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THE UK MINERAL EXTRACTION INDUSTRY

FEBRUARY 2016

This review intends to inform the reader of the key characteristics of the UK mineral extraction industry, primarily the extraction of construction and industrial minerals and coal, with the manufacture of mineral products. It is not intended to cover the extraction of gas and oil, other than where figures are included for reference only.

essential materials
sustainable solutions

Prepared by the Mineral Products Association for the CBI Minerals Group on behalf of the UK mineral extraction industry

This industry-led report is the first of its kind for a generation, probably more. It is intended to show the economic significance of the UK's mineral extraction industry, particularly the non-energy sectors. It follows and complements the recent report published by the UK Minerals Forum 'The Future of our Minerals,' which the CBI Minerals Group facilitated and contributed to. By looking at our historic and current production, and considering our future needs, these two reports are underpinning the development of a UK Minerals Strategy which will be published in 2016.

The mineral extraction industry is vital to the economy and our way of life. Minerals are essential, representing the largest material flow in the economy and should not be taken for granted. Indeed it is hoped that by developing a national strategy, their role and contribution will finally be recognised and valued by Government and all stakeholders, and that the industry can influence a shift to a more positive perception of what it does.

Nigel Jackson
Chairman
CBI Minerals Group

CONTENTS

1 KEY FACTS

210mt
UK mineral extraction

£15bn
Turnover of mineral extraction

£68bn
Turnover of mineral products manufacture

£5bn
Gross value added of mineral extraction

£22bn
Gross value added of mineral products manufacture

£209bn
Gross value added of "first use" markets

£235bn
Total gross value added generated by minerals, including mineral extraction, products manufacture and "first use" markets

16%
Share of the UK total economy directly attributable to minerals

34,000
People employed directly in mineral extraction

4.3m
Jobs supported through the supply chain

Chart 1: **Estimated turnover of UK non-energy minerals and coal (2013)** (Source: ONS, ABS, MPA)

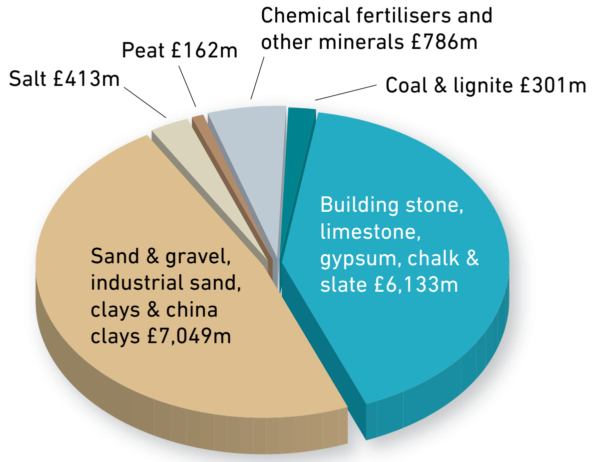


Table 1: **Minerals production in the UK (2013)** (Source: BGS)

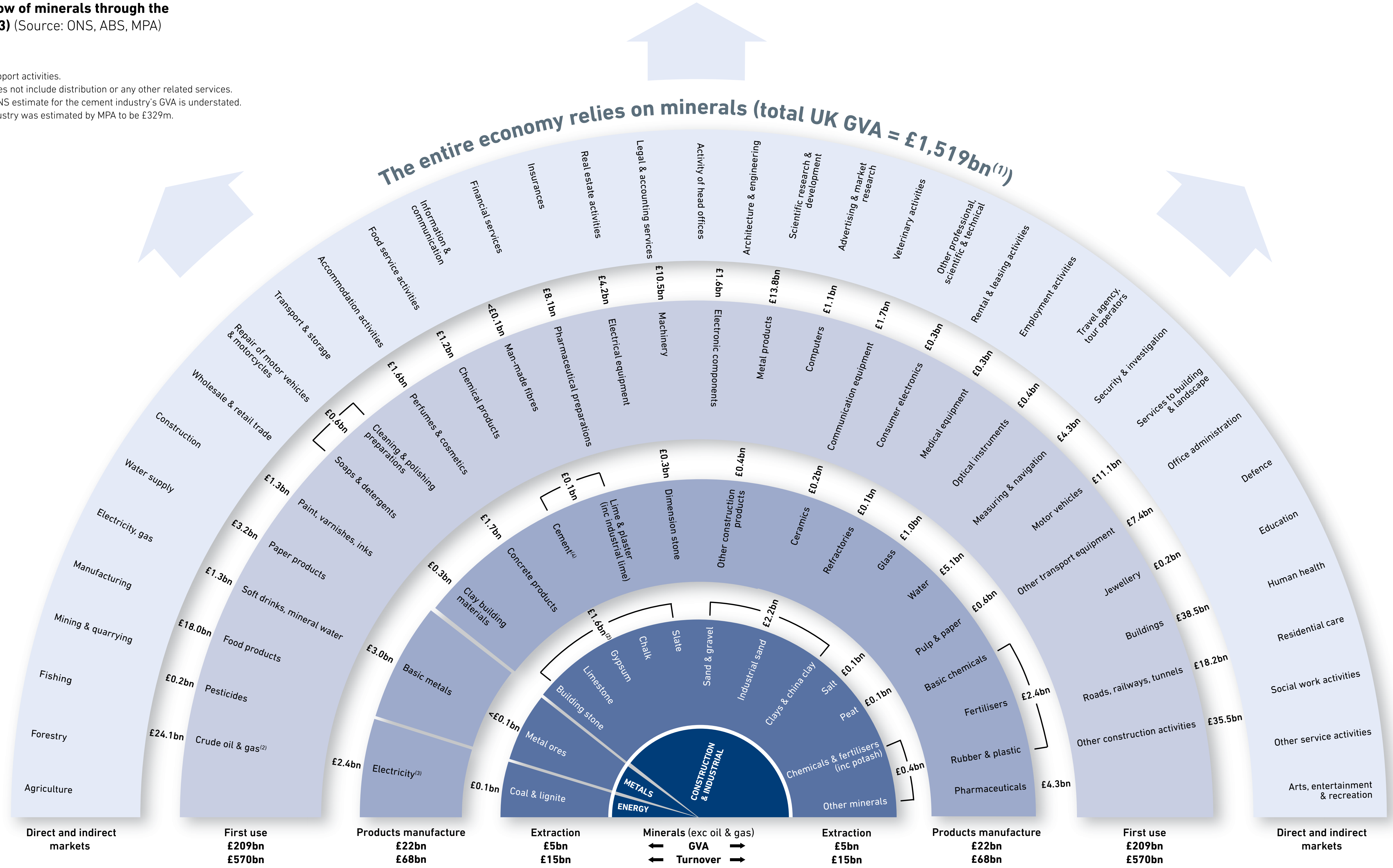
			Million tonnes
Non-energy			**196.9**
	Construction minerals		**172.2**
	Including	Igneous rock (inc granite)	40.5
		Limestone, dolomite & chalk (construction uses)	53.6
		Sandstone	11.5
		Sand & gravel - Land-won	43.4
		Sand & gravel - Marine	14.6
		Slate	0.9
		Gypsum	1.2
		Fireclay	0.1
		Clay & shale	6.5
	Industrial minerals		**24.6**
	Including	Limestone, dolomite & chalk (industrial & agricultural uses)	10.3
		Silica (industrial) sand	4.0
		China clay (kaolin)	1.1
		Salt	6.6
		Potassium compounds (potash)	0.9
		Ball clay	0.7
		Peat	1.0
		Other industrial minerals[1]	0.1
Metals			**<0.001**
	Including	Iron ore	0.0
		Tungsten	0.0
		Tin	0.0
		Gold	<0.001
		Silver	<0.001
		Zinc	0.0
		Copper	0.0
		Lead	<0.001
Energy			**90.0**
	Including	Oil[2]	40.6
		Gas	36.5
		Coal	12.8
	Total		**286.9**

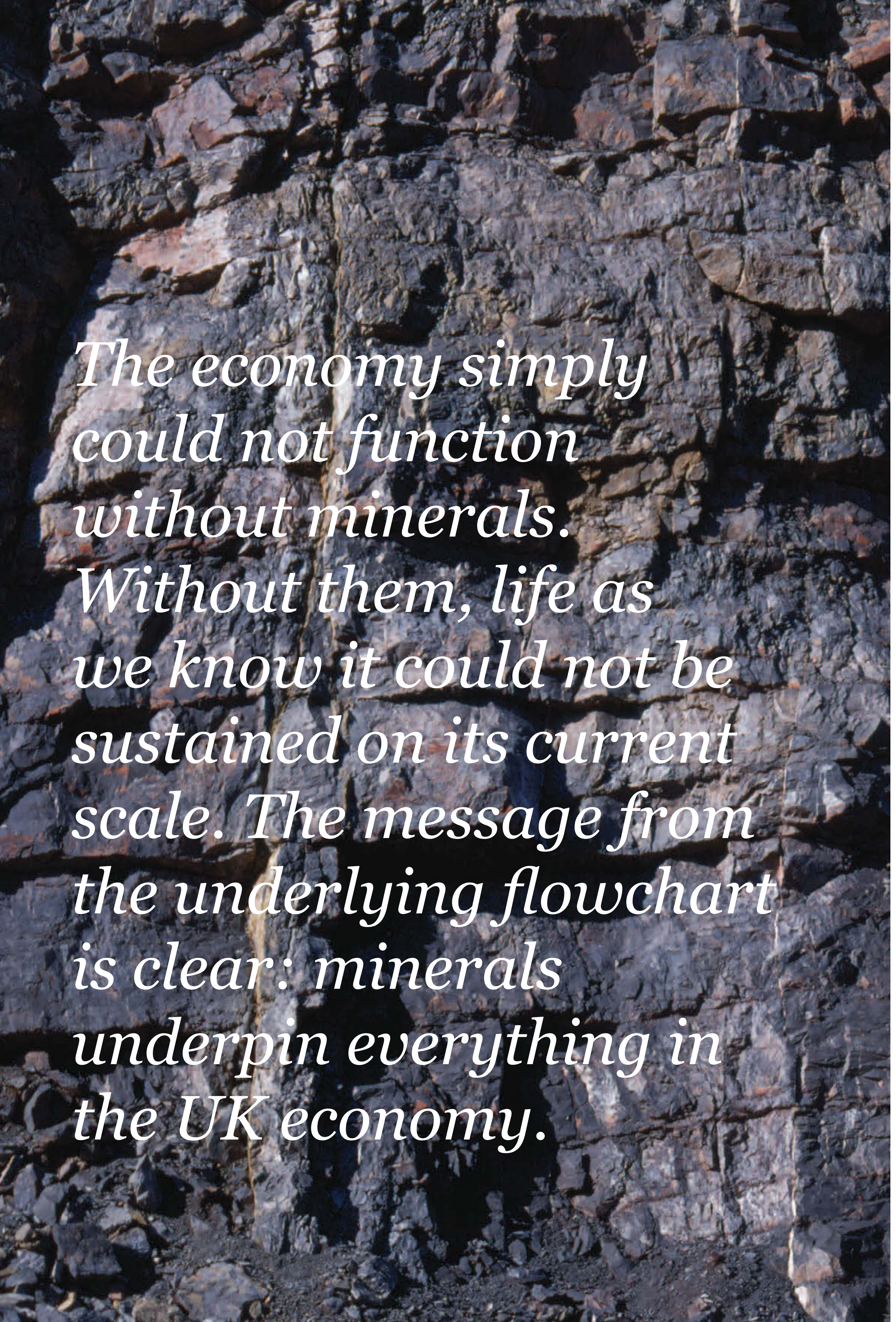
[1] Includes Fuller's earth (bentonite), barytes, fluorspar, talc, calcspar, chert & flint, china stone (feldspar), phosphorus.
[2] Includes crude oil onshore and offshore, and condensates.

2 ESSENTIAL TO THE ECONOMY

Chart 2: **The flow of minerals through the economy (2013)** (Source: ONS, ABS, MPA)

Notes:
[1] Sections A-S.
[2] Includes mining support activities.
[3] Production only. Does not include distribution or any other related services.
[4] MPA believes the ONS estimate for the cement industry's GVA is understated. 2013 GVA for this industry was estimated by MPA to be £329m.



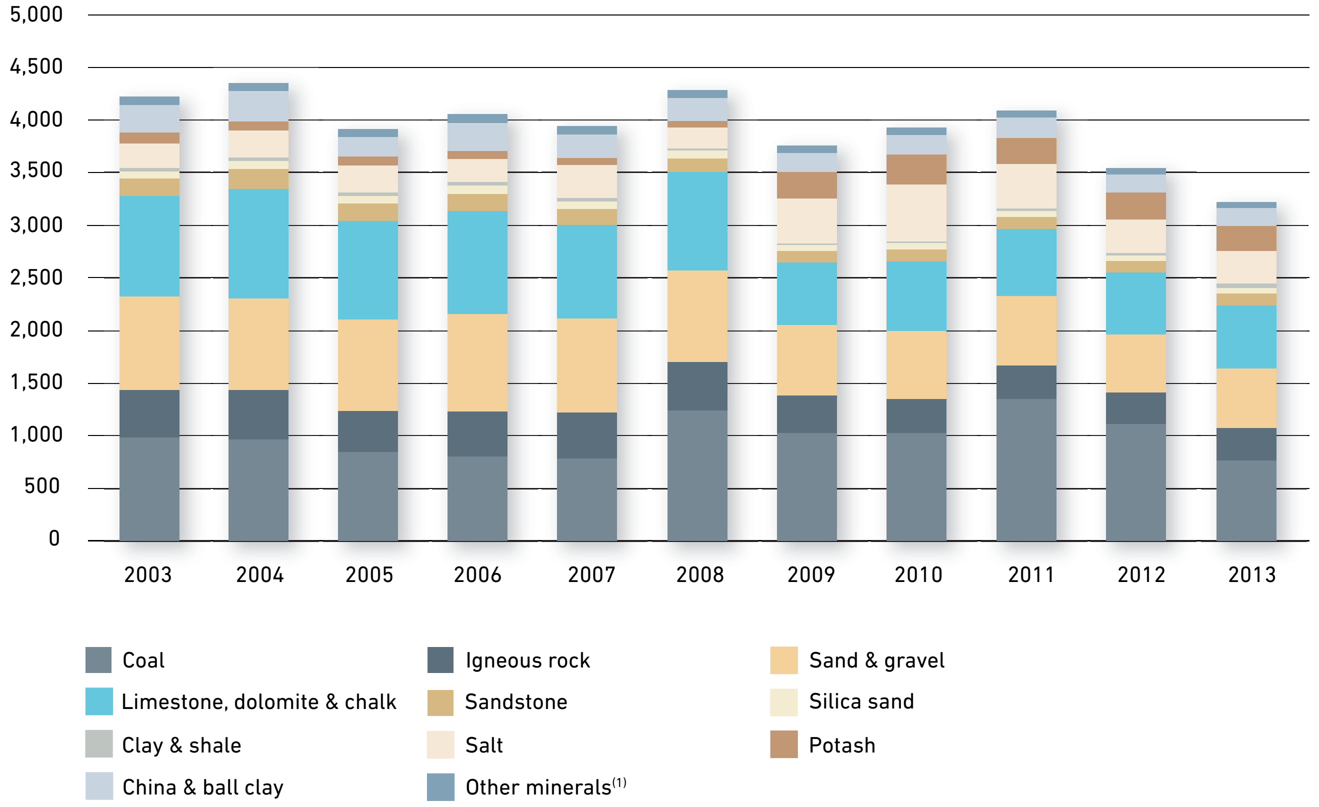


The economy simply could not function without minerals. Without them, life as we know it could not be sustained on its current scale. The message from the underlying flowchart is clear: minerals underpin everything in the UK economy.

2.1 VALUE OF MINERAL EXTRACTION

Although oil and gas may be the most valuable minerals, the vast majority of the UK extraction in volume comprises 197 million tonnes of construction and industrial minerals, and 13 million tonnes of coal, which overall represented a total volume of 210 million tonnes in 2013 and a value of £3.2bn (at 2011 constant prices).

Chart 2.1: **Value of UK minerals production (2011 prices)** (Source: BGS)



(1) Includes gold, silver, other non-ferrous metals, gypsum & anhydrite and miscellaneous minerals.

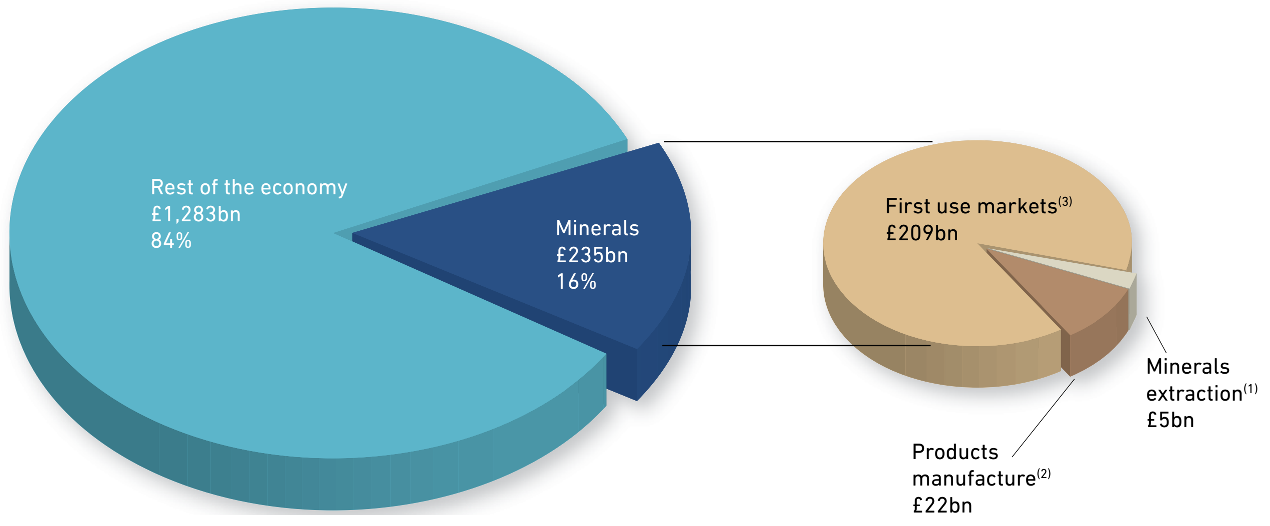
2.2 GROSS VALUE ADDED (GVA)

Minerals directly contribute to the UK economy by generating £235bn in gross value added, representing 16% of the total UK economy.

