOLOGICAL SURVEY

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The Economic Importance of Minerals to the UK

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Extracting ball clay, north Devon.

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Introduction

Minerals have been extracted from the Earth since prehistoric times and the history of civilisation and industrial advancement has been linked with man's ability to harness and use the materials available to him. Through knowledge and technological innovation there has been a continuing evolution and expansion in the minerals we consume and the range of uses to which they are put. The old mining industry adage *'if you can't grow it, it has to be mined'* is a truism that is often forgotten. Minerals play a fundamental role in underpinning growth in the economy and in contributing to the UK's high standard of living.

The complex geological history of the UK and its adjacent Continental Shelf has contributed much to our national wealth. The ancient trading of Cornish tin, the close association of coal and iron ore resources that supported the development of the Industrial Revolution and, more recently, the exploitation of our offshore oil and gas resources have all made crucial contributions to the economy. In addition, the UK produces a wide range of construction minerals, notably aggregates, and industrial minerals, such as salt, potash and kaolin. Domestic mineral production will be of continuing economic importance.

Indigenous mineral resources are, therefore, valuable national assets. Unlike human resources, capital, knowledge and manufacturing facilities, they are non-transferable and can only be worked where they occur. The location of mines and quarries fundamentally reflects geology and this distinguishes the extractive industries from other industrial sectors of the economy.

" through technological innovation there has been a continuing evolution and expansion in the minerals we consume and the range of uses to which they are put "

Boulby Potash Mine, North York Moors National Park.

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The importance of minerals to society

Adequate supplies of minerals are essential for manufacturing, construction, energy requirements and agriculture and thus for the sustainable development of a modern economy. The use of renewable energy sources, recycled materials and industrial by-products can, and rightly should, be maximised to meet part of our requirements and to reduce waste. However, new mineral sources will continue to be required. Minerals are basic and essential raw materials for:

- **construction** to develop, maintain and enhance our built environment and transport infrastructure
- **manufacturing** for the production of a wide range of industrial and consumer goods
- **transportation** and **electricity generation** for use in the home, industry and commerce and
- **agriculture** to improve the productivity of the soil.

A classification of the major groups of **economic minerals**[1] in terms of the downstream industries in which they are consumed **(Figure 1)** serves to illustrate the reliance of many critical sectors of the economy on the products of the extractive industries. Individual minerals are consumed in more than one sector and each market area requires a number of different minerals. Whilst people can easily make the connection between minerals extraction and its impact on the environment, it is more difficult to associate the products of the minerals industry with quality of life in terms of material comforts.

Like other industrialised economies, the UK is a major consumer of minerals. **Table 1** shows per capita consumption of a range of minerals and minerals-based products, together with the country's supply position. Volumetrically, construction minerals, notably aggregates, and energy minerals are the dominant minerals consumed by society, with the lowest being for steel-alloying elements and minor metals. Industrial minerals and major base metals occupy the middle ranks. The UK's population is forecast to rise over coming years, which may lead to an increasing consumption of some minerals, notably those used in construction and energy production.

[1]***Economic minerals*** *are rocks, minerals or fluids, that are valued for their physical and/or chemical properties and can be marketed for productive use.*

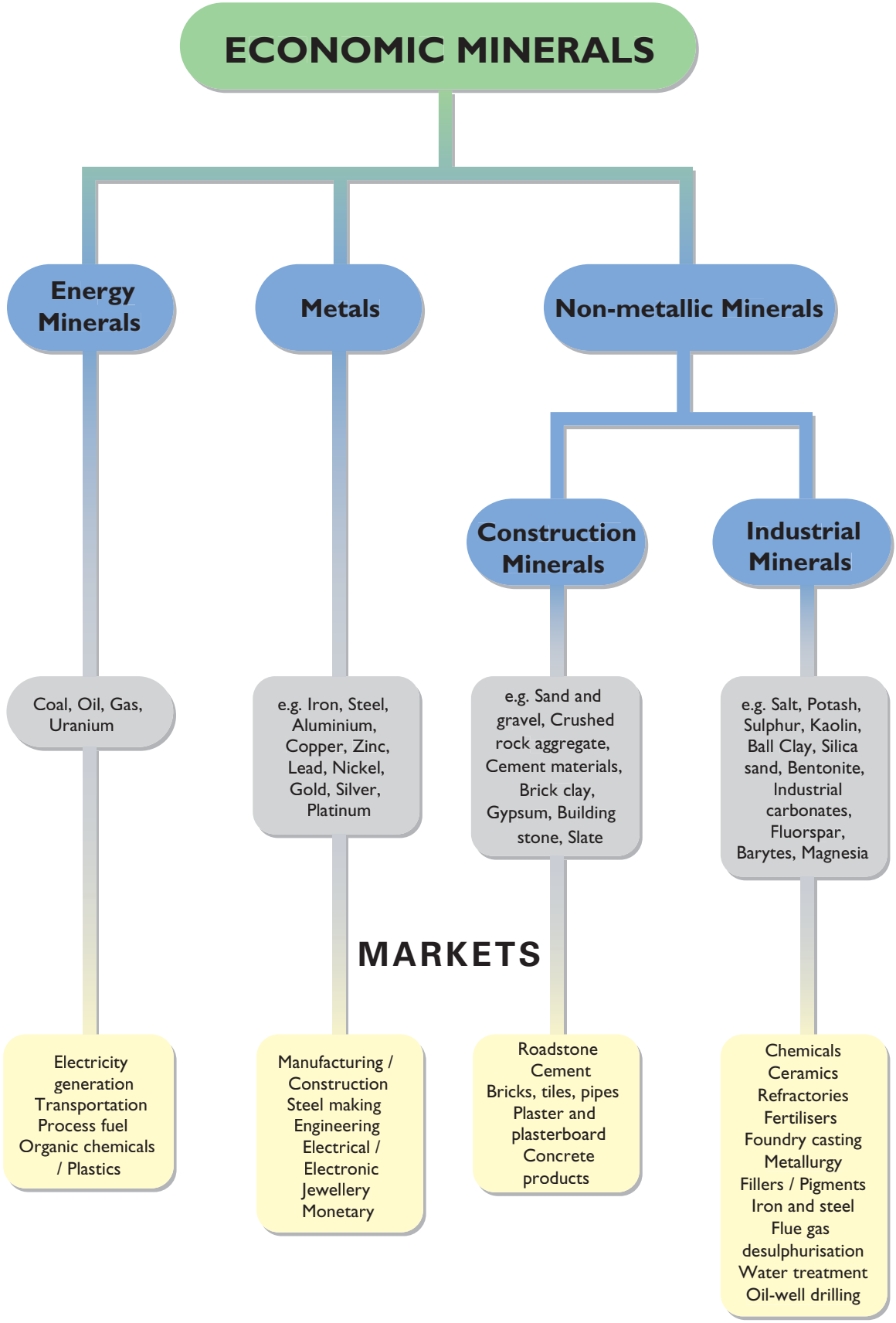

Figure 1 A classification of economic minerals and selected sectors of the economy in which they are consumed.

	Self sufficiency	Per capita consumption kg	Total consumption '000 t
Primary aggregates	100%	3 955	232 000
Natural gas	100%	1 681	99 500[1]
Crude petroleum	100%	1 246	73 800
Coal	50%	990	58 642
Steel	30%	240	14 220
Iron ore	0%	223	13 181[2]
Cement	90%	210	12 361
Industrial & agricultural limestone/dolomite/chalk	100%	178	10 554
Brick clay	100%	118	6 985
Salt	100%	96	5 700
Silica sand	100%	65	3 833
Gypsum, natural & synthetic	90%	62	3 700
Potash	100%	12	728
Aluminium	20%	11	626[3]
Fireclay	100%	8.3	491
Sulphur	30%	5.6	306
Lead	65%	5.2	298[4]
Kaolin	100%	4.5	264
Copper	0%	4.4	261[4]
Zinc	0%	4.0	235[5]
Ball clay	100%	2.7	158
Bentonite & fuller's earth	25%	3.0	178
Barytes	55%	1.8	104
Manganese	0%	1.7	102[6]
Titanium*	0%	1.6	97[6]
Fluorspar	70%	1.4	80
Chromium*	0%	1.4	83[6]
Nickel*	0%	1.0	59[6]
Tin	0%	0.16	10[4]
Molybdenum*	0%	0.09	5[6]
Cobalt*	0%	0.03	1.5[6]
Tantalum*	0%	0.02	1.2[6]
Vanadium*	0%	0.01	0.7[6]

Self-sufficiency is production as a percentage of consumption. In the cases of steel, aluminium and lead the percentages shown record only the production from obsolete scrap. For these metals there are also major outputs from production facilities based on imported materials. Some of the imported minerals occur in the UK but in such small quantities or low grades that they cannot be worked economically, even though they may have been mined in the past, e.g. iron ore and base metals. Others (asterisked) have never been shown to occur as significant resources in the UK.

Four categories of supply position are distinguished.

- Domestic mine/quarry and net exports
- Domestic mine/quarry either supplemented or complemented by imports
- Imported but with major contribution (15 – 65%) to consumption from recycling of obsolete scrap
- Imported with minor or no contribution to consumption from recycling of obsolete scrap

UK population 2002 59.2 million

[1] tonnes of oil equivalent [2] for steel [3] primary + secondary
[4] refined [5] refined + scrap [6] content of refined, ferro-alloy, oxides etc.

Table 1 UK self sufficiency in minerals and metals and per capita consumption, 2002.