Whilst this estimate already points to a significant contribution of minerals to the overall economic activity, it also remains significantly underestimated as it only includes the value added created by the production of raw minerals, the manufacture of "enabling" mineral products, and the production of finished goods that use minerals and minerals products as first use. For example, it would include the production of industrial sand, which is then used to manufacture glass, and then inputs to the manufacture of cars and computers. However, our GVA estimate does not include the value added generated by industries that rely entirely on cars and/or computers, such as services. In fact, as the flowchart on page 3 showed, if we were to include the value added of all sectors that are directly or indirectly dependent on minerals and mineral products in their activity, this estimate would easily reach the size of the entire economy.

Minerals generate £235bn in total gross value added

Chart 2.2: **GVA generated by minerals at various stages of the supply chain (2013)** (Source: ABS, ONS, LFS, MPA)



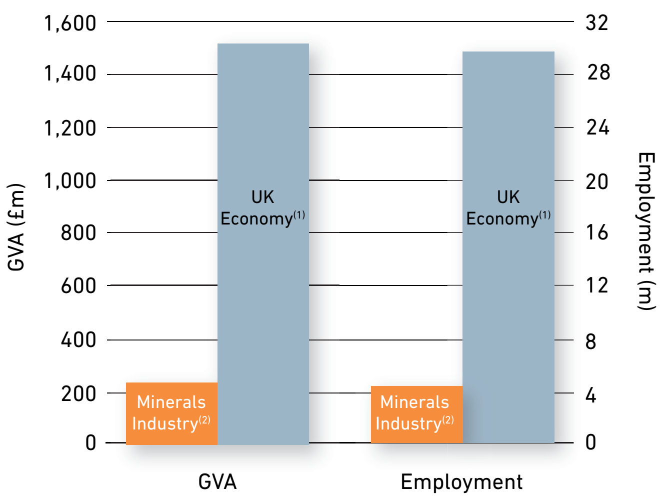
Notes:
(1) Production of raw materials.
(2) Manufacture of "enabling" mineral products, eg cement, paper etc.
(3) First use markets for mineral or mineral products, including construction.

2.3 EMPLOYMENT AND PRODUCTIVITY

Excluding oil and gas, mineral extraction employs 34,000 people and is 2.5 times more productive than the UK average. It also contributes directly as a key input to other highly productive sectors further down the supply chain, such as real estate activities via its contribution to construction activities and the manufacturing sector.

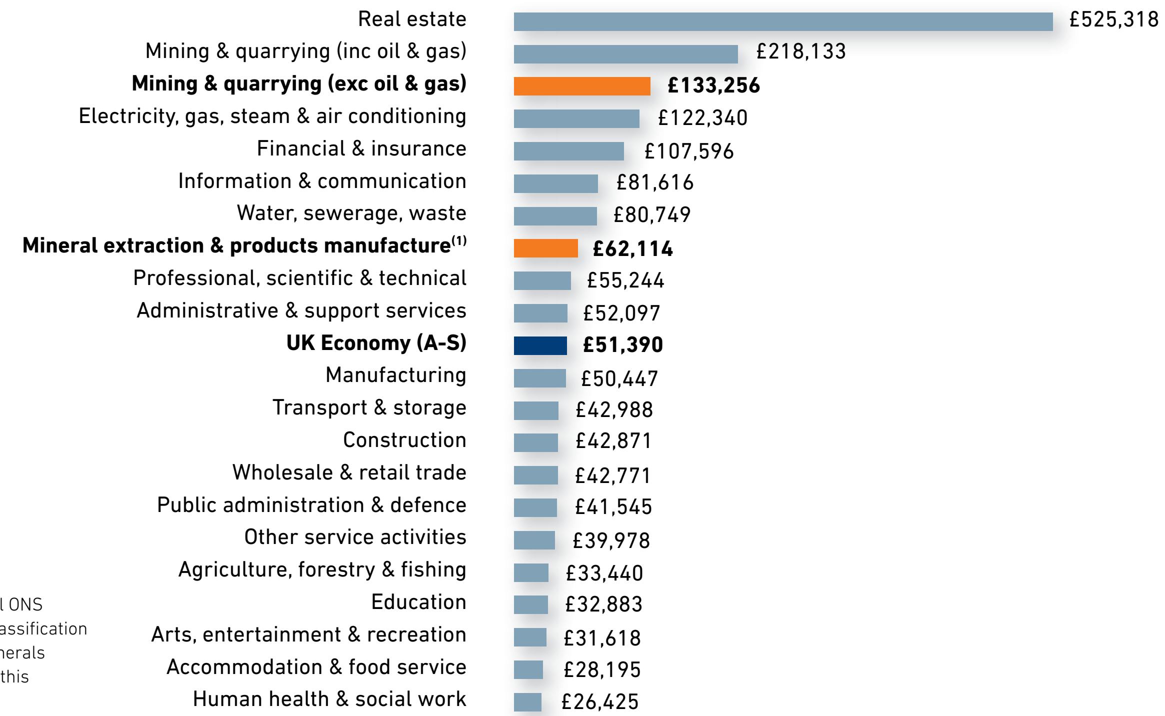
The minerals industry as a whole, defined as the extraction of non-energy minerals, coal, and the manufacture of mineral products, emerges as one of the most productive industries in the economy - every worker produced over £62,000 in gross value added in 2013.

Chart 2.3.a: **GVA and employment generated by the minerals industry relative to the total UK economy (2013)** (Source: ABS, ONS, LFS, MPA)



(1) Sections A-S of the Standard Industrial Classification (SIC 2007).
(2) Includes mineral extraction, products manufacture and "first use" markets.

Chart 2.3.b: **Productivity by industry, £ per employee (2013)** (Source: ABS, ONS, LFS, MPA)



(1) This is not an official ONS Standard Industrial Classification but represents the minerals industry as defined in this publication.

2.4 TRADE

Whilst some minerals are extracted within the UK, a significant proportion are being imported. This reflects country-specific characteristics such as the geology and availability of minerals; but it also arises because it may be more profitable to extract these resources from other parts of the world and/or where regulation may be more supportive of extraction.

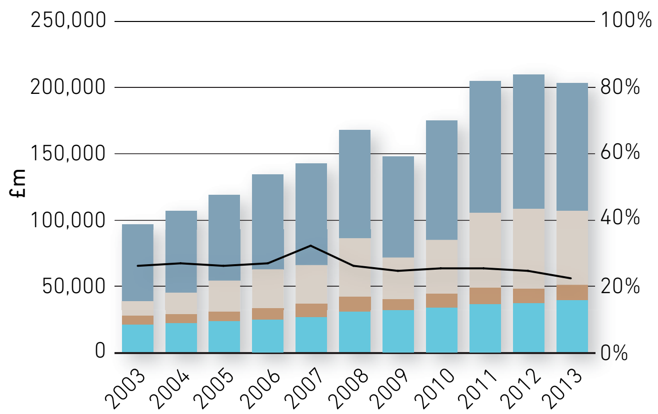
The UK is a significant net importer of non-ferrous and ferrous metals and coal. Nonetheless, whilst the total value of imports in traded basic and semi-manufactured goods increased substantially in recent years, the share of minerals-based goods in total imports (excluding oil and gas) declined from its peak of 33% in 2007 to 13% in 2013.

Construction aggregates are widely available in the UK, which produces about 230 million tonnes each year, including 172 million tonnes of raw minerals and 60 million tonnes of recycled and secondary materials. Imports remain minimal. Yet some construction minerals and mineral products already show signs of vulnerability, as is the case for concrete products, clay bricks and roof tiles.

Whether occurring locally to markets or needing to be transported over longer distances, minerals are essential and many countries have policies and strategies to ensure their continuing supply both from indigenous resources and through trade agreements. England and Wales have planning policy guidance for aggregates, silica sand and cement, where local availability makes this the most economic supply option. There is nothing comparable for other minerals and no economic policy or strategy supporting the use of indigenous resources for any minerals demand.

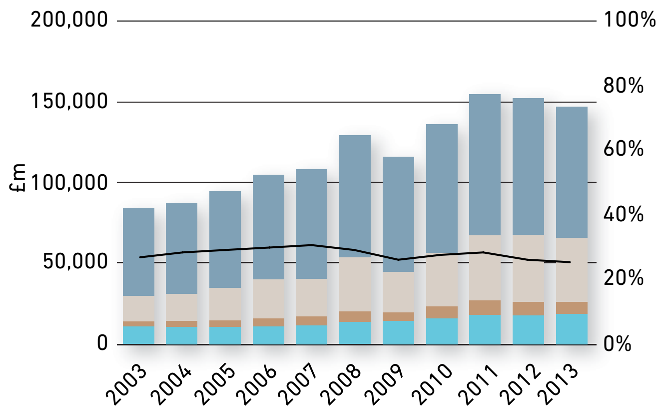
Chart 2.4.a: **Value of UK imports and exports** (Source: BGS)

Value of UK imports c.i.f.*

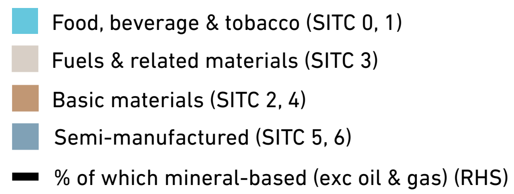


* Cost, insurance and freight

Value of UK exports f.o.b*

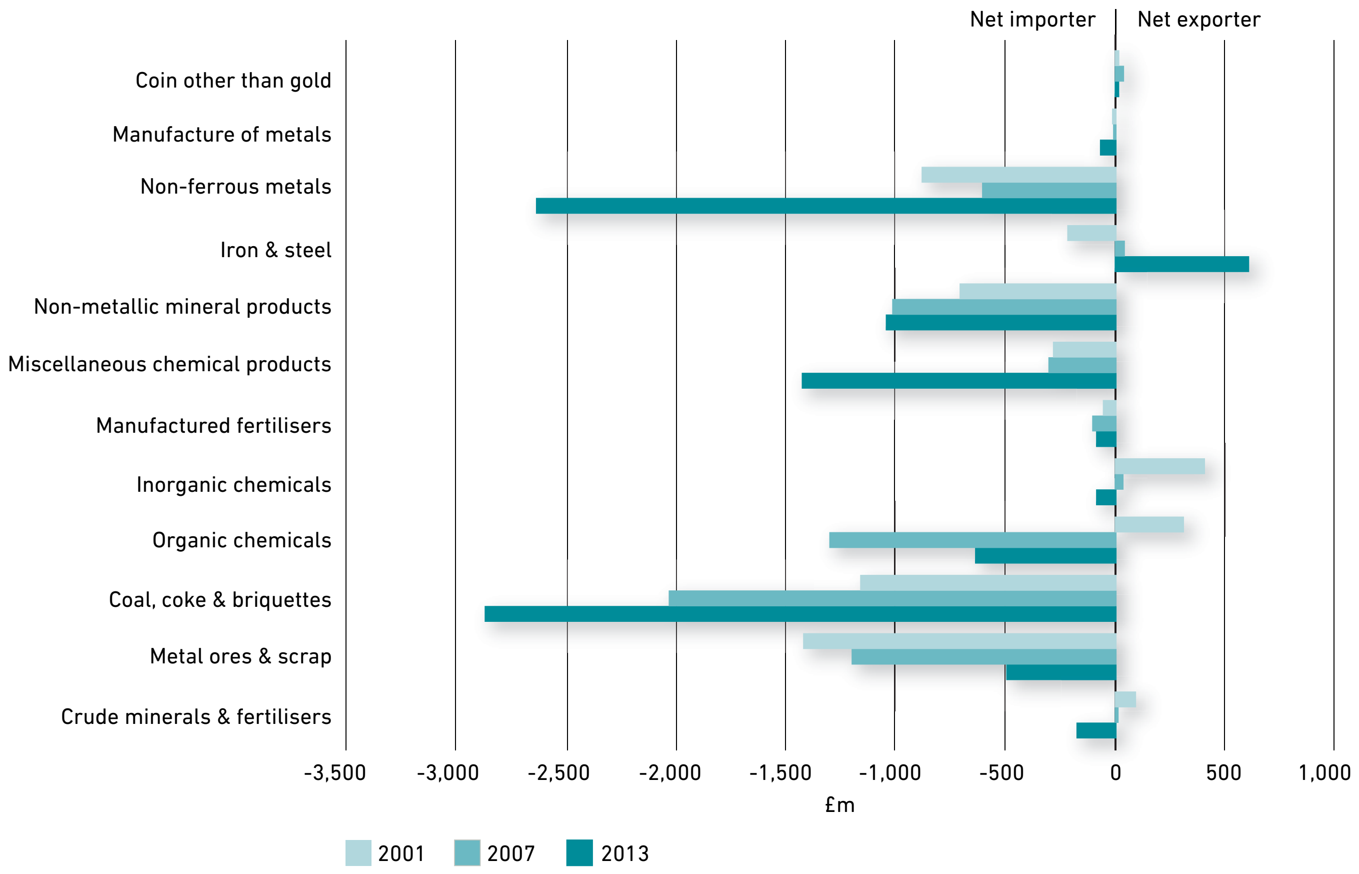


*Free-on-board



Note: Standard Industrial Trade Classification (SITC) is a statistical classification of the commodities entering external trade.

Chart 2.4.b: **UK balance of trade in minerals and mineral-based products** (Source: BGS)



2.5 TAXATION

Minerals make a significant contribution to tax revenues. For example, the minerals extraction industry (excluding oil and gas) contributed directly to about £500m of VAT payments in 2013 through the purchase of goods, materials and services necessary to its operations. More VAT is then generated through the sale of goods and products that use raw minerals in their manufacture.

In addition to the various employment and corporation tax receipts from mineral extraction and mineral products production activities, other taxes are collected for environmental purposes, as a means to offset the environmental impact of mineral activity. The aggregates levy is one of such tax, based on the commercial exploitation in the UK of rock and sand & gravel. It was set up in 2002 and is currently levied at £2 per tonne, generating over £300m per annum in tax revenues. The minerals industry is also increasingly subject to a range of energy and carbon-related taxes and measures.

These revenues contribute to Government's general effort in reducing the annual deficit and national debt, but their value depends mainly on the level of domestic production.

3 PRODUCTION AND TRADE OF MINERALS

3.1 CONSTRUCTION MINERALS

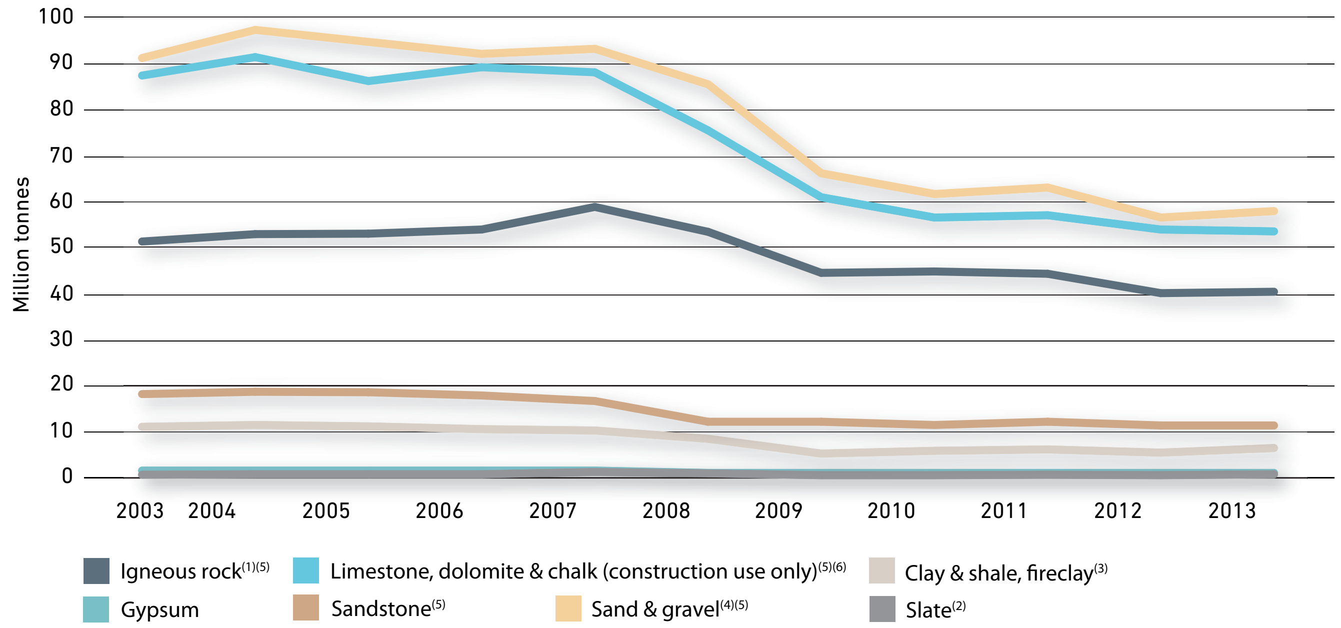
In 2013, 172 million tonnes of construction minerals were produced in the UK including sand & gravel, igneous rock, limestone, dolomite and chalk for construction use, sandstone, clay and shale, fireclay, slate and gypsum. The total value was £2bn. Production volumes dipped since the beginning of the recession in 2008, reflecting the sharp decline in construction activity, but estimates of sales of construction minerals produced by the Mineral Products Association indicate a pick-up in volume since mid 2013.