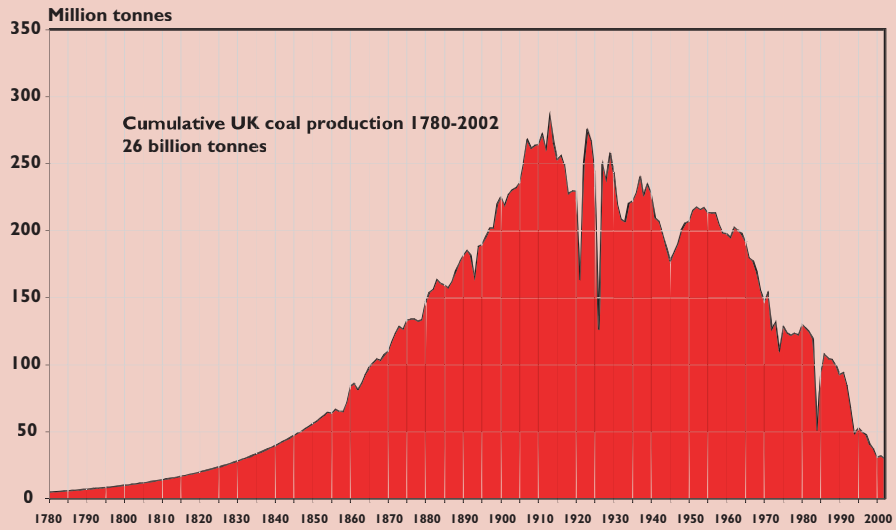

Figure 2 UK coal production 1780–2002.

Minerals supply

Minerals consumed by the UK economy are either extracted from indigenous resources or are imported. In both cases the mineral is derived from the natural environment and extraction will be associated with some level of environmental impact. These natural minerals, or mineral-based products, such as refined metals, are then processed within the economy to produce goods and services that are essential to our overall national economic well-being **(Figure 4)**. However, an increasingly important and additional source of supply are the waste streams associated with economic activity. These include construction and demolition wastes, industrial by-products, scrap metal and glass. Recycling of these materials not only reduces our primary mineral consumption, whether from domestic extraction or imports, but also the quantities of waste that have to be disposed of to landfill.

For its small size Britain is fortunate in having important indigenous resources of a wide range of minerals, particularly energy and industrial minerals. These support extractive industries of considerable economic importance **(Table 2)**. Coal and natural gas each provide approximately one third of the fuel for our electricity generation. The share of natural gas, which has risen sharply since 1990 (the 'dash for gas'), is expected to rise still further but reserves of oil and gas are being depleted and the UK is forecast to become a net importer of gas by 2005. Coal output has been in steep decline since the 1950s, chiefly due to closure of uneconomic deep mines, and imports are now comparable in amount to domestic production. Opencast coal production, one eighth of total output in 1986, now accounts for almost half. Substantial resources of coal remain in the ground and new technology may eventually allow these to be recovered, or exploited in situ, in the form of gas. The UK has historically been self-sufficient in fuel for electricity generation and, thanks to our offshore oil and gas resources, is at present a net exporter of energy, but this is now clearly coming to an end.

The UK has important indigenous resources of a number of non-metallic minerals, notably construction minerals, such as aggregates, brick clay, cement-making materials and gypsum,

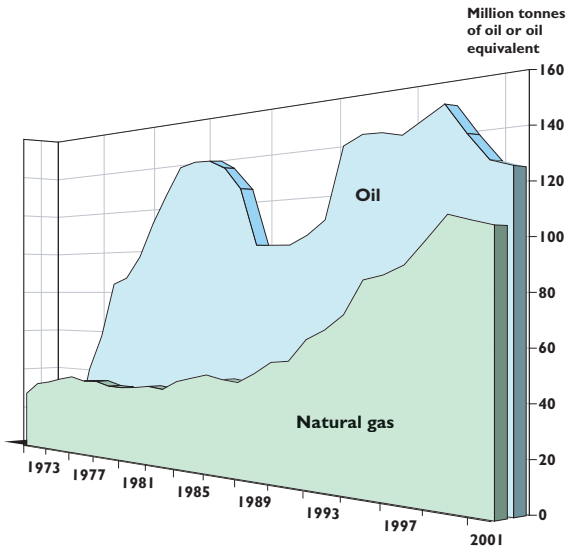

Figure 3 UK production of crude petroleum and natural gas 1973–2002.

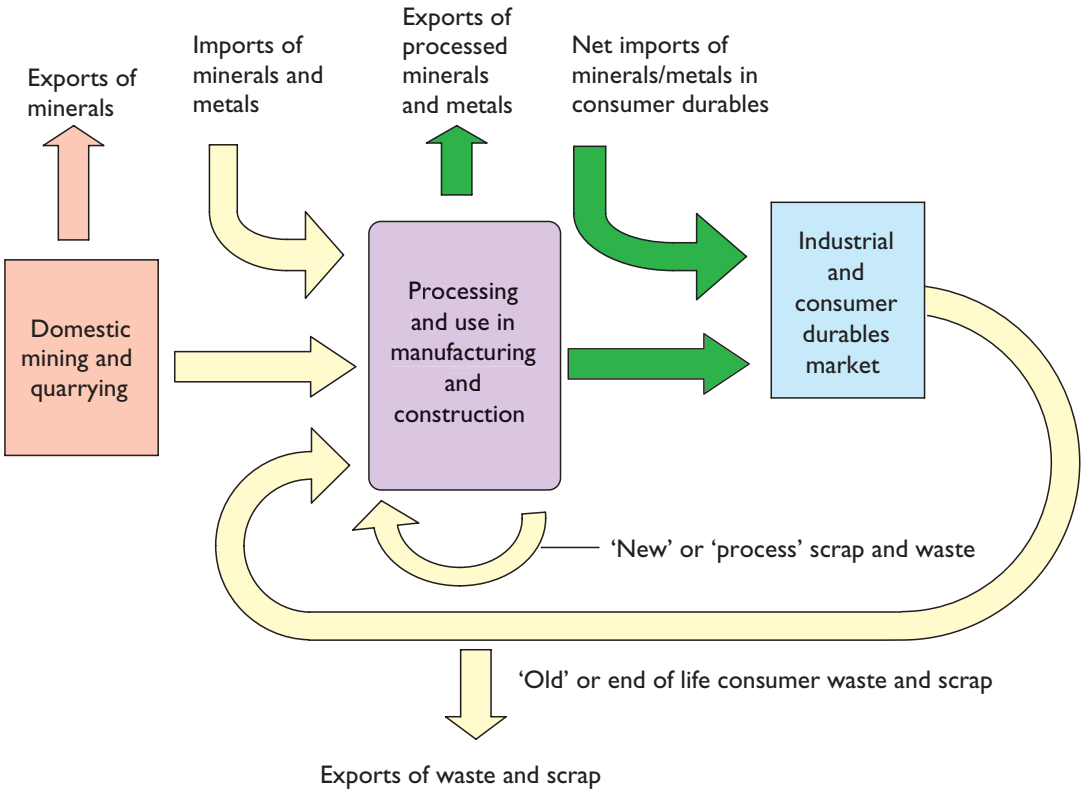

Figure 4 Physical minerals flow through the economy.

and also industrial minerals, such as kaolin (china clay), ball clay, limestone, silica sand, potash, salt, fluorspar and barytes.

The construction industry is an important sector of the UK economy. Although increasing amounts of alternative materials (about 65 million tonnes) are being consumed, large quantities of construction minerals (248 million tonnes in 2002) are also required. These include sand and gravel for concrete, crushed rock (limestone, igneous rock and sandstone) for road construction and maintenance, and clays for brick and tile manufacture. Sand and gravel are widely distributed and significant tonnages are also dredged from the seabed. Large resources in the English Channel will form an important source in the future. Hard rock suitable for use as crushed rock aggregate has an uneven distribution, and southern and eastern England are largely devoid of resources. Consequently significant quantities of crushed rock are imported into South-east England from the Mendips, from the East Midlands and from the UK's only coastal superquarry at Glensanda on the west coast of Scotland. Currently only modest quantities of crushed rock are imported from Europe.

The kaolin deposits of south-west England are world famous for their size and quality and have yielded some 160 million tonnes of marketable product since production began in the mid-18th century.

Figure 4 illustrates in simplified form the essential features of physical minerals flow through the economy. The box 'Processing and use etc.' represents processes that range from the most basic, such as iron ore smelting and cement-making, to the production of finished goods, such as housing, infrastructure and manufactured articles.

The arrow 'Net imports of minerals/metals in industrial and consumer durables' serves to show that the 'footprint' of UK minerals demand is not limited to those materials imported in raw or semi-processed state. One tonne of copper imported to UK may entail the generation of 400 tonnes of waste at a foreign mine.

It is important to distinguish the two types of scrap shown in the diagram: 'old' scrap has been incorporated in finished articles, used and discarded at the end of its useful life, whereas 'new' scrap is simply a means of minimising waste in the manufacturing process. The two are often added together to give a spurious statistic for 'recycling', particularly in the case of metals.