The biggest element of construction minerals is primary aggregates supplies, which comprise of crushed rock and sand & gravel, to which is then added a significant production of recycled materials. In total, the UK produced 164 million tonnes of primary aggregates in 2013, (including rock and sand & gravel) twice as much as the tonnage of oil and gas, as well as about 60 million tonnes of recycled materials. Recycled and secondary materials accounted for 29% of total UK aggregates sales in 2013, the highest in Europe; the European average stood at about 10%.

Construction minerals are widely available in the UK, and import volumes remain low. In 2013, the value of imports represented only about 12% of the total value of the UK production of construction minerals but this is mainly due to higher value building stone.

Some specific construction minerals and mineral products nonetheless show signs of vulnerability in terms of availability and/or international competition. For example, the UK has been a net importer of concrete products since 2009, and reserves of sand & gravel with planning approval are very constrained in some areas. Indeed, despite the existence of numerous deposits of both hard rock and sand & gravel in the UK, replenishment rates - a meaningful measure of long-term availability - suggest that whilst crushed rock has been close to parity in recent years, sand & gravel is being replaced at a slow pace; for every 100 tonnes of material extracted, only around half is being replaced through planning permissions. This has resulted in a significant decline in permitted reserves in the last 15 years, and in the long run could result in shortages of material supply and increased cost to the economy.

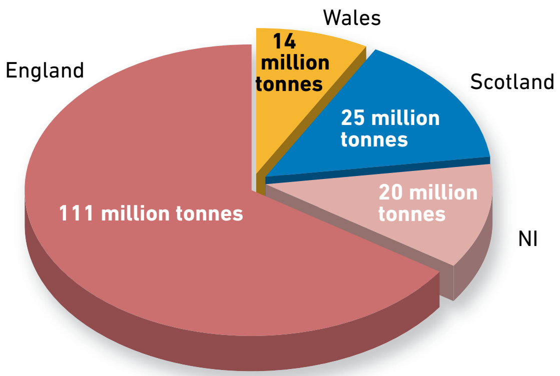
Chart 3.1.a: **UK production of construction minerals** (Source: BGS)



(1) Excluding a small production of granite in Northern Ireland. (2) Slate figures include waste used for constructional fill and powder and granules used in industry. (3) Chalk, clay & shale and fireclay excludes a small production in Northern Ireland. (4) Marine-dredged sand & gravel includes landings at foreign ports (exports). (5) Some materials include estimates for Northern Ireland from 2011. (6) All limestone and dolomite production, excluding agricultural and industrial uses. All of Northern Ireland production is shown under construcion use.

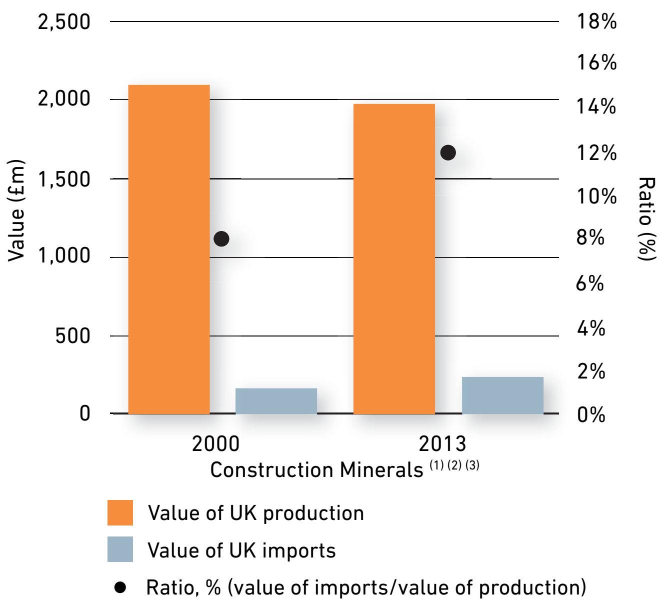
Import volumes for bricks since 2011 emphasise how quickly self-sufficient mineral industries can become exposed to imports. Import volumes of clay bricks increased six-fold between 2011 and 2014, to over 1m tonnes. While some of this effect might be temporary, reflecting the recovery in the construction sector and the wider economy while some UK plants are being recommissioned, it suggests nonetheless that brick manufacturers will need to invest in extra capacity in order to build the Government's plans for more than 200,000 new homes per year. For this to happen, there must be a supportive UK regulatory regime.

Chart 3.1.b: **UK primary aggregates production (2014[1])** (Source: AMRI, MPA, QPA Northern Ireland)



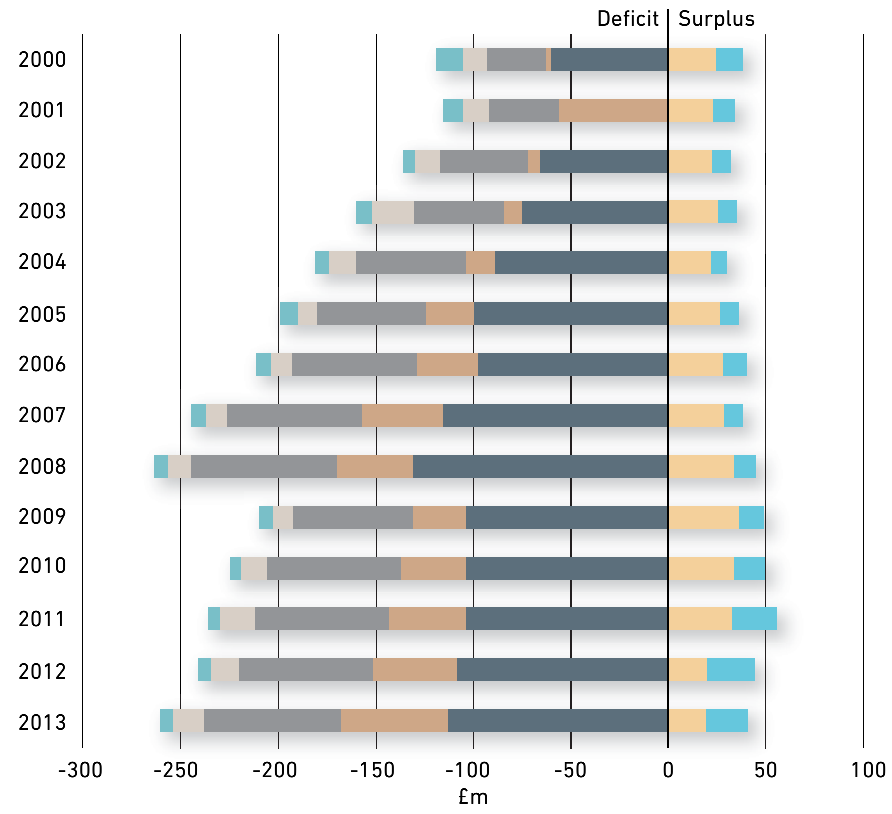
[1] 2013/14 MPA sales volumes growth rates for England, Scotland and Wales are applied to official 2013 AMRI production estimates.

Chart 3.1.c: **Value of UK production and imports of construction minerals** (Source: BGS)



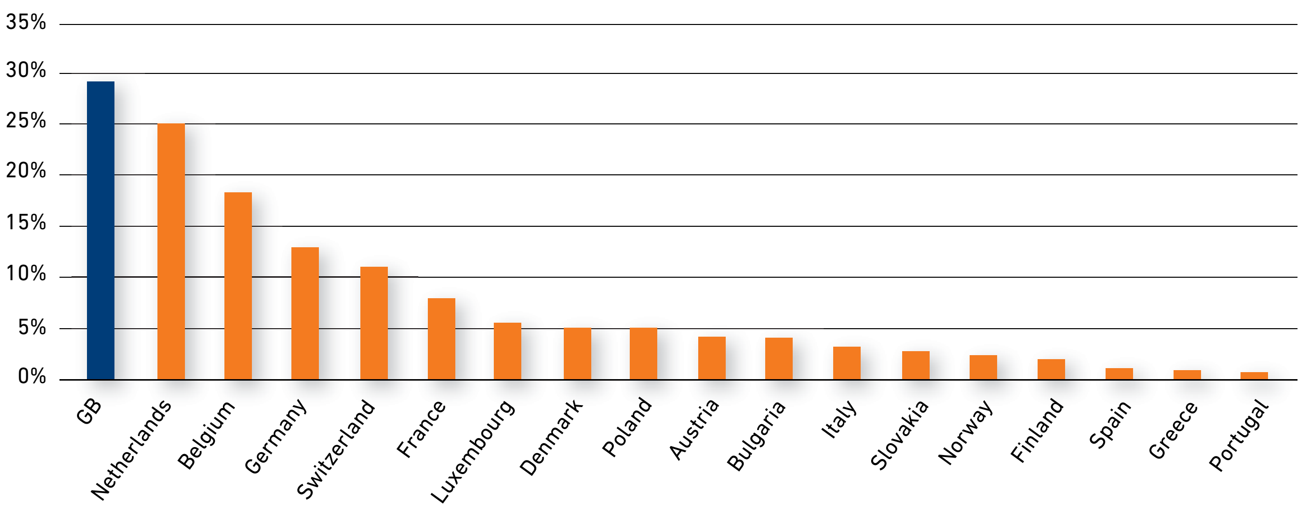
[1] Includes sand & gravel, igneous rock, limestone, dolomite & chalk for construction use, sandstone, clay & shale, fireclay, slate and gypsum.
[2] Imports of limestone, dolomite and chalk for construction use were estimated using the share of material for construction use in total volume of UK production.
[3] Where the value of production was missing, the value of imports per tonne was used.

Chart 3.1.e: **UK trade balance in construction minerals** (Source: BGS)



[1] Trade of limestone, dolomite & chalk for construction use was estimated using the share of material for construction use in total UK production.
[2] Excludes products.

Chart 3.1.d: **Share of recycled and secondary[1] materials in total aggregates sales (2013)** (Source: UEPG, MPA)



[1] Includes manufactured aggregates, recycled aggregates fixed and mobile and aggregates re-used on site.

Chart 3.1.f: **UK concrete products trade balance** (Source: BIS)

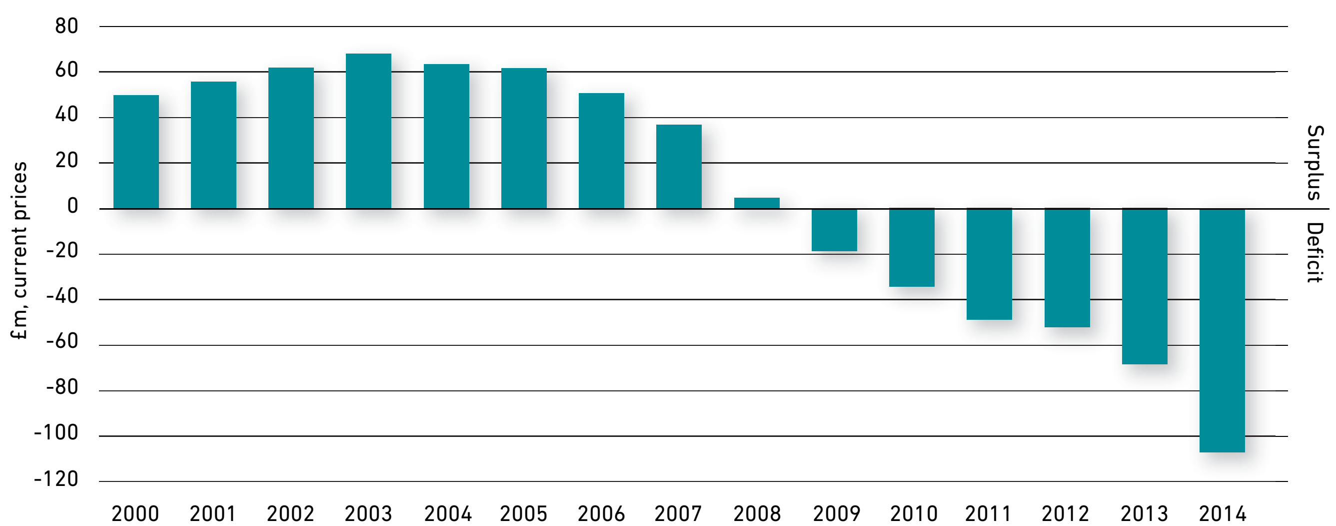


Chart 3.1.g: **UK imports of bricks** (Source: HMRC)

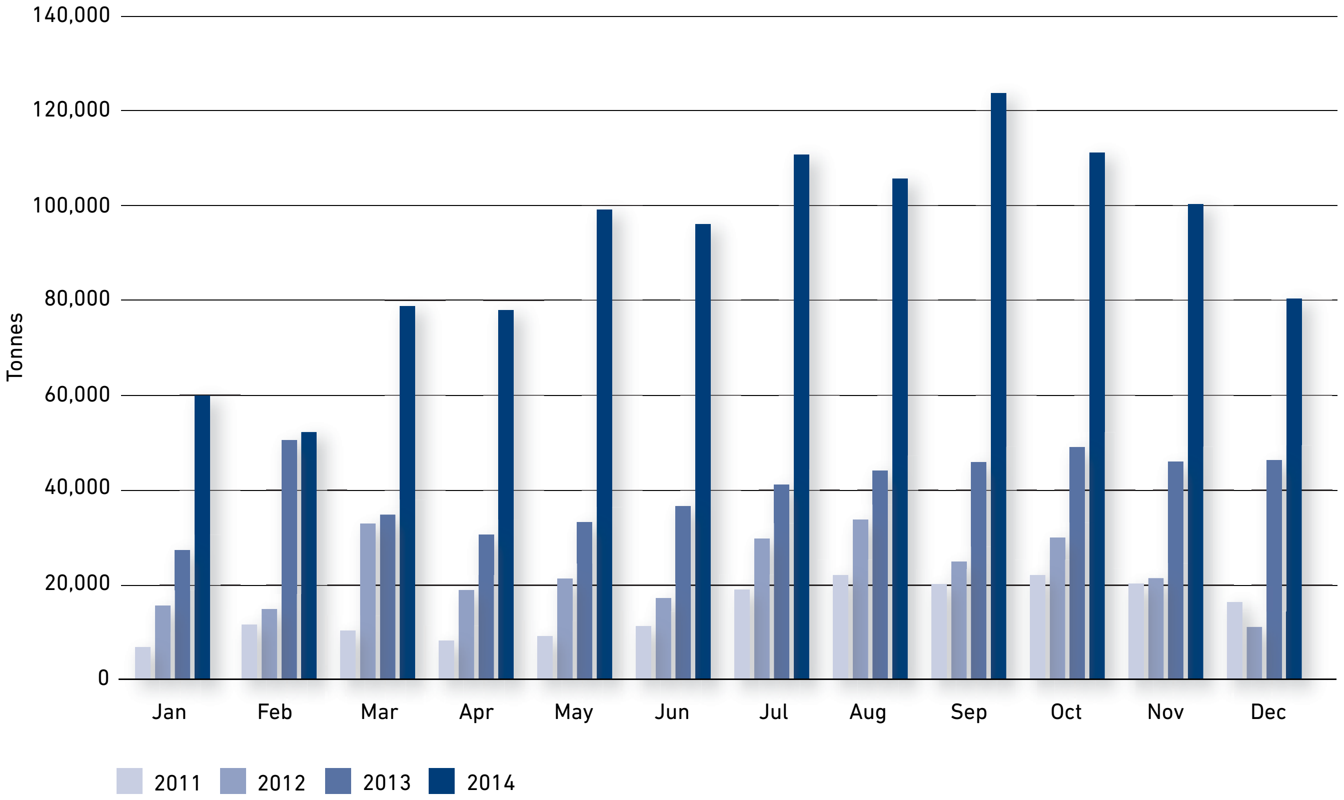
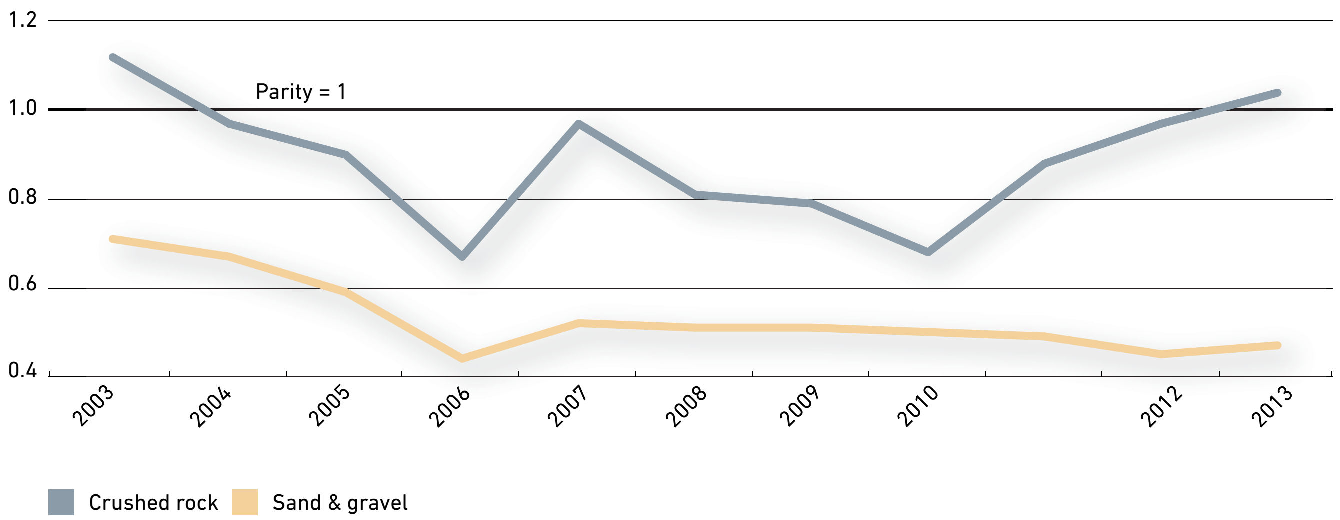
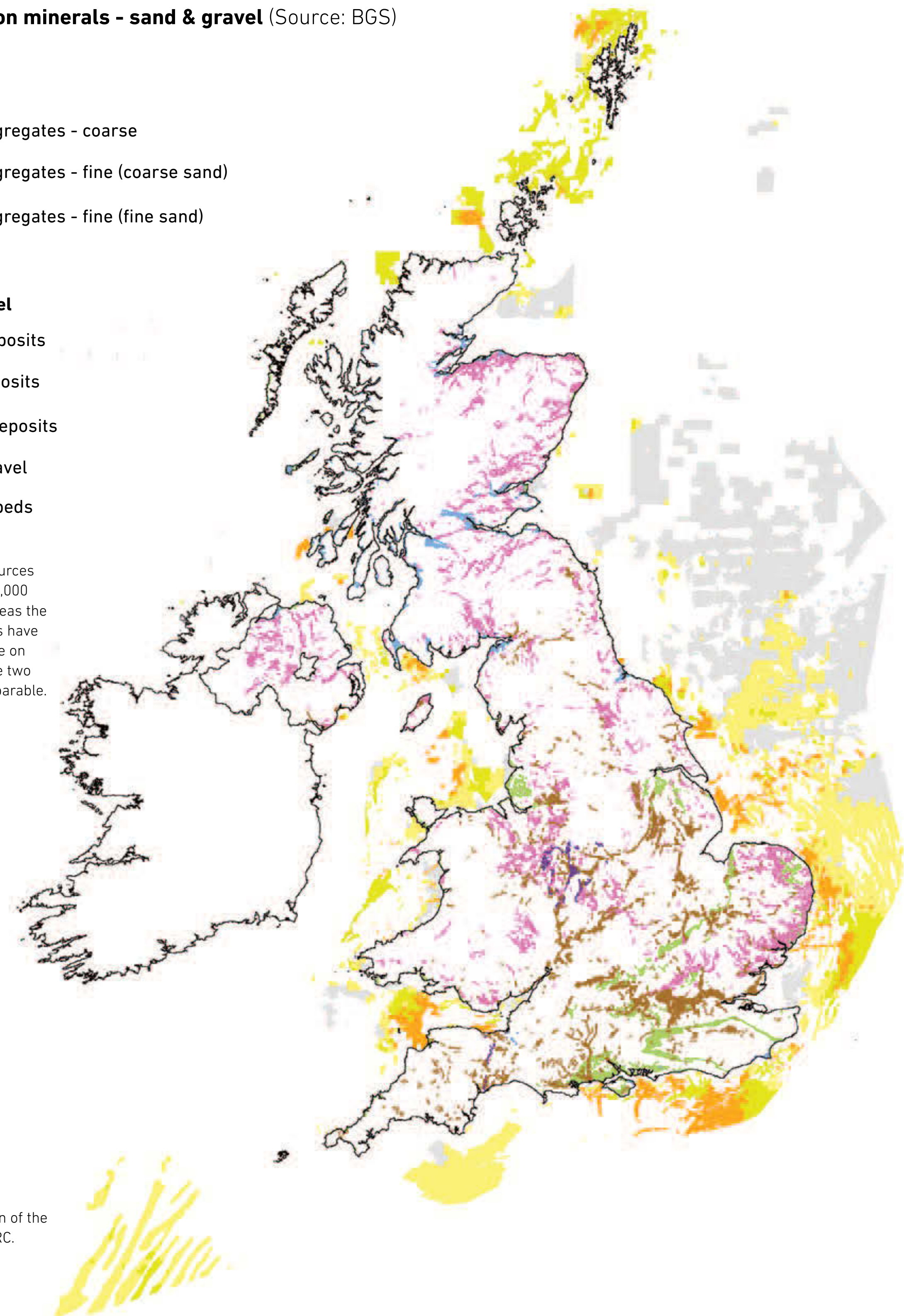