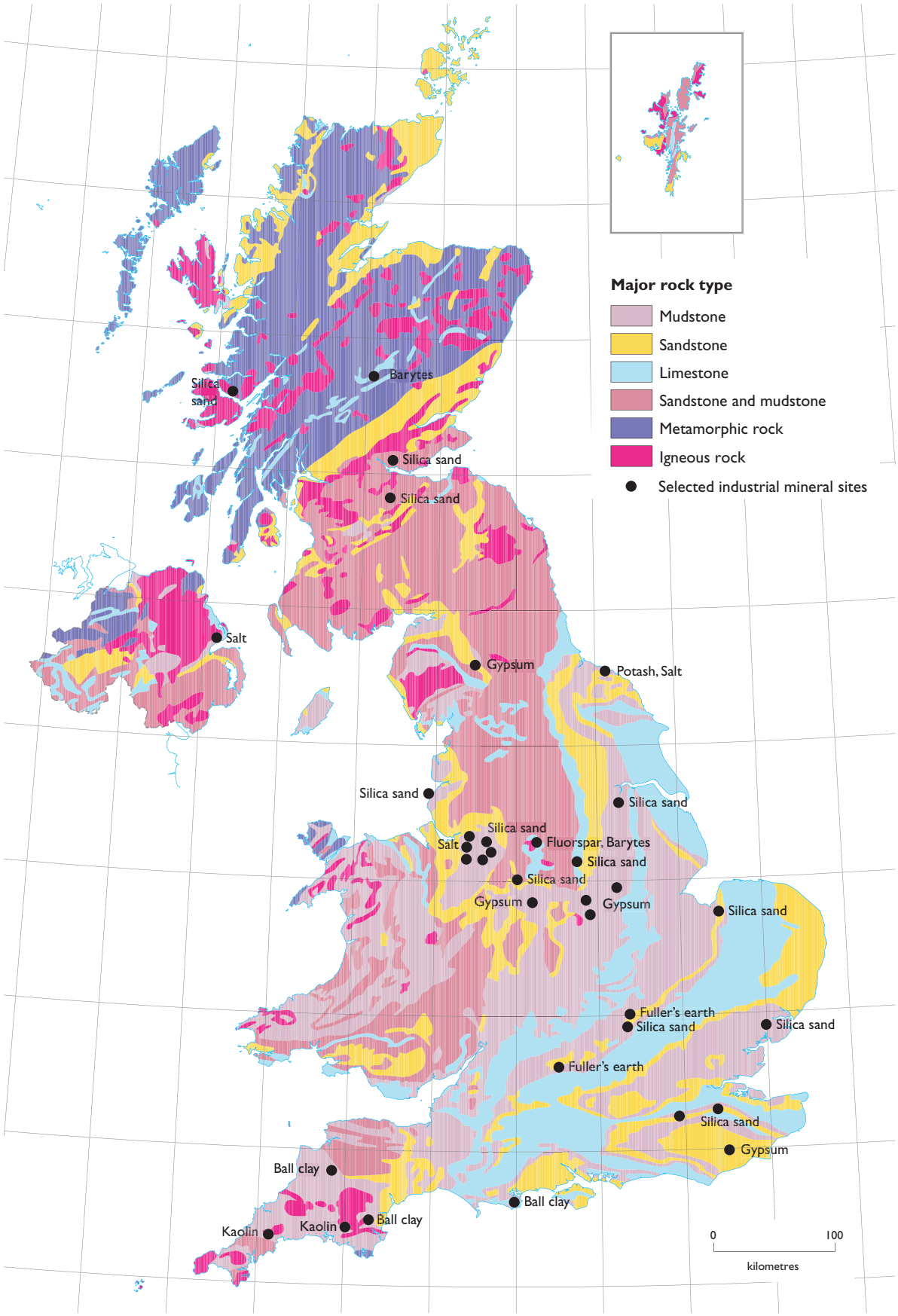

Figure 5 Location of selected industrial mineral operations.

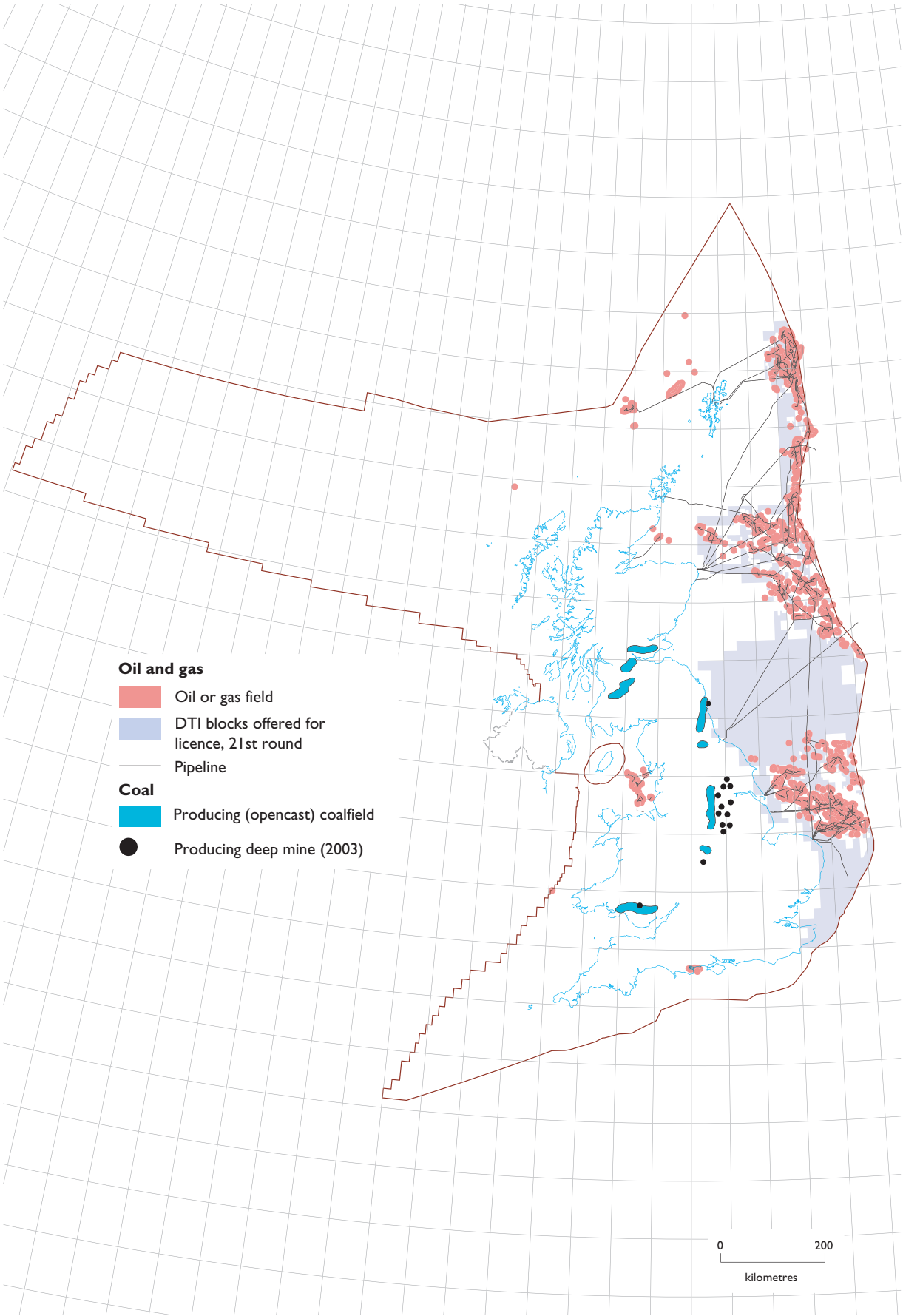

Figure 6 Location of oil, gas and coalfields.

Some 88 per cent of production is exported and the mineral is the UK's most important mineral export after hydrocarbons. Kaolin is mainly used in papermaking but has a range of other uses, including ceramics and a filler in paint, rubber and plastics. The UK is also a leading world producer and exporter of high-quality ball clay which is valued for its plasticity and white-firing properties. It is principally used in the manufacture ceramic whiteware. As with kaolin, over 80 per cent of production is exported and over 50 per cent of the world's production of sanitaryware contains a proportion of UK ball clay as an essential ingredient.

	Thousand tonnes	Value £ million
ENERGY MINERALS		
Coal: Deep-mined	16 391	889
Opencast	13 148	
Oil: Onshore	2 767	14 523
Offshore	113 768	
Gas: Onshore (oil equivalent)	471	8 199
Offshore (oil equivalent)	103 106	
CONSTRUCTION MINERALS		
Aggregates		1 648
of which: Land-won sand & gravel	75 401	
Marine-dredged sand & gravel	19 023	
Crushed rock	144 337	
Cement raw materials (limestone & chalk, clay & shale) (GB)	17 386	227
Clay & shale and Fireclay (for bricks) (GB)	7 476	
Gypsum, natural	1 700	
Slate	742	
Building (dimension) stone (GB)	696	
INDUSTRIAL, AGRICULTURAL AND HORTICULTURAL MINERALS		
Limestone/dolomite/chalk (Industrial use) (GB)	8 915	90
Limestone/dolomite/chalk (Agricultural use) (GB)	1 639	
Brine/rock salt	5 700	148
Potash (refined potassium chloride)	900	68
Silica (Industrial) sand	3 833	53
Kaolin (china clay)	2 163	192
Ball clay	921	44
Fuller's earth	44	5
Fluorspar	53	5
Barytes	59	3
Peat	973	na
Other minerals *	20	<1
UK Landmass	305 735	3 613
UK Continental Shelf	235 897	22 482
TOTAL	**541 632**	**26 095**

*Other minerals: calcspar, lead ore, iron ore, china stone, talc, and flint. GB: Figures for GB only. na: not available
Source: United Kingdom Minerals Yearbook, British Geological Survey.

Table 2 UK minerals production, 2002.

The UK has extensive resources of salt (NaCl), potash (KCl) and gypsum ($CaSO_4.2H_2O$) which were formed from the evaporation of seawater. Rock salt is mined for de-icing roads. However, most salt is extracted in solution as brine for direct use in the inorganic chemicals industry in the manufacture of chlorine, caustic soda and soda ash. These, in turn, are essential intermediates in many other processes, including the manufacture of PVC and glass. Brine is also evaporated to produce white salt. Potash is the main source of potassium, one of the principal nutrients essential for plant growth. Production, which is from a single large deep mine at Boulby in the North York Moors National Park, is mainly used in fertilisers. Substantial quantities are exported. Gypsum is mainly used in the manufacture of plasterboard, plaster and cement. Desulphogypsum derived from flue gas desulphurisation at coal-fired power plants has largely replaced natural gypsum for plasterboard manufacture. However, there remains a demand for natural gypsum which is mainly produced by underground mining.

Silica sands contain a high proportion of silica in the form of quartz and are used in glass manufacture, to form moulds for metal casting and a wide range of other industrial and horticultural uses. High purity deposits have a restricted distribution in the UK. Industrial limestones, including chalk, are composed essentially of calcium carbonate ($CaCO_3$). They have important industrial applications in iron and steelmaking, glass manufacture, sugar refining and numerous chemical processes. Large tonnages are also used in the manufacture of cement, which is an essential constituent of concrete and mortar. The UK has large resources of high-purity limestone. Industrial dolomites, which are also used in iron and steelmaking and glass manufacture, have a more restricted occurrence.

Fluorspar (calcium fluoride) is the only UK source of the element fluorine. It is the essential raw material for the manufacture of fluorine-bearing chemicals which have a wide range of uses, including in refrigeration and air conditioning. The mineral has a restricted occurrence, the principal source being the Peak District. Barytes (barium sulphate) has a high density and is mainly used in hydrocarbon exploration as a weighting agent in drilling fluids to prevent 'blow outs'. It is produced as a by-product of fluorspar, but the main source is a mine near Aberfeldy in Scotland. A large barytes deposit remains unworked in the same area because of planning difficulties.

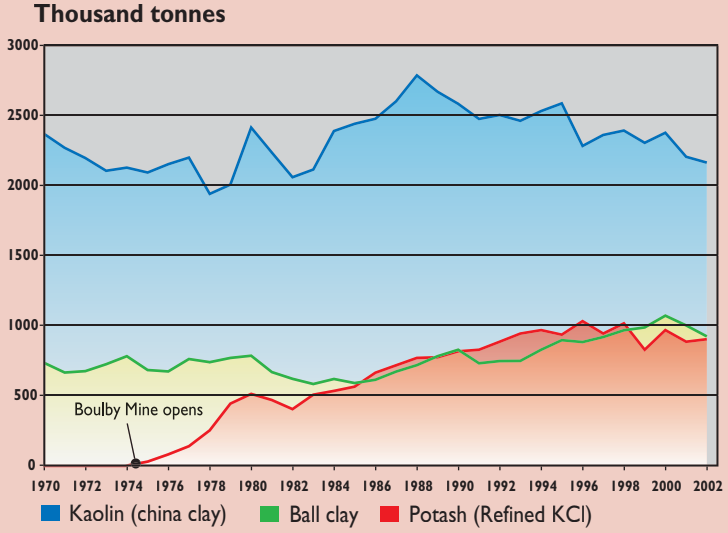

Figure 7 UK sales of kaolin, ball clay and potash, 1970–2002.

In the mid 19th century the UK was a leading world producer of several metals, including iron, tin, copper and lead, but the metal-mining industry has declined in the face of high extraction costs and competition from expanding and lower-cost producers overseas. The extraction of iron ore remained important until the 1950s and continued until the late 1980s but only modest non-ferrous metal mining survived into the 20th century: the last mine worked solely for lead and zinc closed in North Wales in 1978, and the last tin mine closed in Cornwall in 1998. Exploration for metals has continued, particularly for gold, and the proving of viable deposits of both precious metals and base metals still remains a possibility. The UK is now wholly dependent on imports for metals supply apart from steel, lead and aluminium where important contributions are made by the recovery and refining of old (obsolete/post-consumer/end-of-life) scrap. However, at the present time much non-ferrous metal scrap generated in the UK is being exported to China and other Far East countries. Generation and recovery of scrap is high but the contribution of old copper scrap, in particular, to national consumption is practically zero. Many of the steel alloying metals, such as nickel and chromium, and minor metals have never been shown to occur as significant resources in the UK but they are, in effect, also recycled in the form of alloy steel and other alloys.

The UK has a substantial and increasing foreign dependence on minerals supply. The trade position for selected minerals and mineral-derived materials in 2002 is shown in **Figure 10.**

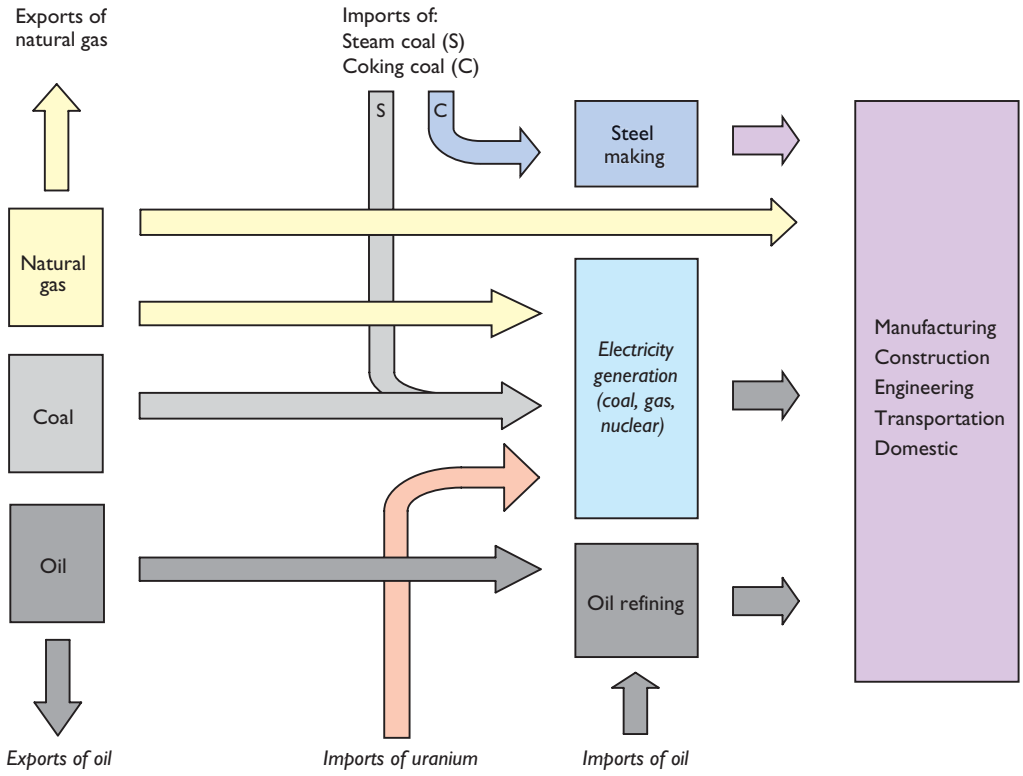

Figure 8 Physical flow of energy minerals through the economy.

The energy minerals flow chart **(Figure 8)** illustrates in simple form the physical flow of these minerals through the economy. The arrow shapes are symbolic and bear no relationship to actual amounts concerned. In spite of large exports of crude petroleum, imports are also necessary for the supply of heavy crude, which is not obtainable from the North Sea fields. Exports and imports of refined and partly refined products are almost in balance. Imports of coal are roughly equal to domestic production. Not shown are the relatively small amounts of gas imports and coal used for other than electricity generation.

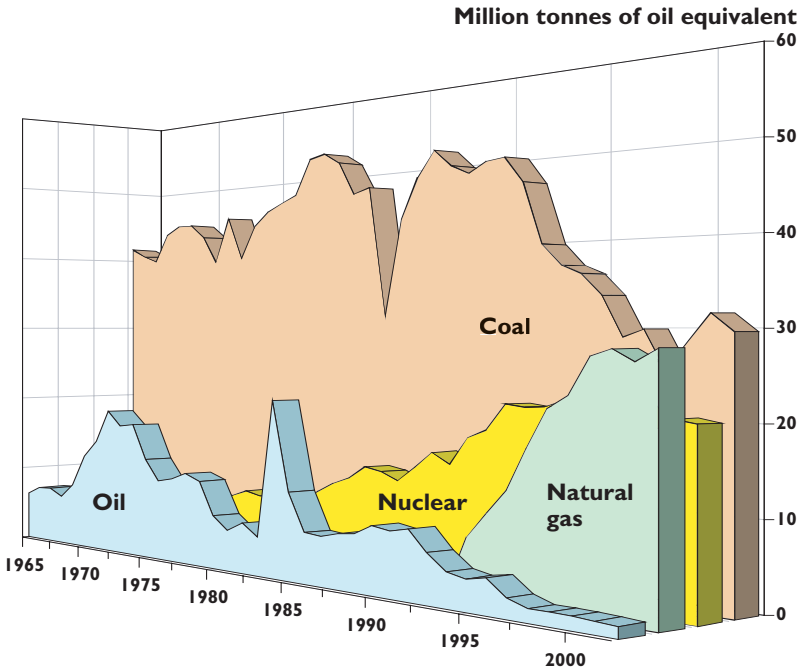

Figure 9 UK: fuel used in electricity generation 1965–2002.

Security of minerals supply

The concept of 'strategic minerals' originated in the era of the Cold War. They were defined as minerals and metals that are both critical to a manufacturing sector and vulnerable to interruptions in supply. Military requirements were relevant but not dominant. The concept of strategic minerals is now unfashionable since the global market is assumed to be able to supply minerals to customers without significant risk of any interruption due to political factors.

However, the fact remains that the UK and other industrialised countries are dependent on foreign sources, often very few in number, for a large number of minerals and metals that are critical to their economies. The measures proposed in the past to mitigate the risk were diversification of supply sources and the maintenance of stockpiles. Both involve increased costs. The UK government maintained a small stockpile — about three months' supply — of a number of strategic metals (in the form of both ores and refined metal) from 1983 until 1996. Diversification has become less practicable in the past quarter-century. The production of many minerals has become concentrated in a smaller number of countries and in the hands of fewer but larger multinational corporations. For example, one open-pit mine, in Indonesia, produces six per cent of the total world output of copper. The consequence of two recent landslides in that mine was an immediate, if small, effect on the world copper price. In this context, China is particularly important: the tremendous rate of growth of China's economy, and its consequent demand for imports of minerals and metals, has recently caused sharp increases in commodity prices and raised the prospect of intermittent world shortages. Equally concerning is the fact that China has for several years dominated the world supply of a number of metals and industrial minerals, such as tungsten, magnesium, fluorspar and barytes, and any abrupt curtailment of exports of these materials from China, caused by rising domestic demand, could significantly disrupt world markets.