Chart 3.1.h: **GB rolling average relenishment rates for aggregates** (Source: MPA)

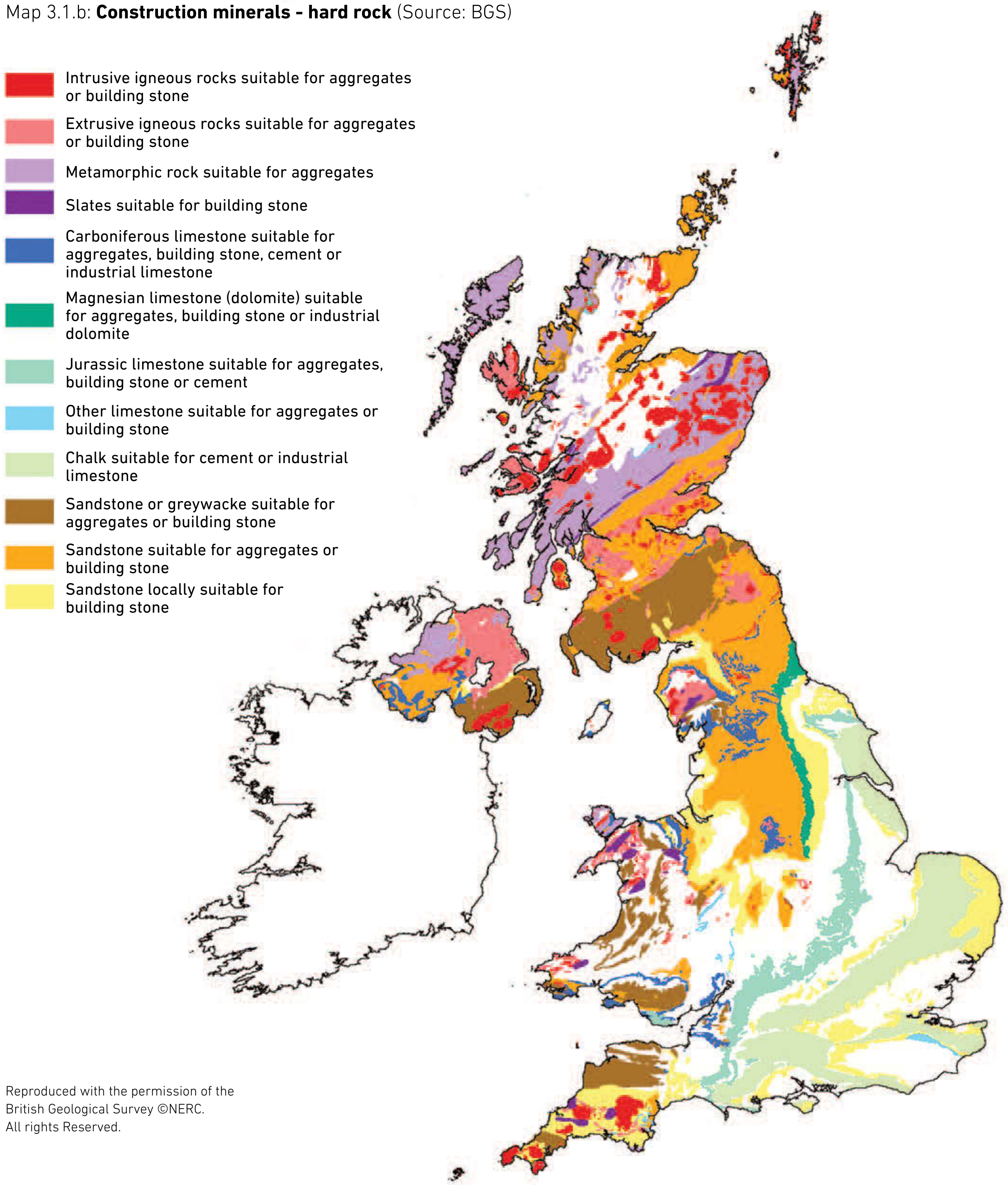


Map 3.1.a: **Construction minerals - sand & gravel** (Source: BGS)



Land-based sand & gravel resources on this map are shown at 1:250,000 scale in a polygon format, whereas the marine sand & gravel resources have been mapped to 1:500,000 scale on a grid basis. The mapping of the two resources are not directly comparable.

Map 3.1.b: **Construction minerals - hard rock** (Source: BGS)



3.2 INDUSTRIAL MINERALS AND METALS

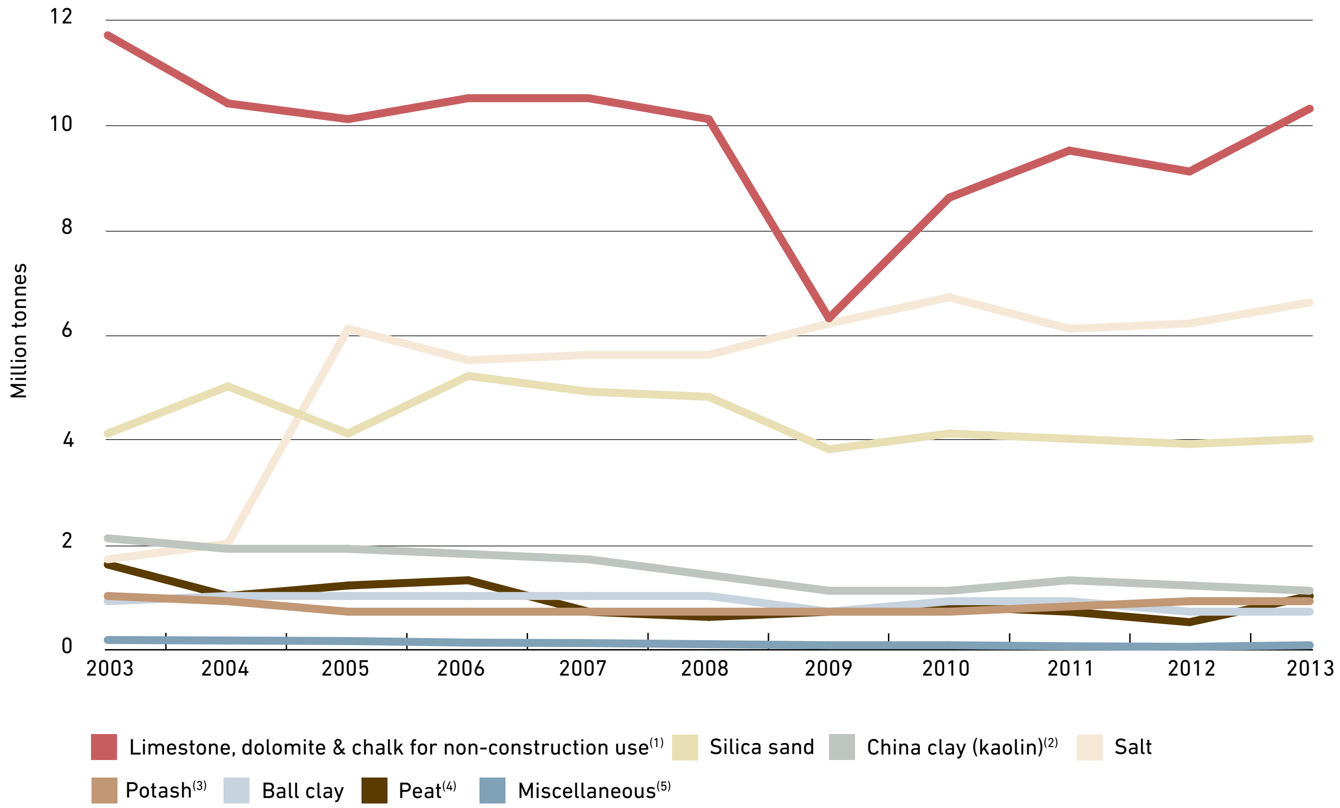
Although limestone is primarily used for construction purposes, there are significant volumes of limestone used for a wide variety of industrial and non-construction purposes, including industrial carbonates (eg lime). Other industrial minerals include industrial (silica) sands, ball clay and kaolin, fluorspar, salt, peat, barytes and potash.

In 2013, about 25 million tonnes of industrial minerals were produced in the UK, including 10 million tonnes of limestone, dolomite and chalk for non-construction use and about 7 million tonnes of salt. The total value of industrial minerals was £917m in 2013.

As a result of the relatively small production levels, the UK is a net importer of industrial minerals. The trade deficit reached £62m in 2013 with most of the deficit due to imports of fertilisers. Overall, the import value of all industrial minerals represented just under 50% of the value of the UK production in 2013.

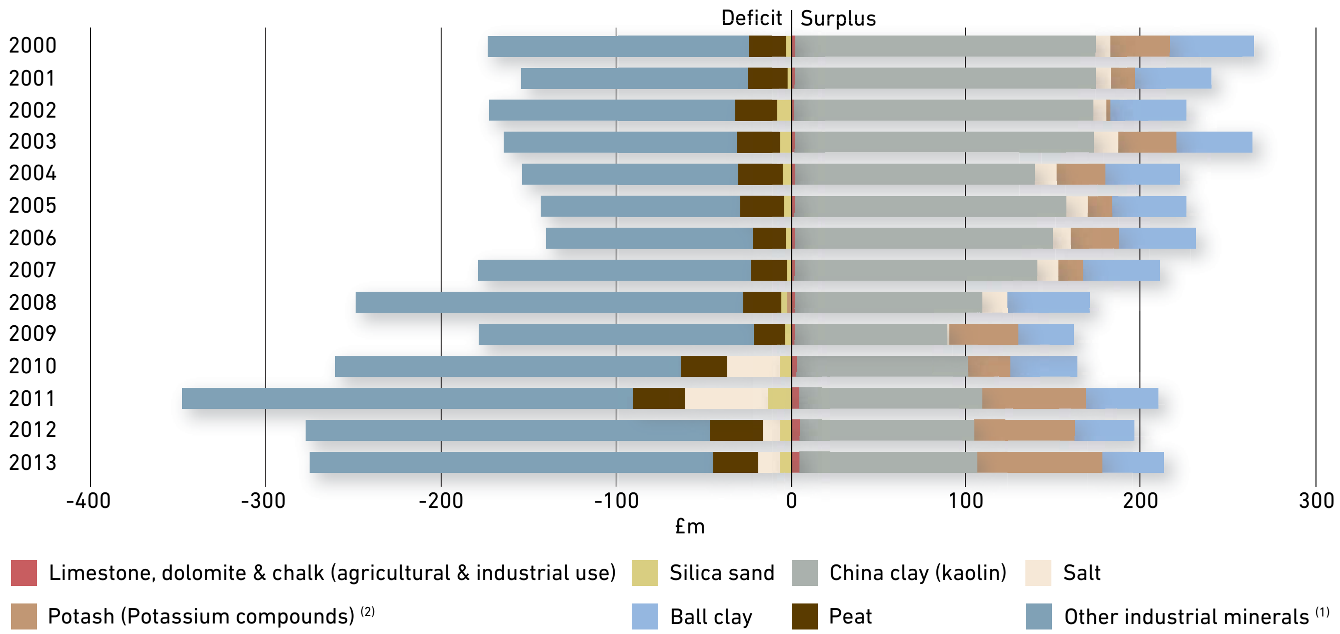
The domestic extraction of metallic ores is almost negligible, with a total volume of 100 tonnes in 2013, mostly lead, and a total value of £1m (in 2011 prices). The opening of the new tungsten mine at Hemerdon in Devon will increase extraction. Imports of metals are much larger, as the trade deficit excluding precious metals reached £2bn in 2013. In volume terms, the largest metal imports are non-precious ferrous and non-ferrous metals.

Chart 3.2.a: **UK production of industrial minerals** (Source: BGS)



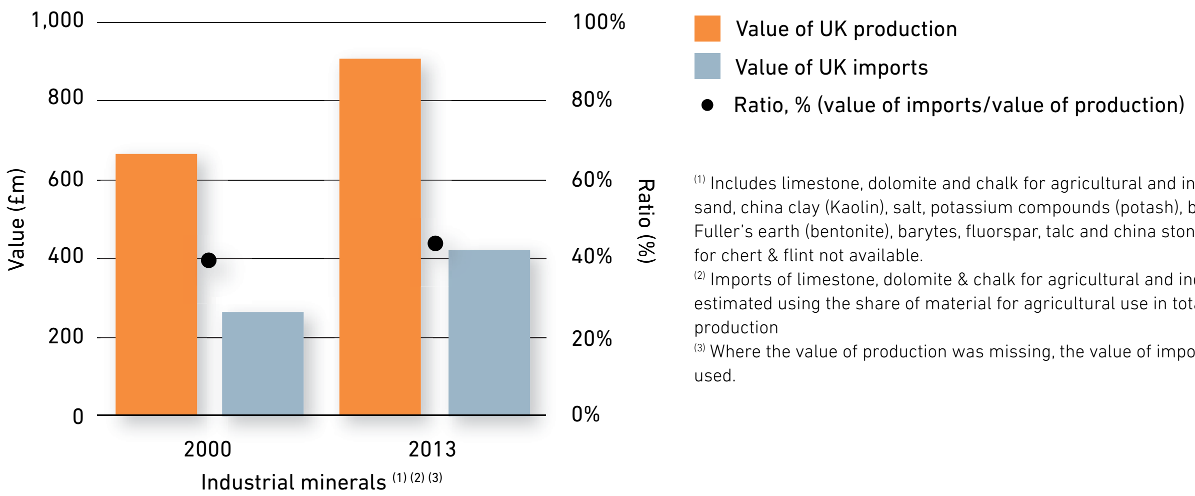
(1) GB only. Limestone, dolomite & chalk production for agricultural and industrial use. All of Northern Ireland production is shown under construction use. (2) Dry weight. (3) Marketable product, includes estimates from 2009. (4) Converted into million tonnes using dry peat conversion factor of 0.8 tonnes per cubic metre. (5) Includes Fuller's earth, barytes, fluorspar, talc, calcspar, chert & flint and china stone (feldspar).

Chart 3.2.b: **UK trade balance in industrial minerals** (Source: BGS)



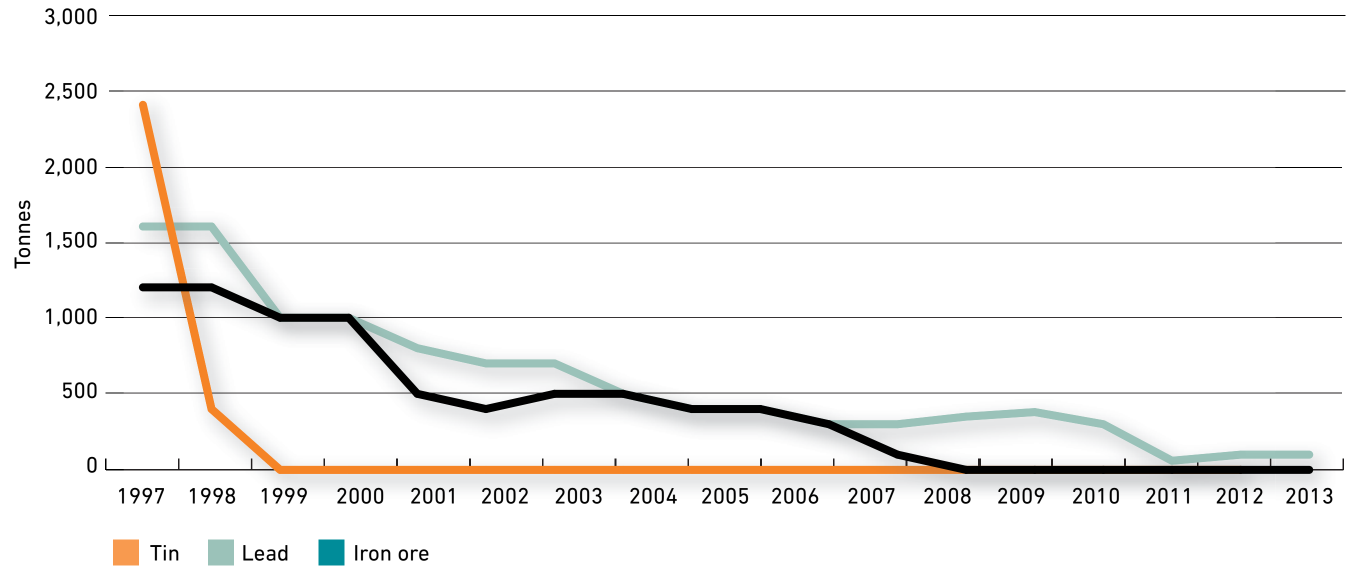
(1) Includes Fuller's earth (bentonite), barytes fluorspar, talc, china stone (feldspar) and phosphorous. Trade data for calcspar and chert & flint is not available.
(2) Imports MPA estimates in some years.

Chart 3.2.c: **Value of UK production and imports of industrial minerals** (Source: BGS)



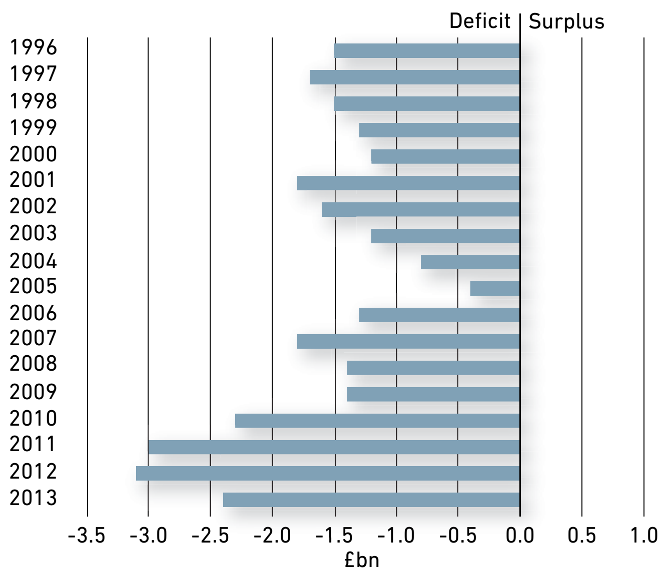
(1) Includes limestone, dolomite and chalk for agricultural and industrial use, silica sand, china clay (Kaolin), salt, potassium compounds (potash), ball clay, peat, Fuller's earth (bentonite), barytes, fluorspar, talc and china stone (feldspar). Data for chert & flint not available.
(2) Imports of limestone, dolomite & chalk for agricultural and industrial use was estimated using the share of material for agricultural use in total volume of UK production
(3) Where the value of production was missing, the value of imports per tonne was used.

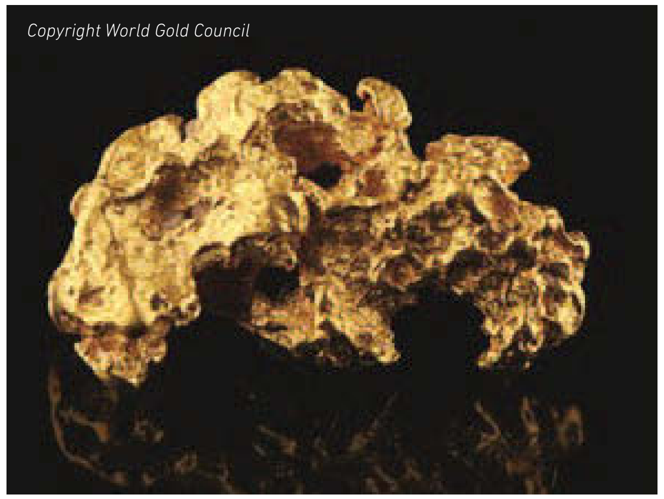
Chart 3.2.d: **UK production of metals**(1) (Source: BGS)



(1) Production of gold and silver commenced in Northern Ireland in 2007 but quantities are too small to show on the scale of this graph.

Chart 3.2.e: **UK trade balance in metals** (Source: BGS)





Note: Precious metals such as gold were omitted as trading distorts the trend in the total metal net trade balance.

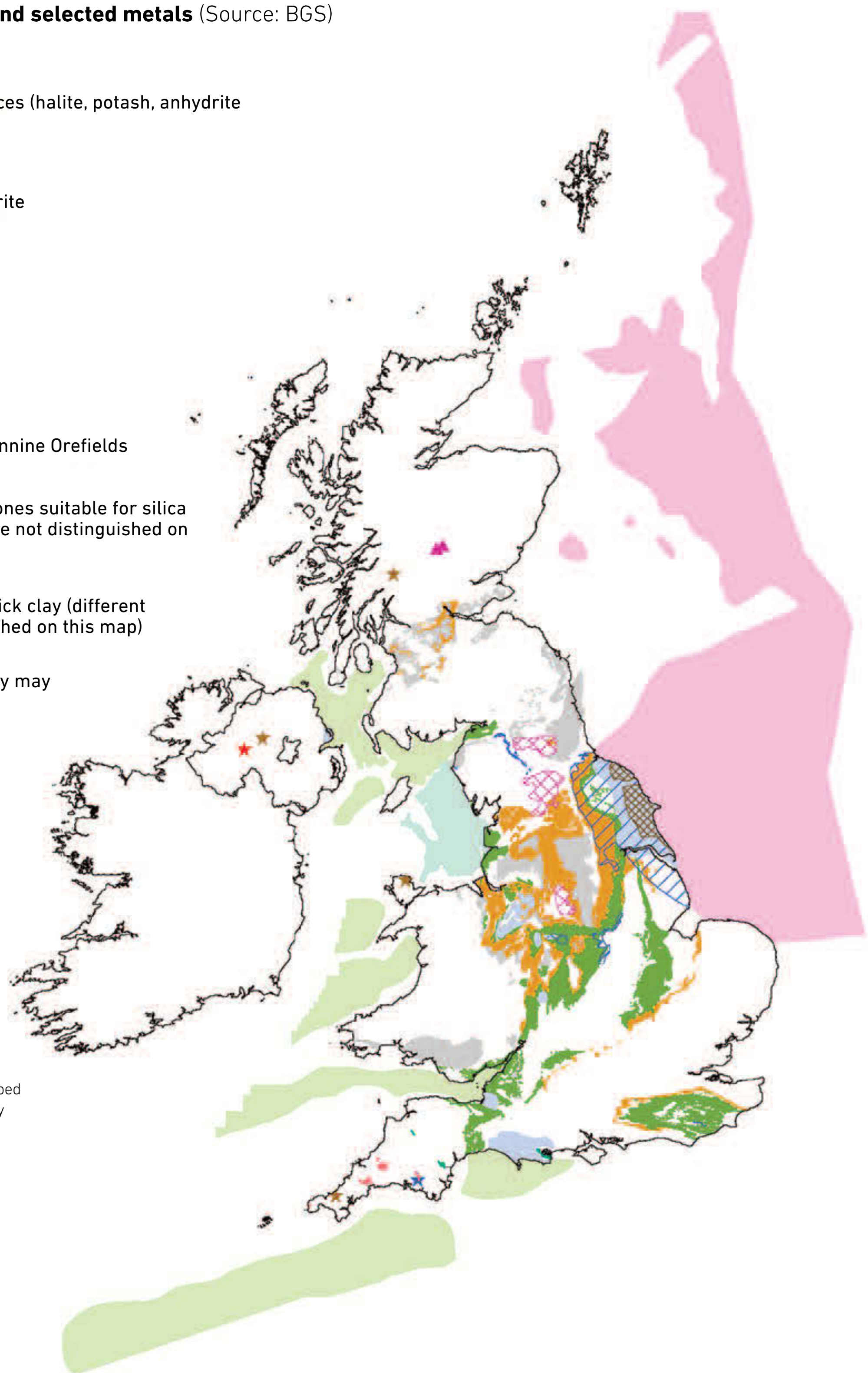
Map 3.2: **Industrial minerals and selected metals** (Source: BGS)

Offshore evaporites

- Extent of evaporite resources (halite, potash, anhydrite and polyhalite)
- Extent of halite
- Extent of halite and anhydrite

Onshore resources

- Onshore potash resources
- Gypsum and anhydrite
- Onshore salt resources
- Barytes deposits
- Northern and Southern Pennine Orefields (fluorspar and barytes)
- Sand deposits and sandstones suitable for silica sand (different qualities are not distinguished on this map)
- Formations suitable for brick clay (different qualities are not distinguished on this map)
- Shallow coal where fireclay may be found
- Kaolin (china clay)
- Ball clay
- Active metal mine
- Developing metal mine
- Active metal prospect



Offshore evaporite deposits have been mapped to a different scale and therefore not directly comparable with resources onshore.

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3.3 COAL

The UK produced 13 million tonnes of coal in 2013, representing a total value of £800m. The level of domestic production of coal is now far below the heights seen in the 1950s, having fallen by 95%. Nonetheless, the UK still consumes a sizeable volume of coal, mainly used by electricity generators, which on average consume around 70% of the total UK coal supply each year, and which now needs to be imported. The UK became a net importer of coal in the early 1980s, importing 33mtoe* in 2013, 2.5 times as much as 20 years ago.

Falling UK production of coal and rising imports have resulted in the value of imported coal rising from 73% to 360% of the value of total UK production of coal between 2000 and 2013.

Map 3.3: **UK energy mineral resources** (Source: BGS)

Onshore hydrocarbon fields

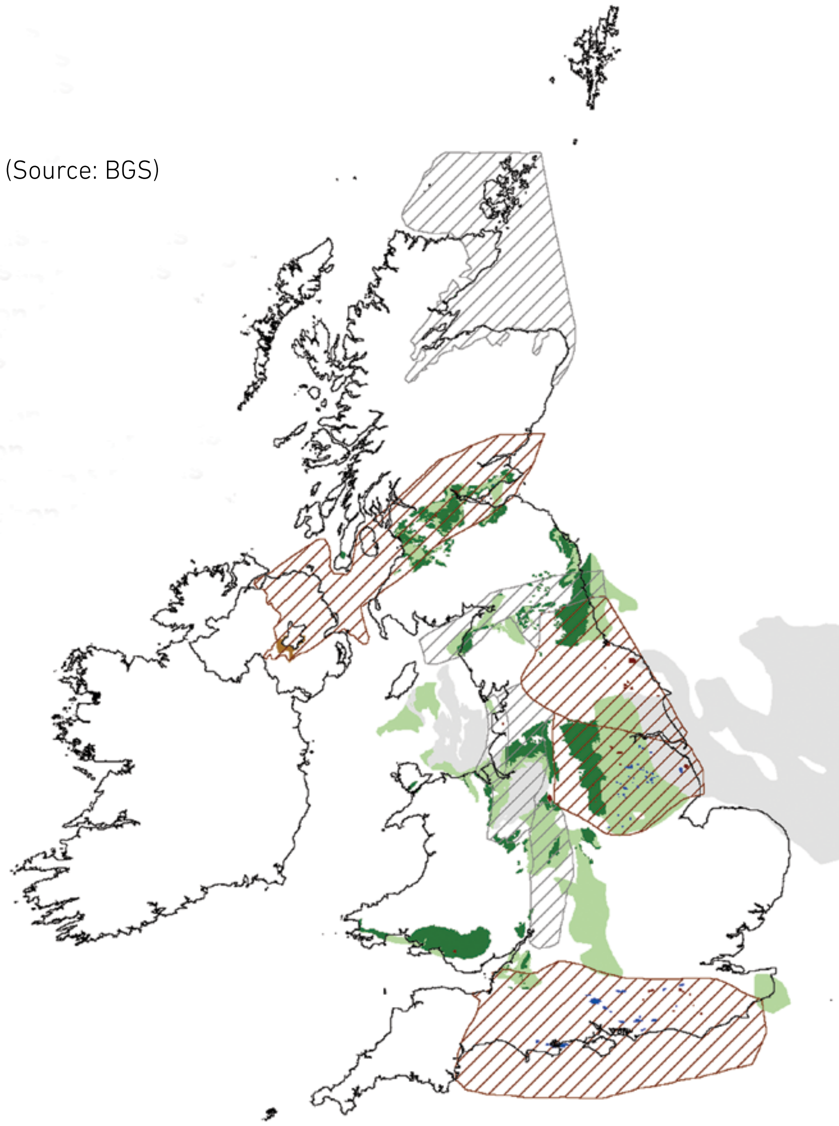
- Coal bed methane
- Gas field
- Oil field

Onshore hydrocarbon basins

- Marginally prospective areas
- Producing areas

Coal fields

- Deep coal >1200m
- Deep coal between 50m and 1200m
- Shallow coal
- Lignite



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*mtoe: million tonnes of oil equivalent

Chart 3.3.a: **UK Coal production and imports** (Source: DECC)

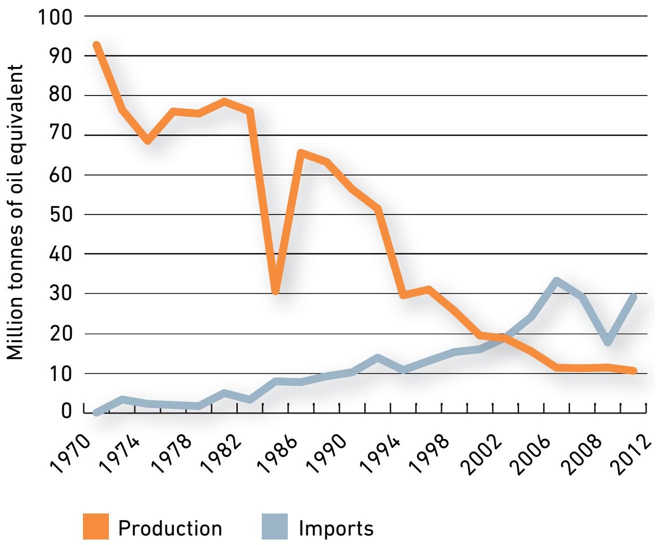


Chart 3.3.b: **Value of UK production and imports of coal** (Source: BGS)

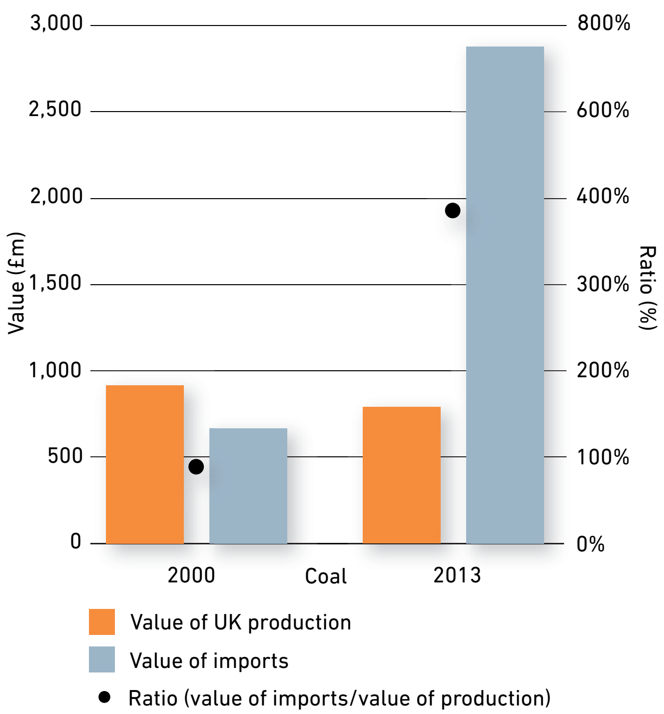
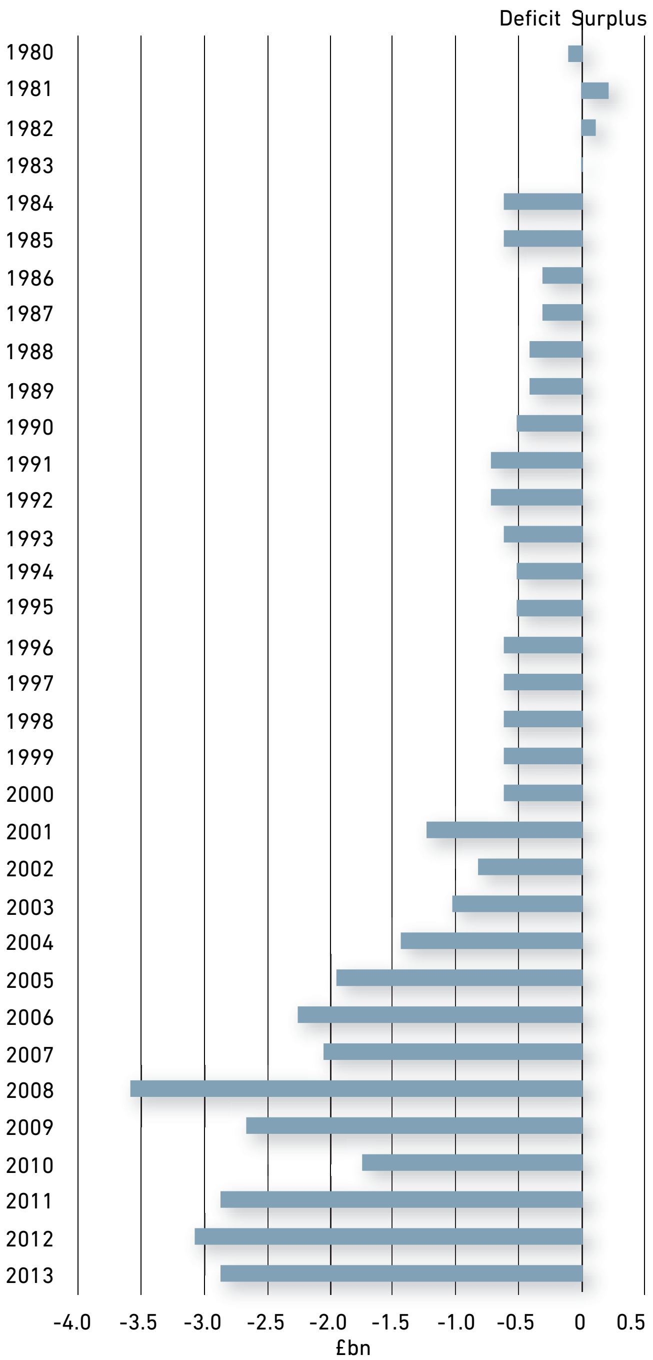