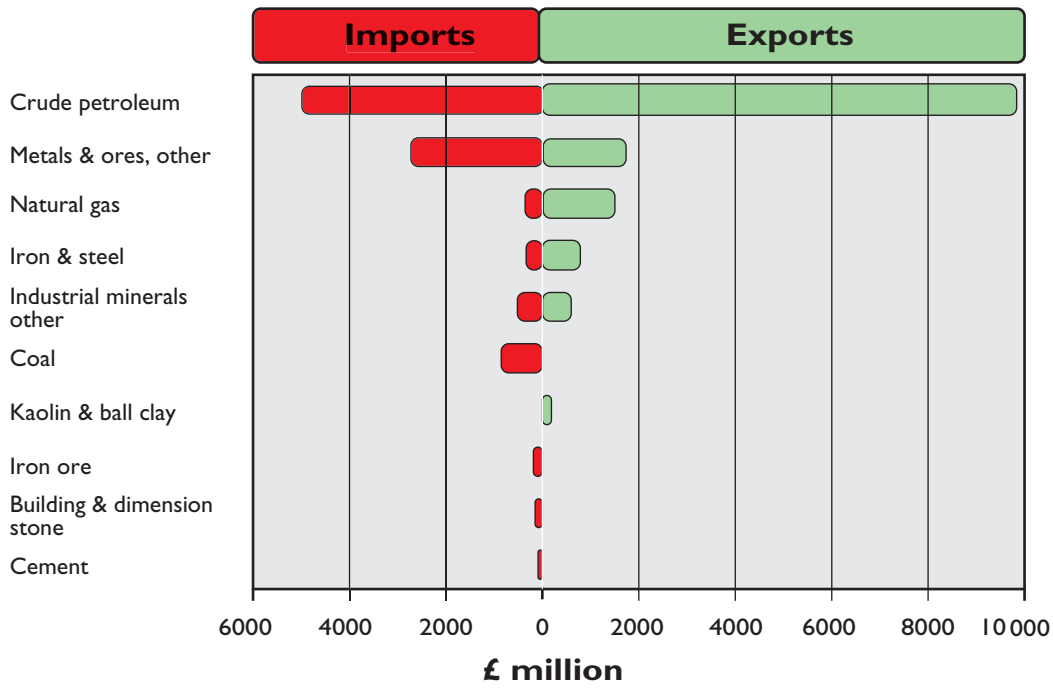

Figure 10 UK trade in major minerals and metals 2002.

D Highley, BGS © NERC

Kaolin extraction using high pressure jets of water.

Mineral production — where and why

There are several factors that determine where a mineral is produced and thus whether it is obtained from domestic resources or has to be imported. These are:

- resource availability
- costs of production
- quality
- access to mineral resources

Resource availability

The location of a mineral deposit, and thus of a mineral operation, is fundamentally determined by geology. If there are no resources of a specific mineral then there can clearly be no production.

Mineral resources are natural concentrations of minerals, or bodies of rock (or fluids such as oil, gas and mineral brines) that are, or may become, of potential interest as a basis for the economic extraction of a mineral product. They exhibit physical and/or chemical properties that make them suitable for specific uses and are present in sufficient quantity to be of intrinsic economic interest. The status of mineral resources in economic terms changes with time as markets decline or expand, product specifications change, recovery technology is improved or more competitive sources become available. However, resource availability is not sufficient on its own to ensure that a mineral resource is suitable for successful exploitation.

Costs of production

A mineral is only economically viable if it can be extracted, processed and sold at competitive prices on world markets or alternatively, for indigenously produced minerals, if it can compete with imported minerals. Mineral extraction may receive government subsidies, but this is not the case in the UK. With the exception of gemstones, the price of a mineral or metal chiefly reflects the costs of production to a marketable form. However, the price paid by the ultimate consumer will also depend on transport costs and any premiums that a producer may add to the price, on the basis of, for example, quality, purity or scarcity.

Changes in demand or supply will also cause the price of a mineral to vary within limits. Demand may rise or fall with cycles in general economic activity; it may also be affected by specific factors such as technology changes in user industries, infrastructure programmes and environmental prohibitions. Supply problems include production getting out of step with demand, due to inaccurate market predictions, and supply shortfalls caused by accidents, strikes and wars. In general, the price of a mineral is self-regulating: weak demand or over-supply causes the price to fall and producers will tend to reduce their output, while strong demand or under-supply, causing the price to rise, is corrected by increased output from existing producers, by marginal producers coming on stream, and by sales of physical stocks — although such corrections are seldom immediate. The prices of the less expensive industrial and construction minerals do not normally fluctuate significantly from year to year. However, in the case of some minor and precious metals, price may vary by as much as 200 per cent in a matter of months. The chief determinants of fundamental mineral and metal prices are:

Extraction and processing

As a generalisation, minerals that can be won by surface extraction methods from quarries and which need little processing beyond crushing and size-grading have relatively low 'ex-pit' values. Thus **sand and gravel and crushed rock aggregates** are the least expensive minerals to produce. Coal from both opencast and underground mines is a little higher up the scale of cost, but many deep coal mines, particularly in Western Europe, are struggling for commercial survival.

Many **non-metallic (or construction and 'industrial') minerals** also occur in surface or near-surface deposits with relatively low costs of excavation. However, it is typical of these minerals that they need a range of processing treatments that may include crushing, drying, calcining, beneficiation (separation from unwanted impurities), size or colour grading, and chemical conversion. Several are 'mined' as liquids, for example, salt in the form of brine. Their final market price is thus significantly higher than that of aggregates.

In the case of **metal ores,** as a rule the rarer a metal is in terms of its abundance in the Earth's crust, the more costly it is to extract and therefore the higher its price. Several of the ores of the commoner metals can be mined from open pits and shipped almost as cheaply as aggregate minerals but the output from the mine, e.g. iron ore, manganese ore, bauxite, needs several costly processing steps before achieving the final marketable metal. Many others are won from deep and expensive underground operations where even the initial cost of proving the existence of a viable deposit is very high and the capital cost of building the mine even higher. Once the ore is raised it is then necessary to separate the metalliferous minerals from waste minerals by fine grinding, which is also a major contributor to costs, followed by froth flotation and smelting or chemical treatment to produce the final metallic product. In contrast to non-metallic minerals, most base metals are produced in highly refined standard forms that are acceptable to all the relevant user industries.

Transport

Transport costs may be a major component of the delivered price of many minerals. The lower the value of a mineral the more profound are the effects of transport costs, which thus apply a 'place value' on a mineral deposit. For aggregate minerals, such as limestone, the place value is very high, because the commodity has a low value per tonne. In the case of limestone in the UK, road haulage transport costs can typically add £6 per tonne to the price of crushed limestone. This means that the availability of a nearby market is of critical importance. Conversely gold has a very low place value and an ore deposit of adequate grade can be mined almost anywhere, with virtually no restriction on the distance to market. Between these extremes are certain minerals and mineral-based commodities that can be traded over short and medium distances using transportation by rail or sea. However, none of these generalisations should be taken as immutable rules: crushed rock aggregate has been traded between continents when the deposit has easy access to sea and a return cargo was available. The normal situation is summarised in **Table 3.**

Very short (60 km)	Short (200 km)	Medium (intra-regional)	Long (trans-oceanic)
aggregate minerals (road)	aggregate minerals (rail)	kaolin (by sea)	coal
brick clay	bricks	ball clay (by sea)	oil
	cement (rail)	cement (by sea)	natural gas
			iron ore
			metal ores & concentrates
			dimension stone
			industrial minerals

Table 3 Typical maximum trading distances.

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Pricing practices

Low-value **bulk minerals** such as aggregates are traded on the basis of current prices. A consumer of bulk minerals, such as a steel maker, who cannot afford to risk uncertainty or interruption in supply of iron ore, will often have to agree a price with a supplier for deliveries over a considerable period into the future. The adoption of 'just-in-time' supply practices, which reduce the cost of holding stocks, has made dependability of supply even more important.

Refined metals illustrate a different situation: although the bulk of transactions in refined metals are also on the basis of private contracts, the dealings on the London Metal Exchange (LME) and other commodity markets establish 'official' prices on a daily basis that act as a guide and basis for negotiation. The LME has standard contracts that closely specify the quality of the goods (usually a minimum metal content such as 99.7 per cent) and consumers and traders (the middlemen between producer and ultimate consumer) buy on a contract with confidence in the quality of the metal, whatever its source.

Between these two extreme examples lies a wide range of minerals and metals for which typical prices are published in trade journals. In the field of **industrial (i.e. non-metallic) minerals** and coal, in particular, prices for a specific mineral may vary widely according to specifications and uses.

Quality

In addition to price, quality may also be an important factor that determines whether a mineral is sourced from overseas or domestically. Metal ores are principally, but not exclusively, used to produce refined metals, which are generally traded on the basis of purity and price. Effectively all suppliers of refined metals are capable of producing material to standard international specifications. However, non-metallic minerals are valued for their diverse physical and/or chemical properties. They tend to be traded both nationally and internationally on the basis of specific properties, which are suitable for particular uses and, sometimes, to meet a particular customer's needs. Consequently individual qualities of specific minerals are often not interchangeable in use. For example, the major market for kaolin (china clay) is in papermaking where it performs two quite separate functions, as a coating pigment and filler. The qualities of

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A coal-fired power station, Nottinghamshire, UK.

kaolin that are used in these applications are quite different and cannot substitute for one another. Matching the consumer's requirement with the right product forms the basis of successful marketing of minerals.

In a similar way UK imports of coal are not just a function of being more competitively priced but they also tend to have lower sulphur contents than indigenously produced coal. This means that they can be burnt in power stations without the need for expensive desulphurisation equipment.

Modern manufacturing technology is placing increasingly stringent demands on raw material quality, where variations in the properties of a mineral beyond specified limits cannot be tolerated. Quality thus also implies raw materials with consistent and predictable properties, in terms of both composition and performance.

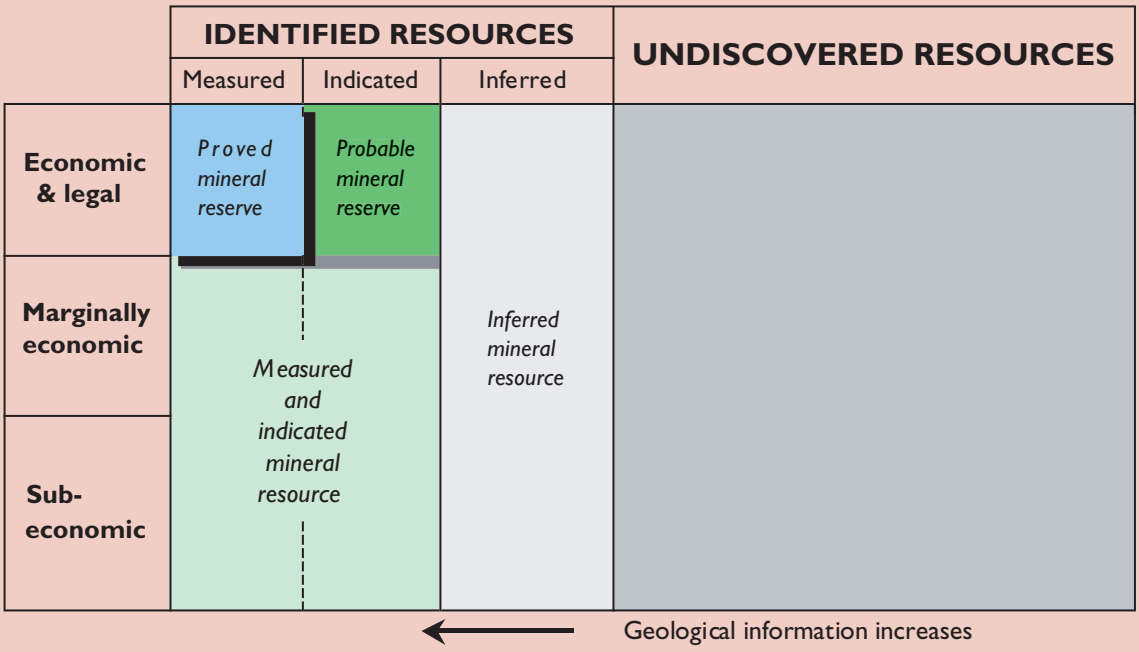
Access to mineral resources

The presence of an otherwise economically viable mineral deposit is not in itself sufficient to ensure that mineral extraction will take place. There is no general state ownership of minerals in the UK, except for oil, gas and coal. Precious metals (gold and silver) and marine-dredged sand and gravel are vested in the Crown. Most other minerals are, therefore, in private ownership and consequently the agreement of the mineral rights owner must be obtained before exploration and extraction can begin. In the case of energy minerals and precious metals a licence must be obtained for the relevant authority to explore for and extract these minerals. Such a licence does not include any rights of access, and the licensees must also obtain any consent under current legislation, including planning permissions.

In common with most other forms of development in the UK, mineral extraction and related activities, such as processing, require planning permission before any development can take place. Without a legal planning consent no mineral working can occur and consequently the inherent economic value of a mineral resource cannot be released and resulting wealth created. Continuity of supply of a mineral may, therefore, be threatened. The authority with responsibility for planning control, including determining planning applications, for mineral working is called a **Mineral Planning Authority.** It is the role of the planning system, through Mineral Planning Authorities, to secure the most efficient and effective use of land in the public interest and to attempt to balance the competing demands of development and environmental protection.

The planning system has an important role to play in contributing to the Government's strategy for promoting sustainable development. Whilst minerals extraction creates undoubted economic and social benefits for the local and wider community, it is almost always associated with some harmful, although temporary, environmental impacts. These impacts need to be minimised and brought within acceptable limits through modern planning conditions and sound site-management practices. Effective planning for minerals supply thus depends on identifying locations where mineral extraction will have least effect on the environment and amenity, undertaking operations with minimum environmental impacts and, as mineral extraction is not a permanent use of land, ensuring high quality restoration to beneficial after-use. Well-restored mineral workings often provide important environmental assets, for example in terms of biodiversity and amenity. The overall aim is to meet society's essential need for minerals in a sustainable way. However, this does mean that there will be occasions when the environmental impacts of mineral extraction and conflicts with other forms of land use are not outweighed by the economic advantages. Consequently minerals cannot be worked everywhere they occur. However, there are concerns in the extractive industries that the constraints on mineral working are increasing in

Figure 11 A classification of mineral resources and reserves. *(After McKelvey, 1972).*



More complicated classification schemes and more heavily qualified definitions have been devised for the purpose of providing financiers, investors and others with dependable reserves data. One variant is used, for example in the London Stock Exchange Listing Rules. In the case of oil, the Securities and Exchange Commission of the US lays down guidelines on the definition of proven reserves.

A mining or quarrying operation normally starts up with enough reserves to ensure a reasonable return on investment and lifetime for the mine. As mining proceeds, new reserves may be proved beyond the original workings but eventually the deposit will be exhausted and the mine or quarry will close. For aggregate minerals in the UK planning authorities calculate a 'landbank', which is the result of dividing total reserves with planning permission in the area concerned by the annual production to give a figure, in years, for the productive life of the reserves. *(A similar calculation is sometimes undertaken for world reserves to give a global 'life index' for any particular mineral or metal. However, this is misleading, as mines close, new ones open and total world reserves of most mineral commodities are larger now than at any time in the past and, with the possible exception of oil and gas, are likely to continue to grow for the foreseeable future).*

number and extent such that their cumulative impact is seriously restricting future options for mineral development. Consequently, despite the occurrence of extensive resources of many minerals in the UK, it is increasingly difficult to find environmentally acceptable sites for mineral working. This may cause supply problems in the longer term.

In relation to other forms of land use, mineral working is a relatively minor use of land, at least in terms of the total area occupied, although visual and transport effects will have a wider impact. In England in 2000, the total area permitted for surface mineral working was about 0.87 per cent of the land area. The area worked but not reclaimed was 0.51 per cent (Arup Economics and Planning, 2002); for comparison, urban settlement areas cover about nine per cent of England.

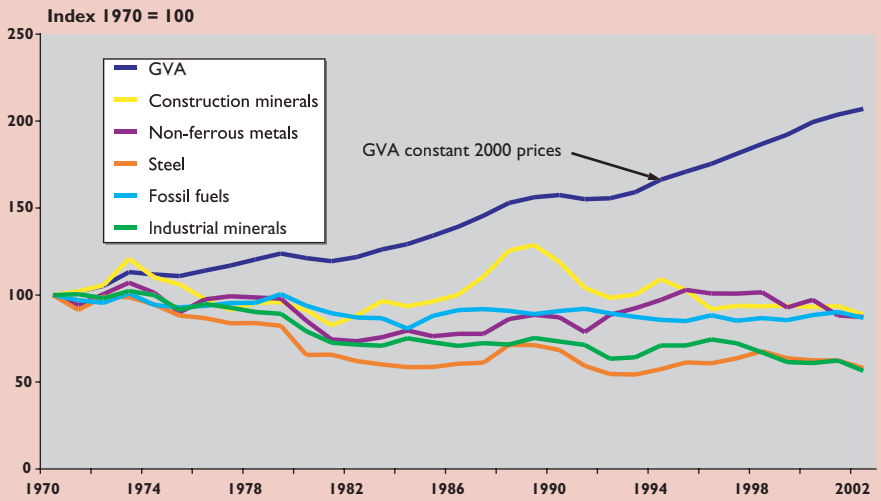


Figure 12 Minerals consumption and economic growth, 1970-2002. *Source: British Geological Survey.*

Reserves

The economic potential of an individual mineral deposit can only be proved by a detailed evaluation programme, involving drilling and associated test work to prove that mineral of sufficient quantity and quality is present. Such an investigation is also an essential precursor to submitting a planning application for mineral working. Since there is no guarantee that planning permission will be granted, the capital involved in acquiring access to a site and evaluating its potential is at risk.

That part of a **mineral resource** that has been fully evaluated and is deemed commercially viable to work is called a **mineral reserve.** However, the term **mineral reserve** should strictly be further limited to those minerals with legal access and for which a valid planning permission for extraction exists (i.e. **permitted reserve**). Without a valid planning consent no mineral working can take place. The ultimate fate of permitted mineral reserves is either to be physically worked out or to be made non-viable by changing economic circumstances. Reserves, especially those that have planning permission to work, are of crucial importance to a mineral company as they represent its future assets.

Sustainable development

General

The Government's strategy for sustainable development (DETR, 1999) stresses that the maintenance of high and stable levels of economic growth and employment need to take place in a way that ensures effective protection of the environment and prudent use of mineral resources. Wealth creation through continuing national and regional investment to create a more competitive economy is also a key element of this strategy. Another key objective of any sustainable development strategy is improving resource efficiency, or simply 'doing more with less.' The rationale for this is to decouple economic growth from environmental degradation and resource use in both production and consumption (DEFRA, 2003; Wuppertal Institute, 2001). Data for the UK indicate that in recent years there has been a relative decoupling of economic growth from the direct consumption of minerals. The UK economy (Gross Value Added) has increased by over 100 per cent since 1970 but the consumption of minerals and unwrought mineral-derived products, both from domestic production and imports, has declined by about 25 per cent on average **(see Figure 12)**. The extent to which the decline is due to improvements in resource efficiency, resulting from, for example, greater recycling, is uncertain. Structural changes in the economy due to the relative decline in UK manufacturing and growth in the services sector, together with a lower level of infrastructure replacement and a decline in house building, will have also contributed.

BGS © NERC

The built environment: a major consumer of mineral raw materials.

Indigenous mineral production contributes to wealth creation and sustainable economic development by providing:

- employment, both directly and indirectly
- markets for other goods and services thereby stimulating activity elsewhere in the economy and importantly,
- basic raw materials for downstream industries in construction, manufacturing and power generation. Here the minerals, or derived products, may be key components of specific manufactured goods or essential to a particular industrial process, thereby adding value that may be several times the cost of the mineral.