Chart 3.3.c: **UK net trade balance for coal, coke and briquettes** (Source: BGS)



4 RESOURCES DESCRIPTION SUMMARY TABLE

Construction minerals	Uses	Summary of resources
Land-won sand & gravel 	Concrete and concrete products; mortar and asphalting sand.	Durable rock fragments and mineral grains derived from the weathering and erosion of hard rocks mainly by glacial and river action, but also by wind. Resources occur in most parts of the UK. Superficial deposits laid down during the last two million years occur along the floors of major river valleys or as river terraces flanking the valley sides and as glaciofluvial sands and gravels in elongate, irregular lenses within till sequences. Bedrock deposits include the Lower Cretaceous Folkestone Formation of the Weald, the Permian Yellow Sands of Durham, and the Triassic Sherwood Sandstone Group in the Midlands and in Devon.
Marine-dredged sand & gravel 	Concrete and concrete products; construction fill, beach nourishment and exports	Relict Quaternary deposits formed by fluvial (river) or glaciofluvial processes but modified by the major postglacial sea-level rise (which took place up to 5,000 years ago) and subsequently re-worked by tidal currents on the continental shelf. Also includes sea-bed lag gravels and degraded shingle beach or spit deposits, as well as modern marine tidal sand banks and sandwave deposits.

Construction minerals	Uses	Summary of resources
Crushed rock (limestone, igneous rock, sandstone) 	Asphalt, roadstone, concrete, concrete products, railway ballast, armour stone, construction fill.	A variety of rock types with technical suitability for different aggregate applications due to their physical characteristics, such as crushing strength, porosity and resistance to impact, abrasion and polishing. Generally located north and west of a line connecting the Humber Estuary with the Isle of Portland. Many formations are worked but of particular importance are: Carboniferous limestone in the Peak District and the Mendips; Precambrian or Cambrian igneous rock intrusions in Leicestershire; Granite intrusions in the Highlands of Scotland; and indurated (harder) sandstones known as greywackes such as the Upper Carboniferous Pennant Sandstones of the South Wales Coalfield or the inliers of Lower Palaeozoic greywackes in western North Yorkshire.
Limestone, chalk 	Cement manufacture.	Carboniferous limestones occur quite widely in the north and west of the UK. Most notable in England are those in the Peak District of Derbyshire, large areas of the northern Pennines, fringes of the Lake District and in the Mendips. Limited occurrence only in the Midland Valley of Scotland. In Northern Ireland there is a broad belt in the south-west and in areas near Cookstown and Armagh. In Wales it outcrops around the flanks of the South Wales Coalfield, on the western flank of the North Wales Coalfield, the west side of the Vale of Clwyd and on Anglesey. Cretaceous Chalk is a soft, fine-grained, white limestone and occurs extensively in eastern and southern England. Jurassic limestone is worked at one site in eastern England.

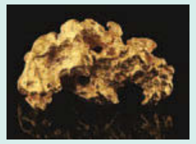
Construction minerals	Uses	Summary of resources
Clay and shale 	Primarily building bricks but also clay roof tiles and pipes.	A wide range of clays are potentially suitable and occur extensively in many parts of the UK. The principal brick clay resources are: Carboniferous mudstones in northern England and central Scotland; Etruria Formation or 'Etruria Marl' (Carboniferous age); Mercia Mudstone Group or 'Keuper Marl' (Triassic age) in the Midlands; Peterborough Member or 'Lower Oxford Clay' (Jurassic age) in Cambridgeshire and Bedfordshire; but there are several others which are locally important.
Gypsum ($CaSO_4.2H_2O$) 	Plasterboard, plaster and cement manufacture, some speciality uses.	Widely distributed in England in rocks of Permian and Triassic age, and to a lesser extent in strata of late Jurassic age. The most important resources are the Tutbury Gypsum in Leicestershire, Nottinghamshire and Staffordshire and the Newark Gypsum in east Nottinghamshire. In Cumbria, several gypsum/anhydrite beds occur in mudstones of late Permian age in the Vale of Eden. In East Sussex, gypsum is found within a series of small 'inliers' of Jurassic rocks in the Robertsbridge area .
Building and roofing stone 	Building, walling and flooring and paving stone, as well as a range of materials used for roofing purposes. Includes monumental stone and material worked for "high end" architectural uses such as cladding buildings. Natural stone is also used for interior features such as staircases, fireplaces, kitchens and bathrooms.	Britain has extensive geological formations that are potentially suitable for use as building stone. The apparent extensive nature of these resources disguises the fact that rocks suitable for use as building and roofing stone may be highly localised. Principal building stone resources include sandstones, limestones, slate, granites and other igneous rocks.

Construction minerals	Uses	Summary of resources
Fireclay 	Light-firing building bricks.	Relatively thin, widely-spaced beds in association with Carboniferous coal formations. In the South Derbyshire Coalfield an unusually high concentration of thick fireclays occurs in the Pottery Clays of the Pennine Upper Coal Measures. The Coalbrookdale Coalfield contains a concentration of fireclays in 20 metres or so of strata within the Lower Coal Measures.

Industrial minerals	Uses	Summary of resources
Salt (NaCl) 	Basic chemical feedstock, white salt and for road de-icing.	Triassic-aged Northwich Halite Formation and an upper Wilkesley Halite Formation in the Cheshire basin; Permian-aged strata in north east England beneath Teeside, North Yorkshire and northern Lincolnshire; Triassic saltfields in parts of Lancashire, Worcestershire, Staffordshire, Cumbria, Dorset and Somerset; Triassic Mercia Mudstone Group in southern Co. Antrim, Northern Ireland.
Potash (potassium-bearing minerals) 	Fertilisers (Potassium is an essential plant nutrient).	At depth near Whitby, North Yorkshire, two main horizons of Permian age: the Boulby Potash, which is the most extensive, and a higher horizon, the Sneaton Potash. Polyhalite also occurs in the area and is currently under investigation.
Silica sand 	Glass manufacture (containers, flat and speciality), foundry sand, and a range of industrial, agricultural/horticultural and sports uses. Silica sand uses also include water filtration, precision casting for the aerospace and automotive industries, binders and fillers for paints and adhesives and proppants for oil and gas.	Loosely consolidated sands and weakly cemented sandstones ranging from recent to Carboniferous in age which have the desired physical and chemical properties. In England, the most important are as follows, but other formations are also used for specific industrial purposes: Congleton and Chelford sands in Cheshire; Leziate Beds of Lower Cretaceous age, near King's Lynn in Norfolk; Folkestone Formation of the Lower Greensand Group of the Weald; upper part of the Woburn Sands Formation near Leighton Buzzard; and sandstone within the Carboniferous Millstone Grit Group in Staffordshire. In Scotland the principle resources are the sandstones of the Passage formation in central Scotland and the high purity, Cretaceous-age Lochaline White Sandstone Formation in the Morvern peninsula and on the Isle of Mull.
Ball clay 	Principally ceramic whiteware (sanitaryware, tableware and tiles).	Confined to three Palaeogene ('Teriary') basins in south west England: the Bovey Basin in south Devon, Petrockstowe Basin in north Devon and the Wareham Basin in Dorset.

Industrial minerals	Uses	Summary of resources
Industrial carbonates (Limestone, chalk and dolomite) 	Wide range of industrial applications, including lime and dolime and for steel and glass manufacture; agricultural and environmental use.	Limestones are widely distributed, but many are unsuitable for industrial uses because of their chemical and/or physical properties. Carboniferous limestones of particular importance include the Bee Low Limestone in the Derbyshire Peak District; the Cove Limestone, in the southern part of the Yorkshire Dales; the Park Limestone in south Cumbria and north Lancashire and the Knipe Scar Limestone on the eastern side of the Lake District. However, other Carboniferous limestones have also been worked for some industrial uses. Cretaceous Chalk occurs in thick and extensive deposits in eastern and southern England and also in Northern Ireland. Dolomites and dolomitic limestones of late Permian age crop out as a narrow, easterly dipping, north-south belt running for some 230km from Newcastle to Nottingham; within this of particular importance are the Raisby, Ford, Cadeby and Brotherton Formations. Carboniferous limestone has been dolomitised in parts of the Peak District, Shropshire and in South Wales. Dolomite also occurs elsewhere on a local scale.
Kaolin (china clay) 	Papermaking, ceramics, fillers in paints, rubber, plastics. By-products of China clay extraction are used as construction aggregates in Cornwall and Devon, and sometimes further afield.	Confined to the granites of south-west England, in particular the central and western parts of the St Austell Granite and the south-western margin of the Dartmoor Granite.

Industrial minerals	Uses	Summary of resources
Fluorspar (CaF_2) 	Principally used in the manufacture of hydrofluoric acid (HF), the starting point for the production of a wide range of fluorochemicals - including refrigerants, specialty plastics (eg teflon), electronic circuit boards, anesthetics, solar panels and Li-ion batteries. It is also used as a flux in the manufacture of both aluminium and steel.	Mineralisation occurs in two areas in the UK: the Southern and Northern Pennine orefields. Currently, production is only from underground and surface operations in the Peak District National Park. The mineral mainly occurs in limestones in steeply inclined east-west and east-north-east to west-south-west fissure veins (rakes) with individual veins up to several kilometres in length and up to 10 metres wide; and is often also associated with varying amounts of barytes and lead. Some concealed orebodies have also been discovered related to cavity infillings and replacement deposits in receptive limestone.
Barytes ($BaSO_4$) 	Mainly used as a weighting agent in drilling fluids for oil and gas exploration. It also has applications as a filler in the car, marine, radiation protection and paint industries; and for LCD glass and dielectrics manufacture.	Barytes is not uncommon in the UK but economic deposits have been extracted from only a few localities. Currently production is only from the Precambrian aged Ben Eagach Schist formation at Foss Mine near Aberfeldy in Scotland, and as a by-product from the fluorspar operations in Derbyshire. The Duntanlich deposit near Aberfeldy is a major and significant long-term resource. Deposits have also been worked in Shropshire, the Lake District, central Scotland and South Devon.

Metals	Uses	Summary of resources
Tungsten-tin 	It was widely used in electric light filaments but now, due to its hardness, it is mainly used as tungsten carbide for cutting and drilling in metalworking, mining, oil and construction industries. It is also used in the military industry.	Major deposit at Hemerdon, near Plymouth, Devon has a resource of 97.4 million tonnes at 0.22% WO_3 and 0.023% Sn (inferred and indicated). Production started in September 2015.
Gold 	In addition to its use in jewellery and as an investment, it is widely used as a conductor in the electronics industry because of its corrosion-free properties.	Open pit mine operating in Omagh, Northern Ireland. A second deposit discovered at Curraghinalt, Northern Ireland. Planning permission granted for a deposit at Cononish, near Tyndrum, Scotland. Total Measured, Indicated and Inferred Mineral Resource is 154,000 troy ounces of gold and 589,000 troy ounces of silver.
Zinc-copper-lead 	Widely used in industrial applications such as in electric wiring, batteries, coating to protect more reactive metals and in alloys to give greater strength and resistance to corrosion.	Parys Mountain zinc-copper-lead deposit in Anglesey has a total historic resource of about 7.76 million tonnes at 9.3% combined zinc, lead and copper, with minor gold and silver values. Extensive deposits of copper (and tin) exist in Cornwall and west Devon, some of which have planning permission for extraction, although no extraction is currently taking place.

Coal	Uses	Summary of resources
Coal (both shallow and deep) 	Primarily electricity generation but also domestic/ industrial fuel.	Pennine and South Wales Coal Measures groups of Upper Carboniferous (Westphalian) age. Older coal seams in part of northern England and the Midland Valley of Scotland, particularly in the Passage Formation. Very large resources of Carboniferous coal remain at depths greater than 1,200 metres, particularly eastwards of the Pennine coalfield below the North Sea. Unquantified, but probably large, resources exist on parts of the UK continental shelf however much of this is likely to be lignite. Large resources of lignite exist in the vicinity of Lough Neagh, Northern Ireland.
Coalbed methane (CBM) and Underground coal gasification (UCG) 	Electricity generation and domestic/ industrial fuel.	Unworked coal seams and potentially from active or abandoned coal mines. CBM: minimum 0.4 metre seams at 200 to 1,200 metre depth, with appropriate levels of permeability. UCG: minimum 2 metre seams at 600 to 1,200 metre depth. Pennine and South Wales Coal Measures of late Carboniferous age (Westphalian); older coal sequences in northern England and Midland Valley of Scotland.

APPENDIX 1
DETAILED RESOURCES DESCRIPTION

Construction minerals

Construction aggregates (MPF 2013)
Land-won sand & gravel

Sand & gravel deposits are accumulations of the more durable rock fragments and mineral grains, which have been derived from the weathering and erosion of hard rocks mainly by glacial and river action, but also by wind. The properties of gravel, and to a lesser extent sand, largely depend on the properties of the rocks from which they were derived. Most sand & gravel is composed of particles that are durable and rich in silica (quartz, quartzite and flint). Other rock types, mainly limestone, may also occur in some land-won deposits including deleterious impurities such as lignite, mudstone, chalk and coal.

Sand & gravel resources can be classified, according to their age and geology, into 'superficial' also known as 'drift' deposits and 'bedrock' or 'solid' deposits.

Superficial deposits comprise sediments laid down during the last two million years. They mainly comprise river sands and gravels which take the form of extensive spreads that occur along the floors of major river valleys, generally beneath alluvium, and as river terraces flanking the valley sides. River terraces are the dissected, or eroded, remnants of earlier abandoned river floodplains. Deposit thickness varies from less than 1 metre to maximum values of around 10 metres. Sand to gravel ratios are variable, but river deposits typically are relatively clean with a lower fines content (silt and clay) than glacial deposits. Important resources are associated with the Thames, Trent and Severn and their tributaries, but many other river deposits are also worked. In general, the composition of the sand & gravel of a river basin reflects that of the rocks in the uplands drained by the river and its tributaries.

Other superficial deposits comprise the glaciofluvial sand & gravels. These deposits were associated with glacial action and laid down by the glacial meltwaters issuing from ice sheets and glaciers. The deposits are commonly associated with till (boulder clay), and may exhibit complex relationships, occurring as sheet or delta-like layers above till deposits, or as elongate, irregular lenses within the till sequence. As a result, the distribution of glaciofluvial deposits is less predictable in geographical extent than river sand & gravel deposits. They may also exhibit considerable lateral variations in thickness, composition and particle size distribution and generally contain more fines (silt and clay).

Bedrock deposits occur as bedded formations, ranging in age from Permian to Palaeogene, and are relatively unconsolidated and easily worked. Some deposits such as the Lower Cretaceous Folkestone Formation of the Weald and the Permian Yellow Sands of Durham, consist entirely of sand. The sandy pebble beds (conglomerates) of the Triassic Sherwood Sandstone Group in the Midlands and in Devon are important sources of coarse concrete aggregate. Bedrock deposits are generally much thicker than most superficial deposits.

Construction aggregates (MPF 2013)
Marine-dredged sand & gravel

On the continental shelf, sand & gravel resources are unevenly distributed and vary in their thickness, composition and grading, and in their proximity to the shore. The origins of these sediments offshore are directly comparable to those of terrestrial deposits. They are relict Quaternary deposits formed by fluvial (river) or glaciofluvial processes but modified by the major postglacial sea-level rise (which took place up to 5,000 years ago) and subsequently re-worked by tidal currents. They represent a range of former depositional environments, including fluvial channel-fill or terrace deposits, glaciofluvial meltwater plain deposits, sea-bed lag gravels and degraded shingle beach or spit deposits, as well as modern marine tidal sand banks and sandwave deposits.

There are considerable regional variations in the composition of the sand & gravel deposits. For example, the gravelly deposits off Great Yarmouth are mostly flint gravels of fine pebble size, whereas gravels from the Humber area are much coarser, and are principally composed of igneous, metamorphic or hard sandstone types, derived from former glaciofluvial deposits.

Construction aggregates (MPF 2013)
Crushed rock (limestone, igneous rock, sandstone)

A variety of rocks are, when crushed, suitable for use as construction aggregates. Their technical suitability for different aggregate applications depends on their physical characteristics, such as crushing strength, porosity and resistance to impact, abrasion and polishing. 'High quality' crushed rock aggregate, to meet demanding specifications, is commonly derived from hard, dense and cemented sedimentary rock and the tougher, crystalline igneous rocks.

Limestone

Limestones of Carboniferous age are the major source of limestone aggregate and represent one of the largest resources of good-quality aggregate in Britain. These limestones are commonly thickly bedded and consistent which enable them to be quarried extensively and economically. They typically produce strong and durable aggregates with low water absorption. The two main producing areas, the Mendips and Derbyshire, are distinctly different due to major differences in local geology. The limestones of the Mendips are faulted and folded with many clay-filled fissures contaminating the resource. These limestones are ideal for large scale quarrying for crushed rock aggregate but are generally unsuitable for high purity industrial uses. In contrast, the limestones of Derbyshire are flat-lying and noted for their chemical uniformity and consistency over wide areas. They are quarried for industrial use as well as for aggregate.

Other major limestones being worked for aggregates include the Devonian limestones of south Devon, the Permian Magnesian Limestone of north-eastern England and to a lesser extent Silurian limestones of the Welsh Borders. Certain of the harder, less porous Jurassic and Cretaceous (the Chalk) limestones are also quarried for less demanding aggregate applications.

The Permian limestone, which crops out in a narrow, easterly-dipping belt between Newcastle and Nottingham, is mainly dolomites and calcareous dolomites, but in places there is gradation into limestone. These Permian limestones and dolomites are highly variable and are much softer than typical Carboniferous limestone with higher porosity. Hence, they are generally quarried for their industrial uses or for low-grade aggregate applications. However, some beds are sufficiently strong and durable to be used as concreting aggregate and are worked in several quarries near Maltby, South Yorkshire and near Durham.

Igneous and metamorphic rock

Resources of igneous and metamorphic rocks are predominantly concentrated in Scotland and Northern Ireland. In England and Wales resources are more localised and only occur in the north, midlands and west. The small outcrops of Precambrian/Cambrian igneous rock (slightly metamorphosed diorite and granodiorite intrusions) in Leicestershire provide a source of hard rock in the Midlands, which are well placed to serve markets in the South East. The deposits are of economic importance out of proportion to their relatively small size.

Elsewhere extraction is mainly concentrated on fine to medium-grained intrusions, mostly of dolerite, such as the Whin Sill in northern England, but similar types of bodies occur in the Midland Valley of Scotland, the Welsh Borders and the South West. Volcanic rocks (extrusive lavas or tuffs) are generally more variable in quality. Palaeogene basalts are worked in Northern Ireland and Carboniferous volcanics in central Scotland. A very high skid resistant stone is produced from the Borrowdale Volcanic Group in the Lake District.

In the western Highlands of Scotland there are large intrusions of granite and these are worked at a few localities for crushed rock aggregates; of particular importance is the Strontian Granite on the north-west side of Loch Linnhe.

Sandstone

Sandstones are sedimentary rocks consisting of sand-sized particles composed predominantly of quartz but with variable amounts of feldspar and rock fragments set in a fine-grained matrix or cement. Compositional differences, both of the sand grains and the matrix, give rise to different rock names under the general heading of 'sandstone', such as quartzites, greywackes, gritstones, and arkoses. Sandstones of various geological ages occur extensively in Britain, including a few in the geologically younger surface rocks of south-east England.

The suitability of a sandstone for aggregate use mainly depends on its strength, porosity and durability. These qualities are related to mode of formation and geological history. Thus the mineralogical composition, grain size, degree of grain sorting, nature and degree of cementation, degree of compaction and weathering state are fundamental rock properties which directly affect the end-use performance of the sandstone and its economic potential. Individual sandstone units also vary in thickness and lateral extent.

Many types of sandstone are too porous and weak to be used other than as sources of constructional fill. In general, older more indurated sandstones (subjected to tectonic compression) exhibit higher strengths and are suitable for more demanding aggregate uses. Some sandstones (greywackes) also have a high polishing and abrasion resistance and are particularly valued for road surfacing where they provide resistance to skidding. They are the premium products of the crushed rock quarrying industry.

The Upper Carboniferous Pennant Sandstones of the South Wales Coalfield are indurated greywackes, which have been subjected to compression, and are typically highly resistant to polishing and in most cases they combine durability with good strength. The major cause of variation in aggregate properties is the degree of weathering. Weathering weakens the aggregate and reduces its durability. All surface exposures of Pennant Sandstone are weathered to some degree and the depth of weathering is controlled by the distribution of joints and other rock discontinuities. Pennant sandstones also occur in the small coalfields of the Forest of Dean, Gloucestershire and Bristol area.

The Precambrian Longmyndian rocks forming relatively high ground around Shrewsbury are also important resources of road surfacing aggregate. These sandstones are subgreywackes and produce a particularly high quality roadstone which is utilised in high specification applications. In western North Yorkshire, Lower Palaeozoic rocks occur in a series of inliers unconformably overlain by Carboniferous limestones near Settle and Ingleton. These rocks are strongly folded and comprise a mixed sequence of greywackes, siltstones, arkoses and conglomerates. They are quarried at several sites for the production of high specification road surfacing aggregates.

Cement raw materials (MPF 2014)
Limestone/chalk

Limestones of various geological ages are widely distributed in the UK. They vary considerably in their chemistry and thickness and thus their suitability for cement manufacture on a large scale. Dolomites and magnesian limestones are unsuitable for cement manufacture, because of their high magnesia (MgO) contents; limestone for cement should contain less than 3% MgO.

Cement manufacture is based primarily on Carboniferous limestones and on Cretaceous chalk. Carboniferous limestones are relatively extensive and occur as thick deposits that are easy to work and which are generally of relatively high purity. The Peak District of Derbyshire has extensive resources and the limestones are characteristically flat-lying and are noted for their uniformity over wide areas. Large areas of the northern Pennines and the fringes of the Lake District are also underlain by Carboniferous limestones, some of which are relatively thick, pure and consistent in quality. Elsewhere, Carboniferous limestones occur mainly in the Mendips, although here they do not exhibit the same degree of purity.

Limestones of Jurassic age occur in a belt extending from the Dorset coast, north-eastwards through central England to the Yorkshire coast. The limestones of Middle Jurassic age are the most extensive, although individual beds are comparatively thin. Currently Jurassic limestone (Lincolnshire Limestone) is worked at only one site in England, at Ketton, in Rutland. Limestone of Devonian age, which have a restricted distribution in Devon, were formerly worked for cement manufacture at Plymstock, near Plymouth.

Cretaceous Chalk is a soft, fine-grained, white limestone and occurs extensively in eastern and southern England. It is composed of the calcareous debris of planktonic algae, largely in micron-sized plates. It is generally of high purity with a uniform composition. Small quantities (1%) of clay are present throughout the chalk, and centimetre thick beds of calcareous mudstones also occur. However, the lowest 25 - 60 metres of the chalk have a higher clay content and it is this material that was formerly extensively worked as a natural cement mix. The chalk is up to several hundred metres in thickness. It is generally highly porous and has a high moisture content. Consequently wet or semi-wet manufacturing processes are normally used to make cement from chalk.

In contrast to the rest of the UK, Scotland has few limestone resources. Carboniferous limestone occurs to a limited extent in the Midland Valley of Scotland and is most thickly developed in the east. Lower Carboniferous rocks in Northern Ireland include two thick limestone formations separated by fine-grained clayey material. Carboniferous limestone crops out mainly in a broad belt in the south-west of the province and in areas near Cookstown and Armagh. Cretaceous chalk occurs in Northern Ireland where it is locally known as the White Limestone, it is some 50 metres thick and extensively overlain by Tertiary lavas.

In South Wales Carboniferous limestones crop out around the flanks of the South Wales Coalfield. Jurassic limestones with interbedded mudstones occur to the south of the coalfield and are also worked for cement manufacture. In North Wales Carboniferous limestones occur in three main areas: on the western flank of the North Wales Coalfield, the west side of the Vale of Clwyd and on Anglesey.

Brick clay (MPF 2007)

A wide range of clays (including clay or shale waste from other mineral extraction operations, notably coal) have been used in the past in the manufacture of structural clay products. Clays occur extensively in many parts of Britain and resources are, therefore, potentially very large. However, many clays are unsuitable for brickmaking.

Sedimentary clays consist essentially of clay minerals and quartz, although many other minerals may occur in accessory amounts, which may considerably affect the suitability of the clay for brick manufacture. In a brick clay, there must be sufficient clay minerals present to make it plastic to mould and to retain its shape prior to firing. Sufficient fluxing materials must also be present for the clay to vitrify (partially fuse to form a glass to give the product strength) at temperatures between 900 - 1,100°C. An adequate proportion of non-plastic constituents, usually quartz, are also required to prevent excessive shrinkage and deformation during drying and firing. In good quality brick clays, the predominate clay minerals are kaolinite and illite. These impart desirable properties which are important in forming and firing the brick. Carbon and sulphur can have a major influence on firing performance and emissions, and low levels are preferred (< 1.5% and 0.1% respectively). The familiar red/brown colour of most bricks is due to the presence of iron minerals in almost all clays. However, the presence of carbonate minerals, such as calcite and dolomite, can produce paler-coloured bricks. Carbonate minerals must be in fine-grained form as coarse carbonate leads to a problem known as 'lime-blowing' (falling away of the surface of a brick due to expansion, following hydration of nodules of lime). Production of very pale buff/cream 'through-colour' bricks is presently only made possible by using fireclays with low iron contents. Fully-durable yellow bricks (such as London 'stocks') are made from a mixture of clay and calcium carbonate (chalk). The principal brick clay resources, in approximate order of tonnage used in brickmaking, are:

Carboniferous mudstones in northern England and central Scotland: Variable in quality, with only a small proportion suitable for brick manufacture (most are too high in carbon and sulphur). Despite this, they are the most important resource.

Etruria Formation or 'Etruria Marl' (Carboniferous age): High quality clay is close in composition to the 'ideal' brick clay. Extracted and used mainly within Staffordshire and other parts of the West Midlands.

Mercia Mudstone Group or 'Keuper Marl' (Triassic age) in the Midlands: The mineralogy of parts of the resource gives rise to distinctive pale-bodied bricks due to the presence of carbonate minerals.

Peterborough Member or 'Lower Oxford Clay' (Jurassic age): Extraction of these clays is confined to Cambridgeshire and Bedfordshire, where they are used in the manufacture of 'fletton' bricks, so named because they were produced by the Fletton Process developed near the village of Fletton, Peterborough.

Fireclays (from Carboniferous coalfields in the Midlands and the North): Associated with coal seams and produced mainly as a by-product of opencast coal extraction, used extensively in high-value extruded buff bricks which are manufactured at sites across the Midlands, the North and Scotland.

Minor brick clay resources are locally important and include brickearth in Kent and Essex; the Reading Formation in Hampshire and the Chilterns; the Gault clay in Kent, West Sussex and Hampshire; the Thanet Formation in Essex; Carboniferous and Devonian mudstones in South West England, the Skiddaw Group near Barrow-in-Furness and alluvial clays on Humberside.

Gypsum (MPF 2006)

Gypsum and, particularly, anhydrite are widely distributed in England in rocks of Permian and Triassic age, and to a lesser extent in strata of late Jurassic age. The most important resources are those associated with the Tutbury Gypsum in Leicestershire, Nottinghamshire and Staffordshire and the Newark Gypsum in east Nottinghamshire. The former occurs as a single bed up to 3.5 metres thick and is only worked by underground mining. In contrast the Newark Gypsum in Nottinghamshire comprises multiple beds and nodular bands of gypsum of variable thickness and purity spread over some 15 to 18 metres of strata. The individual worked beds range from about 0.3 metres to 1 metre in thickness and are worked by opencast methods. Some of the beds are of very high purity and are the source of the highest quality gypsum produced in the UK.

Gypsum at the horizon of the Tutbury/Newark Gypsum has been traced from North Yorkshire to Somerset and is also identified in the Carlisle Basin in Cumbria and in the Cheshire Basin. The thickness and quality of the gypsum is mostly unknown. In Cumbria, several gypsum/anhydrite beds occur in mudstones of late Permian age in the Vale of Eden. In East Sussex, gypsum is found within a series of small 'inliers' of Jurassic rocks in the Robertsbridge area of the High Weald AONB. Gypsum occurs in four beds at the base of the Purbeck Limestone Group.

Building and roofing stone (MPF 2007)

Britain has extensive geological formations that are potentially suitable for use as building stone. Reflecting the geology, different parts of the country have distinctive rock types, which also results in the distinctive character of the built environment in these areas. The apparent extensive nature of these resources disguises the fact that rocks suitable for use as building and roofing stone may be highly localised. This is a direct function of local geology where bed thickness and extent, incidence of discontinuities, such as fractures and joints, and degree of cementation of the rock all have a fundamental effect on the suitability of the rock for building stone. Principal building stone resources include sandstones, limestones, slate, granites and other igneous rocks.

Fireclay (MPF 2006)

The close association of coal and fireclay means that fireclay resources are mainly confined to coal-bearing strata, most of which of Carboniferous age. A characteristic feature of Coal Measures strata is the pronounced cyclicity of the sedimentation, with coal seams and seatearths appearing at irregular intervals. The occurrence of potential fireclays as relatively thin, widely-spaced beds in close association with coal seams means that surface coal mining operations provide one of the few viable sources of the clay.

Although fireclays occur in similar geological environments they exhibit a wide range of mineralogical compositions. Seatearths may also exhibit rapid vertical and lateral variations in composition. All are contaminated to a greater or lesser extent by impurities, which render part, or the whole, of a seam unusable. Siderite (iron carbonate) and carbonaceous matter, present as coaly material and fossil debris, are common impurities.

In the South Derbyshire Coalfield, and in sharp contrast to Coal Measures strata elsewhere, an unusually high concentration of thick fireclays occurs in the Pottery Clays of the Pennine Upper Coal Measures. This has meant that during former and recent opencast coal operations very large tonnages of fireclay have been extracted and stockpiled for future use. The largest site was Donington Island which ceased coaling in 1984. More recently additional quantities of fireclay were stocked from an adjacent site. Some of the lower quality fireclays have been used for site restoration but the remaining stockpiles are the principal source of fireclay in Britain. There are remaining resources of fireclay within the Pottery Clays.

The Coalbrookdale Coalfield has historically been an important, long-term source of fireclay. Here, to the south of the River Severn, a concentration of fireclays occurs in 20 metres or so of strata within the Lower Coal Measures, between the thick fireclay to the Little Flint Coal and the New Mine Coal. A highly siliceous fireclay (the Halifax Hard Bed) is worked on a very small scale near Halifax. Modest quantities of fireclay are also produced from the Carboniferous coalfields in the Midland Valley of Scotland mainly as a by-product of opencast coal extraction. Some thick and highly refractory fireclays, with no associated coal, were formerly mined in Scotland but these are no longer of economic significance.

Industrial minerals

Salt (MPF 2006)

The UK has huge resources of salt, which mainly occur in England, with only limited resources in Northern Ireland. Salt-bearing strata of Permian and Triassic age underlie extensive areas. Resources of Triassic age are economically the most important and are derived from the Cheshire Basin. Permian deposits are only worked in the north east of England.

The most important salt resources in England occur within the Triassic Mercia Mudstone Group, which has a widespread outcrop. However, salt-bearing strata generally only occur where the Mercia Mudstone thickens in major depositional basins. There are two salt-bearing formations in the Cheshire Basin, a lower Northwich Halite Formation and an upper Wilkesley Halite Formation. Production is entirely confined to the former. The maximum known thickness of the formation is some 280 metres and the salt occurs in beds that are virtually pure halite and in others where there are varying amounts of mudstone and siltstone. It has been estimated that some 25% of the formation consists of mudstone. The Wilkesley Halite Formation is even thicker and has a known thickness of some 405 metres. The upper half of the Wilkesley Halite Formation is somewhat purer than the Northwich Halite.

Triassic saltfields have also been worked in the past at Preesall in Lancashire, in Worcestershire, Staffordshire, on Walney Island in Cumbria and in Somerset. Extensive areas of salt-bearing strata also underlie Dorset. It is highly unlikely that any of these deposits will become of commercial interest as a source of salt in the foreseeable future.

In Northern Ireland bedded halite in the Triassic Mercia Mudstone Group underlies the area between Carrickfergus and Larne (in south Co. Antrim), and has been worked for over 100 years. Fifteen km to the north of the current producing mine, a drillhole intersected 400 metres of Triassic halite in three seam groups as well as 113 metres of halite in the older, deeper Permian Upper Marls. Significant salt resources have not been identified in any other part of Northern Ireland to date.

Salt-bearing strata of Permian age extends at depth from Teesside beneath much of east Yorkshire and into north Lincolnshire. It was exploited by brine pumping on Teesside and is mined at the Boulby Potash Mine. Thick salt deposits also occur lower in the Permian sequence within the Fordon Evaporites. A stratigraphically higher salt horizon, the Sneaton Halite, occurs above the Boulby Halite but is less extensive.

Potash (MPF 2011)

The potash resources that occur at depth near Whitby in North Yorkshire are of late Permian age and occur at two main horizons; the Boulby Potash, which is the most extensive, and a higher horizon, the Sneaton Potash. In both these beds sylvinite is the main potassium mineral present. Potash in the form of carnallite ($KCl.MgCl_2.6H_2O$) and polyhalite ($K_2SO_4.MgSO_4.2CaSO_4.2H_2O$) also occurs.

The Boulby Potash averages 7 metres in thickness but ranges from nil to over 20 metres. The bed consists of sylvinite with minor clay minerals and anhydrite, and traces of other minerals. The material mined is of high grade by international standards with a mean KCl content of 34% (21% K_2O). However, grade varies both vertically and laterally. The potash bed has a sharp basal contact with the underlying rock salt and a sharp, but undulating upper contact with the overlying Carnallitic Marl.

The polyhalite is another potential potassium resource in the area and is currently under active investigation. The stratigraphically higher, but less extensive evaporite succession, the Sneaton Halite Formation, also includes the Sneaton Potash Member. These deposits are not currently of economic interest.