Employment

Maintaining high and stable levels of employment is a key objective of the Government's sustainable development strategy. The numbers of people employed in the extractive industries has been declining for many years. This decline has occurred in the production of several minerals but has been most marked in the coal industry, where about 100 000 jobs have been lost in the last 15 years or so. However, for many minerals, such as aggregates, kaolin and ball clay, a reduction in employment has been associated with substantial increases in productivity (output per employee).

In 2002 about 55 000 or 0.2 per cent of the total workforce of 28.5 million was employed in the extractive industries. In comparison, employment in the construction sector was some 1.9 million. Whilst these numbers are modest (although generally accepted as being understated), the available jobs require a wide range of skills and, importantly are mainly located in rural areas. They are also relatively well paid and non-seasonal compared with other opportunities in these areas.

The minerals industry supports jobs in three ways, namely through direct, indirect and induced employment (Anon, 2001; British Geological Survey, In press).

- **Direct** employment and income effects of the industry are of those directly employed in the extraction, processing and management of mineral operations in the UK.
- **Indirect** employment and income effects of the industry are of those that supply goods and services to the minerals industry and which are directly attributable to these purchases. The level of indirect employment supported in the UK by these purchases depends largely upon the extent to which they are sourced from the UK as opposed to overseas suppliers. However, the existence of a home market may be important to those businesses trying to survive in a competitive global market.
- **Induced** employment and income effects of the industry are of those employed in businesses sustained by the re-spending of incomes generated by direct and indirect expenditures.

Economists use an employment multiplier to estimate the indirect and induced employment based on those directly employed by an industry. Recent estimates (British Geological Survey, In press) of the multiplier for the minerals industry range between 1.6 and 1.9, although the total employment is relatively small irrespective of the multiplier. However, their quality and location in rural areas is important. In addition to indirect and induced employment, the extractive industries provide essential raw materials for a wide range of downstream industries. Much larger employment in these industries may be at risk if they were not supplied from domestic sources.

Direct contribution to the economy

The importance of individual industries, including the extractive industries, to the national economy may be

measured by their contribution to Gross Value Added (GVA). This is a key indicator of economic performance and refers to an increase in ability to produce goods and services.

Value Added is defined as the difference between the value of an output (e.g. sales revenue) and the cost of the bought-in inputs used to produce it (e.g. fuel and other raw materials, but not labour). It represents the enhancement in value added to a product or service by a company before the product is offered to customers. The GVA of an industry is simply the sum of all the value added by individual companies in that industry. Value added is important since it represents the wealth created by a company to pay salaries, wages and pensions to employees, dividends to shareholders, interest to lenders of capital, taxes to government and to fund the development of the business.

Adding value to minerals extracted from the ground is an important objective, the greater the added value the greater the benefits that accrue to both the extractor and the nation. Maximising the benefits from working mineral resources is an objective of sustainable development. As minerals are at the start of the supply chain their production is generally associated with a high added value.

The GVA of the minerals extractive industry as a whole is included in national accounts (Office for National Statistics, 2003) under the heading 'Mining and quarrying', which includes oil and gas extraction. Mining and quarrying contributed £25 531 million to GVA in 2002 equivalent to 2.8 per cent of national GVA. Oil and gas extraction with a GVA of £22 743 million accounted for 89 per cent of the sector total **(see Table 4).**

However, the UK economy is dependent on minerals that are both produced domestically and imported. The GVA of those industries that are essentially dependent on minerals, such as construction, the production and supply of electricity, and certain manufacturing industries, is shown in **Figure 13.** Together they account for some 16 per cent of UK GVA.

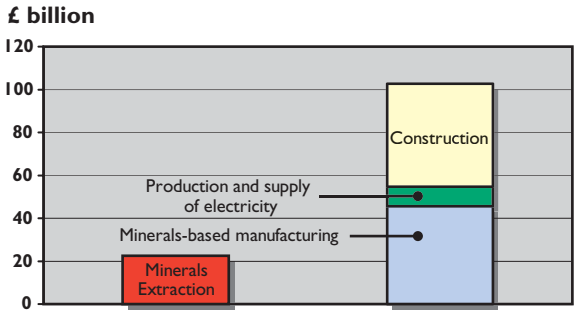


Figure 13 Contribution of minerals-based sectors of the economy to UK Gross Value Added, 2002.

Improving the UK's productivity and competitiveness is a key objective of the UK Government. A standard method for measuring labour productivity is GVA per employee, which gives an indication of the level of output generated by one worker in an industry. The extraction of oil and gas has an exceptionally high GVA per employee (£600 000 in 2002). However, extraction of non-energy minerals compares very favourably with other primary industries (agriculture and fishing) and also UK manufacturing as a whole **(Figure 14).** Relative to its major competitors the UK's productivity performance is poor. Hence improvement in this measure is an important objective.

Sector	£ Million
Mining and quarrying	**25 531**
of which: Extraction of mineral oil and gas	22 743
Mining of coal	539
Other mining and quarrying (of non-energy minerals)	2 251

Table 4 Gross Value Added of mining and quarrying at current basic prices: by industry, 2002.
Source: UK National Accounts. Office for National Statistics.

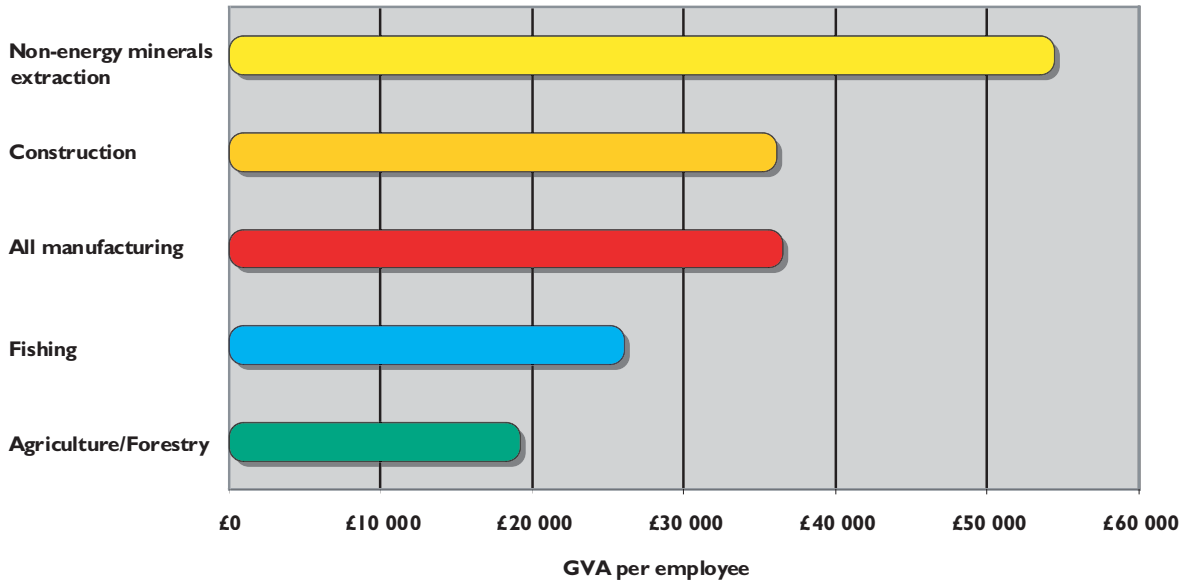


Figure 14 UK Gross Value Added per employee, 2001.

Value of mineral production

The relatively small contribution that coal mining and 'other mining and quarrying' (the extraction of aggregates, and other construction and industrial minerals) sectors make to GVA **(Table 4)** suggests that their economic importance is relatively minor. It is, however, worth examining what minerals are included in these sectors to allow a better understanding of their contribution to the national economy.

There are over 2000 mines and quarries in the UK with individual turnovers that range from a few thousand pounds to some £100 million. These are operated by about 1000 companies. The British Geological Survey has for many years made an estimate of the total value of UK sales of minerals for publication in its annual *United Kingdom Minerals Yearbook*. This has allowed a broad analysis of the relative economic importance of individual minerals **(Figure 16** and **Table 2)** and their performance to be monitored over the longer term. Demand for, and the production of, minerals is continually evolving due to changing economic, technical and environmental factors. As with GVA, the value of UK mineral production is dominated by energy minerals, notably oil and gas.

A comparison of the value of mineral production (in constant prices) in the different sectors of the extractive industries in 1970 with that in 2002 provides a good illustration of their relative fortunes **(Figure 15)**.

Following the discovery on the UK Continental Shelf of gas in 1965 and oil in 1970, and the rapid build-up in production thereafter, the UK emerged as a major world producer of hydrocarbons. In sharp contrast to 1970, therefore, oil and gas now dominate the total value of mineral production. In contrast, coal production has declined markedly, as natural gas has become the favoured fuel for electricity generation resulting in the 'dash for gas.' More recently, however, natural gas has become more expensive and coal consumption has levelled off, but about half is now supplied by imports.

The value of the UK's remaining recoverable oil and gas reserves is substantial. It depends on the estimated physical amounts remaining, the current rate of extraction and the assumed future price of oil and gas, net of the cost of extraction. At the end of 2002, oil reserves were valued at £63 billion and gas reserves at £46 billion (Office for National Statistics, 2003). Expressing oil and gas reserves in monetary terms allows these subsurface assets to be compared with other economic entities. This provides a means for the commercial depletion of those assets to be set against national income.

The value of metalliferous minerals production has declined, principally because of the demise of tin mining, but the value of construction and industrial minerals has stayed remarkably constant in real terms during this

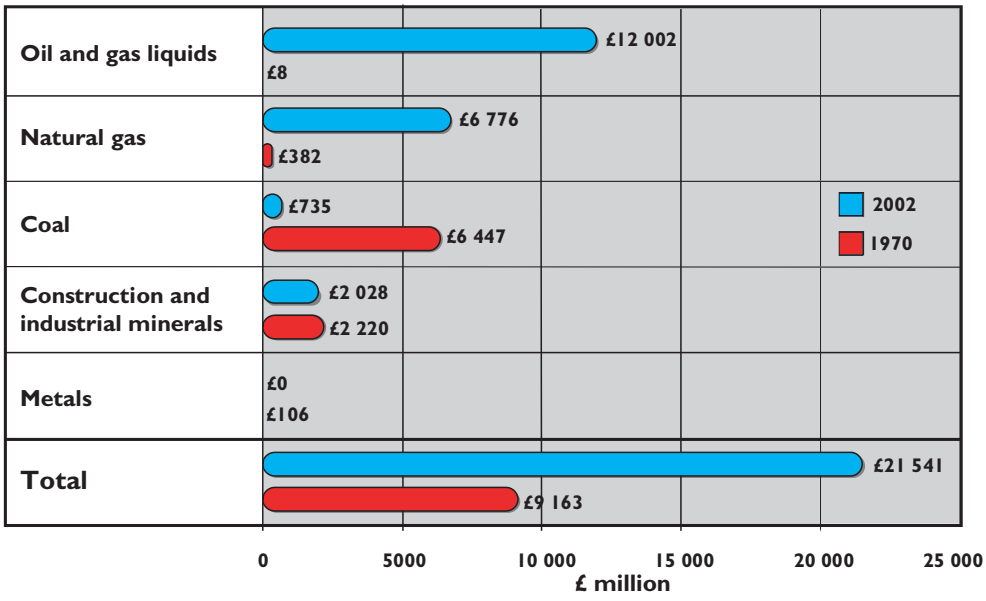


Figure 15 Value of the major sectors of the UK minerals industry in 1970 and 2002 (in constant 2000 prices).

period. This is because the production and prices of these minerals has remained fairly stable over time.

Indirect contribution to the economy

The importance of minerals to the UK economy is not attributable solely to the value of production and the numbers of people who are directly or indirectly employed in their extraction. Account also needs to be taken of their importance as essential inputs to a wide range of downstream industries, including power generation, construction and manufacturing in relation to:

- the importance of these downstream industries to the UK economy;
- the importance of indigenously produced minerals to the competitiveness of these industries; and
- the number of jobs that might be at risk if there were interruption or termination in the supply of indigenously produced minerals.

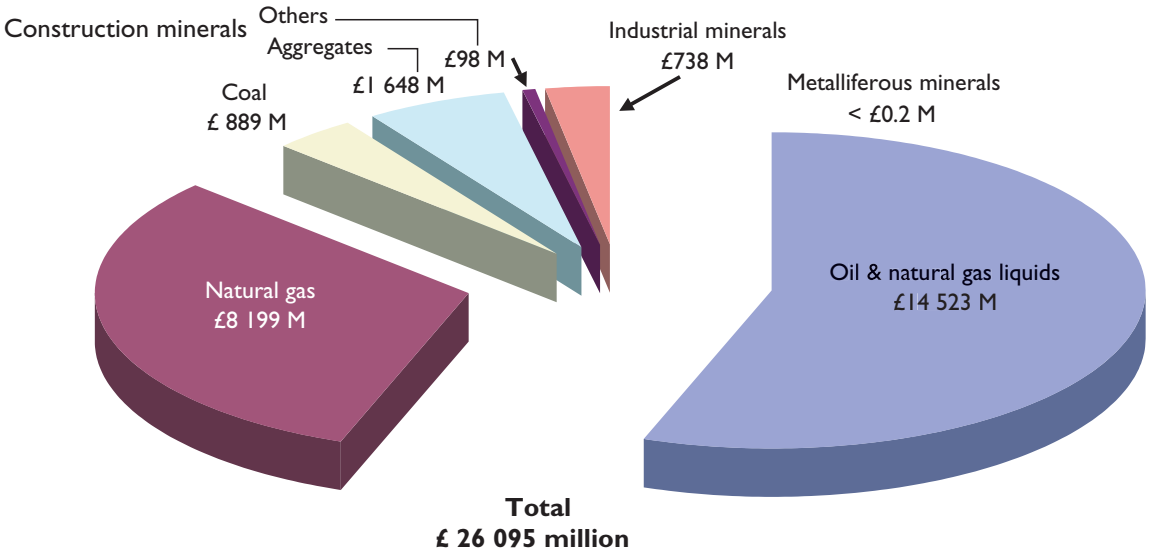


Figure 16 Value of UK mineral production by major sector, 2002.

Industry	Total sales of principal products of the industry £ million
Ready-mix concrete	941.3
Coated roadstone	395.5
Cement	755.6
Lime	64.2
Mortar	103.3
Concrete products for construction purposes	1 829.8
Other articles of concrete, plaster and cement	105.3
Plaster	118.2
Plaster products for construction purposes	351.2
Clay, bricks, tiles and construction products in baked clay	632.0*
Ceramic tiles and flags	85.4
Ceramic household and ornamental articles	471.0
Ceramic sanitary fixtures	199.2*
Hollow glass products	477.8
Flat glass	231.0*
Glass fibre	284.3
Inorganic basic chemicals	1,107
Plastics	2 716
Casting of iron	464
Casting of steel	122.0

Table 5 UK: Total manufacturing sales of selected mineral-based industries, 2002.
*Source: ProdCom: Office for National Statistics. * Data for 2001.*

A detailed analysis of this type is beyond the scope of this paper. However, the inputs of selected domestically produced non-metallic minerals to the manufacturing sector illustrates their importance. These minerals are essential inputs to the ceramics, glass, cement, concrete products, lime and inorganic chemicals industries to name just a few. The sales of the principal products of a selection of the industries that are highly dependent on domestic minerals is shown in **Table 5.** Total sales of these industries alone are nearly £10 billion.

The construction industry is also a critical sector of the national economy. In 2002 the total value of the work done in the construction industry in Great Britain was £83.6 billion: £45.3 billion of new work and £38.3 billion repair and maintenance. Domestically produced construction minerals provide a major input (248 million tonnes in 2002) to this sector. The Government is committed to improving the built environment and transport infrastructure in order to secure its further economic and social development objectives. This means efficient and effective transportation, affordable housing and investment in essential services in the regions, including new or improved roads, rail links, airport facilities, homes, hospitals, schools, offices, shops and flood defences. Large quantities of construction minerals will continue to be required to achieve these objectives.

Conclusions

Adequate supplies of minerals are essential for economic development. For its small size the UK is relatively well endowed with mineral resources and their extraction and use have played an important role in the development of the UK economy over many years. The UK continues to have an economically important minerals industry, with oil and gas, and construction and industrial minerals being important sectors. The contribution that they make to the national economy may be considered in two ways. First, there is the primary contribution that they make in terms of added value and employment; and, then, there is the secondary contribution that these industries make to the competitiveness of the downstream industries they support. Nevertheless, the UK also has substantial and increasing foreign dependence on mineral supply, and consequently UK resource use is placing increasing demands on the environments of our trading partners. There has been a decoupling of economic growth with the minerals directly consumed by the economy. However, while the amount of material recycled has increased, there will be a continuing demand for the products of the UK's extractive industries for the foreseeable future.

A Bloodworth, BGS © NERC

A brick manufacturing plant.

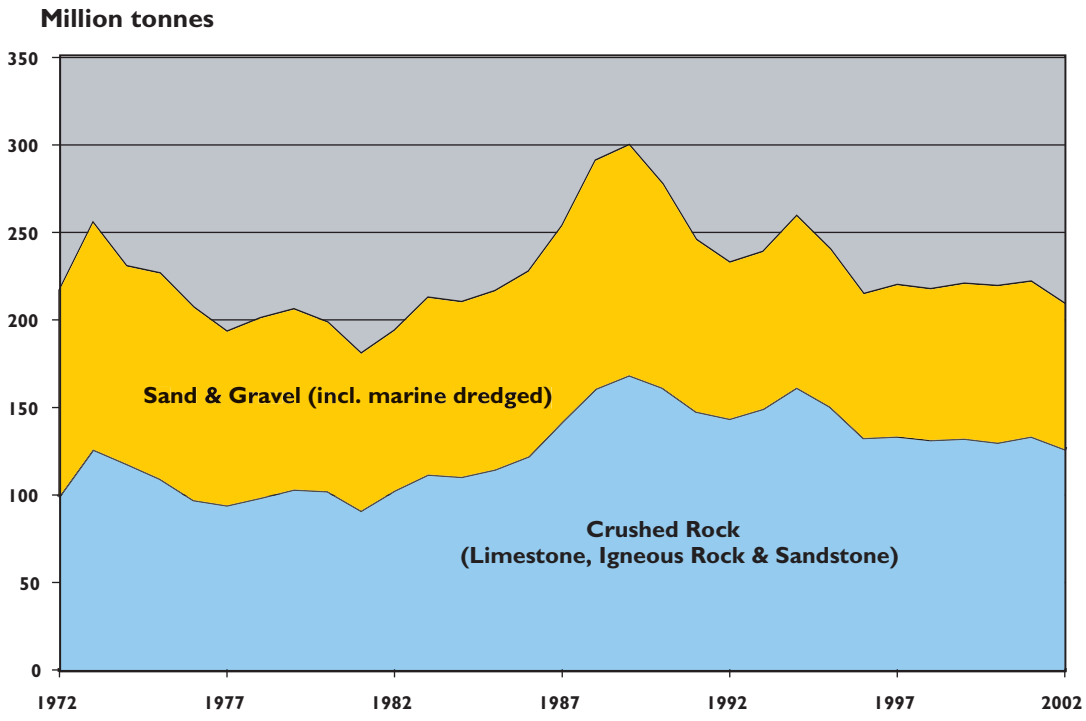


Figure 17 Great Britain: Production of primary aggregates, 1972–2002.

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D Cameron, BGS © NERC

Cliffe Hill Quarry, Leicestershire. An important source of crushed rock aggregate (igneous rock).

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