Silica sand (MPF 2009)

Silica sands are produced from loosely consolidated sands and weakly cemented sandstones ranging from recent to carboniferous in age. Although sand and sandstone deposits are widely distributed in the UK, only a small proportion of these possess the desired physical and chemical properties to be considered as potential sources of silica sand. These, in turn, will differ appreciably in purity, particle size and thickness.

The Congleton and Chelford sands in Cheshire occur as irregular sheets, which infill troughs in the underlying clays and mudstones. The Congleton Sand is highly valued as a source of foundry sand. The Chelford Sand is purer and coarser and is the most important source of sand for flat glass manufacture in the UK. Remaining resources of low iron (white) Chelford Sand are believed to be limited.

Silica sand is produced from deposits of Lower Cretaceous age at several locations in England, including the Leziate Beds of Lower Cretaceous age, near King's Lynn in Norfolk and the Folkestone Formation of the Lower Greensand Group of the Weald between Buckland and Godstone in Surrey and Maidstone and Borough Green in Kent. The Surrey deposits in particular have low iron contents making them suitable for the production of colourless glass sand.

The upper part of the Woburn Sands Formation of the Lower Greensand in the vicinity of Leighton Buzzard, Bedfordshire is a source of sand for foundry and horticultural applications, and water filtration. Water filtration sands are also produced from the Pleistocene Kesgrave Group in Essex.

Sandstone within the Carboniferous Millstone Grit Group in Staffordshire is worked for silica sand principally at Oakamoor. The sandstone has a high iron content for a source of silica sand, but appropriate treatment with hot acid leaching yields a high quality silica sand containing 0.035% Fe_2O_3 which is required for colourless glass and ceramics manufacture. The sand is also used in a wide range of other industrial applications. A similar sandstone deposit of Carboniferous age was previously worked at Blubberhouses, near Harrogate, North Yorkshire for the production of colourless glass sand.

Sand for coloured glass containers are produced from thin, wind-blown deposits of recent age in the Messingham area of North Lincolnshire. Sand for a variety of industrial applications, including flat glass polishing, is produced from the intertidal zone of the Ribble Estuary off Southport. Sands of Triassic age are worked in Nottinghamshire and Worcestershire and resin

coated sands are produced from sandstones of Jurassic age in North Yorkshire. Sands of the Tertiary age Poole Formation in Dorset are used in glassfibre manufacture.

Important and extensive silica sand resources occur in central Scotland. These are principally associated with medium to coarse-grained sandstones of the Passage Formation, which is Carboniferous in age. The Passage Formation comprises a cyclic sequence dominated by sandstones, which are white, grey and pale yellow in colour, but also includes mudstones, siltstones, seatearths and thin coals. The main silica sand sites are now located on the eastern side of the Central Basin, with large workings at Burrowine Moor and Devilla Forest in Fife, and Levenseat in West Loathian. Small quantities of silica sand are produced from sandstones within the Carboniferous, Upper Limestone Group at Hullerhill in North Ayrshire.

The highest purity silica sand in Britain occurs in the Cretaceous-age Lochaline White Sandstone Formation in the Morvern peninsula and on the Isle of Mull on the west coast of Scotland. The sandstone consists of a very pure white to pale yellow, well-sorted, medium-grained, quartz sandstone up to 12 metres thick. The deposit is sub-horizontal and laterally extensive and has been preserved from erosion by a covering of younger Palaeogene volcanics. It is extracted by underground mining at the Lochaline Mine. After processing the sand contains 99.8% SiO_2 and 0.014% Fe_2O_3 and most of the production is used in the container and domestic glassware market, although it is also a key ingredient in the manufacture of silicon carbide abrasives, borosilicate glass for laboratory and scientific use and chemical and domestic ovenware.

There are limited resources of silica sand in Wales. Carboniferous sandstones on the northern flank of the South Wales Coalfield and in North Wales have relatively high silica contents and were worked for silica rock for refractory use in the past. However, they are hard, quartzitic sandstones from which sand would be difficult to produce. Locally the sandstones have weathered to produce unconsolidated sand deposits. One such deposit is worked for silica sand near Llanarmon in Denbighshire. There are no significant silica sand resources in Northern Ireland.

Industrial limestone and chalk (MPF 2006)

Although limestones are widely distributed in the UK, many are unsuitable for industrial use because of their chemical and/or physical properties. The only important resources of industrial limestone in England are the Carboniferous limestone and Cretaceous-age Chalk.

Carboniferous limestones are the major source of both construction (aggregate) and industrial limestone raw materials in England. They are extensively quarried in the Mendips, the Peak District, parts of the northern Pennines and around the fringes of the Lake District, as well as in adjacent areas of both North and South Wales. A high proportion of the limestones worked in the Derbyshire Peak District are used for industrial purposes. They are characteristically flat lying and are noted for their uniformity over wide areas. The Bee Low Limestone is the most extensively quarried unit and is consistently of very high purity and of consistent chemistry throughout the region. In contrast, Carboniferous limestones in the Mendip Hills are typically steeply dipping and highly faulted. This feature constrains their non-constructional usage, since the resultant clay-filled fault zones, joints and fissures tend to contaminate the resource.

Large areas of the northern Pennines and the fringes of the Lake District are underlain by Carboniferous limestones, some of which are relatively thick, pure and consistent in quality. Notable units of high purity limestone include the Cove Limestone, which crops out widely in the southern part of the Yorkshire Dales; the Park Limestone in south Cumbria and north Lancashire and the Knipe Scar Limestone at Shap on the eastern side of the Lake District. Relatively small amounts of industrial limestone are extracted, but lime for the steel industry is produced on a large scale at Shap.

In South Wales the limestones extend beneath the coalfield, cropping out around its flanks. Limestones in Gower and South Pembrokeshire have been exploited, on a minor scale. Carboniferous limestone is worked in Monmouthshire for the chemicals industry, amongst other purposes. In North Wales limestone occurs in three main areas: on the western flank of the North Wales Coalfield, the west side of the Vale of Clwyd, on Anglesey and the Menai Straits. This limestone is currently worked for lime and industrial fillers.

Carboniferous rocks in Northern Ireland include two thick limestone formations. These have been exploited for construction aggregates at a number of quarries, with some minor agricultural lime production. In contrast to the rest of the UK, Scotland possesses few limestone resources. Dalradian rocks in the Central Highlands of Scotland and Shetland contain beds of limestone, which are worked for agricultural lime.

The thick and extensive deposits of the chalk of eastern and southern England constitute an important source of limestone raw materials, which are used in the manufacture of cement, in agriculture and for the production of chalk 'whiting'. Cretaceous Chalk occurs in Northern Ireland where it is locally known as White Limestone, it is some 50 metres thick and is extensively overlain by Tertiary lavas. This White Limestone is worked at four sites for agricultural purposes and industrial fillers.

Industrial dolomite (MPF 2006)

Dolomites and dolomitic limestones of late Permian age crop out as a narrow, easterly dipping, north-south belt running for some 230km from Newcastle to Nottingham. It comprises a series of dolomites, dolomitic limestones and limestones up to 300 metres thick. The sequence is highly variable, both regionally and locally, in its geology, and chemical and physical properties and thus in its suitability for particular applications.

In north-east England (County Durham), the Raisby Formation and Ford Formation are important carbonate resources. The Raisby Formation is a major source of high-grade dolomite for steelmaking. In South Yorkshire, Derbyshire and Nottinghamshire, the Permian sequence is made up of two carbonate units (the Cadeby and Brotherton formations) separated by calcareous mudstone. The total thickness (mostly <125 metres) is much less than in County Durham. The Cadeby Formation is between 30 - 70 metres in thickness and consists of a varied sequence of dolomites and limestones. Most quarries in the formation produce aggregate, but locally near Doncaster it is of higher purity, with a low iron content, and is extracted for glassmaking. It is also of relatively consistent high quality near Worksop where it is quarried for manufacturing refractory products.

The Carboniferous limestone has been dolomitised, or partially dolomitised, in many parts of its outcrop and in some areas the dolomitisation is sufficiently extensive to form a dolomite resource. In the Peak District of Derbyshire a large area of Carboniferous limestone between Matlock, Monyash and Brassington has been dolomitised, although it is of variable thickness and quality. There is currently no production of industrial dolomite from these rocks. Dolomitic limestone of Carboniferous age is also extracted near Oswestry in Shropshire mainly for construction use, although some is sold as agricultural lime. Some Carboniferous dolomite is also produced in Gloucestershire for agricultural use.

Carboniferous limestones containing dolomite deposits of commercial significance are found in South Wales, cropping out around the flanks of the South Wales coalfield. To the south of the coalfield, along its eastern fringes in the Taffs Well-Risca-Pontypool area, the whole limestone sequence is dolomitised and has been worked at a number of quarries although they have limited use as a source of industrial dolomite. Dolomite occurs infrequently in North Wales, but has been worked on a small scale near Llandudno for agricultural purposes.

The Durness Limestone in north-west Scotland is mainly of Cambrian age and is worked at Ullapool for dolomite which is sold mainly for aggregate and agricultural purposes. In Skye metamorphosed Durness Limestone known as Skye Marble is worked at Torrin for dolomite, which is largely used for agricultural applications. Dolomite is unusual in the Dalradian limestones of Scotland, with the exception of the Appin Limestone, which is reported to be dolomitic in most outcrops. Dolomite is not produced in Northern Ireland, but resources occur within the main Carboniferous limestone units in Fermanagh and Tyrone.

Kaolin (china clay) (MPF 2009)

Kaolin resources in Britain are confined to the granites of south-west England and the deposits are world class in terms of size and quality. All the main granite intrusions have been worked to some extent in the past, but production has historically been based on the central and western parts of the St Austell Granite and the south-western margin of the Dartmoor Granite.

The UK kaolin deposits were formed by the in situ alteration of the feldspar (mainly plagioclase) component of the granites. The kaolinisation process involved the decomposition of feldspar by hydrothermal fluids and surface weathering to form kaolinite and mica. Most other minerals are largely unchanged by this process. Zones of commercial kaolinisation are generally related to permeable fracture and vein systems through which the kaolinising fluids circulated. Kaolinised zones contain a wide spectrum of rock types from hard, unaltered granite ('stent') through to a soft kaolinised 'clay matrix' consisting of a friable aggregate composed principally of quartz, mica, unaltered feldspar, tourmaline and fine-grained kaolinite which mainly occurs in the < 20 μm fraction. The kaolinite content of the clay matrix is variable but typically in the range 10 - 25%.

Ball Clay (MPF 2011)

Economic deposits of ball clay are confined to three Palaeogene ('Teriary') basins in south west England. Here they occur as beds of variable thickness, interbedded with silt, sand, lignite and clays that have too high a carbon and iron content for economic use. Plastic clays with a similar age and character to those in Devon and Dorset also occur around Lough Neagh in Northern Ireland. However, they exhibit high iron contents and no resources have been identified in Northern Ireland that would be acceptable to ceramic producers.

The wide variation in the mineral composition and particle size of ball clays, together with the crystallinity, or structural perfection, of individual kaolinite crystals results in differing ceramic and rheological (fluid) properties. This natural variability occurs both between and within seams, and from basin to basin. It is related to the origin of the clays and is caused mainly by differences in source rocks, the degree of weathering, and the environment in which the clays were deposited. The availability of such a wide range of clays, some of which are unique, is a rare geological phenomenon. The ball clay resources of Devon and Dorset are, therefore, of national and international importance.

Fired colour is a function of iron and titanium (TiO_2) contents, whilst unfired strength and plasticity is largely related to fineness of particle size and the crystallographic perfection of kaolinite. Fine-grained, poorly-crystalline kaolinitic clays tend to have the highest plasticity and unfired strengths. In contrast the best fluid (fast casting) properties are associated with coarser, well-crystalline kaolinites. These latter clays were probably derived from weathering profiles developed on the Dartmoor Granite and some resemble china clay (kaolin) in character. The fine-grained kaolinites were more likely to have been derived from mudstones and slates.

Ball clays in the Bovey Basin include the whitest-firing and most fluid UK ball clays, which is important for sanitaryware and tableware manufacture. Ball clays from north Devon include seams of high silica clay, which are coarser than those in south Devon and Dorset. They are mainly used in tiles but also sanitaryware blends. Dorset clays are noted for their high plasticity and unfired strength, and also low carbon contents. They are particularly suited for tile manufacture and also in electro porcelains, refractories and kiln furniture.

Fluorspar (CaF2) (MPF 2010) (MP2011)

Fluorspar resources occur mainly in two areas in the UK: the Southern and Northern Pennine Orefields. The mineral occurs in limestones in steeply inclined east-west and east-north-east to west-south-west fissure veins (locally known as rakes) with individual veins up to several kilometres in length and up to 10 metres wide. Groups of thin veins may be developed locally. Fluorspar occurs mainly as vein infillings in faults that cut limestones of Carboniferous age. Intense alteration of limestone, and occasionally other vein wall rocks, has led to the formation of important replacement deposits adjacent to several major veins. Fluorspar always occurs in association with other minerals, the most important commercially being barytes (BaSO4) and galena (PbS). The proportion present can be highly variable depending on location within the orefield.

Currently, production is only from underground and surface operations in the Peak District National Park.

In the Southern Orefield which includes the Peak District, mineralisation is largely confined to the eastern part of the limestone outcrop. The fluorspar-barytes-lead mineralisation occurs in major veins (rakes) and stratabound replacement deposits (flats), together with some cave infill deposits (pipes). The richest mineralisation is concentrated in the uppermost limestones (Monsal Dale Limestones) beneath the overlying cover of mudstones (Millstone Grit), which acted as an impermeable cap rock to the mineralising fluids. There is a broad mineral zonation of fluorspar-barytes-lead veins with fluorspar being the dominant mineral in the east, and barytes and calcite progressively more abundant westward. More recent exploration has been directed at finding concealed orebodies related to cavity infillings and replacement deposits in receptive limestone. The mineralogy of these deposits does not correspond with the broad mineral zones seen in the veins.

Most deposits in the Northern orefield are found in near-vertical veins within thin alternating carbonaceous limestones, sandstones and shales and occasionally in basic intrusives associated with the Whin Sill. Sub-horizontal sheets of replacement fluorspar mineralisation locally occur in favourable lithological horizons adjacent to some of the larger veins. Along the southern margin the orefield fluorspar deposits occur in massive carbonaceous limestone.

Barytes (MPF 2006) (MP2005)

Barytes has been worked in many parts of the UK. The most important deposits are near Aberfeldy in Perth and Kinross in Scotland and in the Southern and Northern Pennine orefields.

Current output is only from the Foss Mine near Aberfeldy in Scotland, and as a byproduct from the fluorspar operations in Derbyshire.

Significant production was also formerly recorded in other areas, notably Shropshire, the Lake District, south Devon and central Scotland.

In England, barytes occurs mainly as vein infillings in faults, which cut a variety of rock types. The most important are limestones of Carboniferous age but veins cutting slates, mudstones and volcanic rocks of Precambrian, Lower Palaeozoic and Devonian age have also been worked. Intense alteration of limestone wall rocks has also led locally to the formation of replacement deposits adjacent to major veins in the Northern and Southern Pennines. However, vein and replacement deposits tend to be small.

In contrast, bedded or stratabound deposits are much larger. The Foss Mine (located in the Ben Eagach Schist Formation) is a stratabound barytes deposit, which occurs in highly, folded Precambrian (Proterozoic) metasedimentary rocks and is the major UK source.

A much larger resource of barytes is the nearby Duntanlich deposit, which is also geologically much less complex and easier to mine. Dalradian Supergroup rocks that host barytes deposits near Aberfeldy extend for over 200km across central Scotland from Islay in the south west to Portsoy in the north east. Indications of barytes mineralisation have been found at a number of localities along this zone. The possibility that similar styles of mineralisation could be found in England cannot be discounted.

Metals (MPF 2010)

Tungsten-tin

The major low-grade Hemerdon tungsten-tin deposit, located near Plymouth, comprises a sheeted greisen vein and stockwork complex of quartz-tourmaline-wolframite-cassiterite in a Variscan granite and Devonian metasedimentary rocks. This deposit has been known about for some time and tungsten minerals were extracted during the first half of the 20th century. Further exploration was carried out in the 1980s but despite the granting of planning permission the project did not go ahead. In 2007 the deposit was purchased by Wolf Minerals Ltd who undertook a review of all the previous work, conducted some additional drilling to upgrade the resource to 97.4 million tonnes at 0.22% WO_3 and 0.023% Sn (inferred and indicated), completed a feasibility study, raised financing and acquired all the necessary environmental permits. Mine construction is underway with the first production expected in 2015. Hemerdon is one of the largest tungsten resources in the western world and, with estimated annual production of about 3000 tonnes of tungsten, this project would become one of the world's largest tungsten mines.

Gold

In Northern Ireland, the small open pit Omagh gold Mine, operated by Omagh Minerals Ltd, a subsidiary of the Galantas Gold Corporation, is located near Omagh in County Tyrone. Another deposit, Curraghinalt, has been explored by various companies periodically since its discovery in the 1980s. Both Cavanacaw and Curraghinalt are mesothermal, high-grade (10-15 g/t gold) narrow vein deposits. The area around these deposits is prospective for the discovery of additional, orogenic gold mineralisation.

Note: there are no figures mentioned in the MPF for the size of the resources at these locations.

In Scotland, several small gold prospects were discovered in the Dalradian terrane by commercial companies and by BGS in the 1980s and 1990s. These include the Calliachar-Urlar Burn veins near Aberfeldy and Stronchullin in Knapdale. The most important discovery was at Cononish near Tyndrum in Perthshire. This deposit, discovered in 1984, comprises a single, near-vertical quartz vein with an average width of 1.7 metres. The current total Measured, Indicated and Inferred Mineral Resource is 154,000 ounces of gold and 589,000 ounces of silver (using 3.5 g/t gold cut-off). Scotgold Resources Ltd received planning permission for the site in February 2012. Scotgold is also exploring for similar deposits over a wide area of the Dalradian belt in Scotland.

Zinc-copper-lead

The only advanced prospect in Wales is the Parys Mountain zinc-copper-lead deposit in Anglesey which is under development by Anglesey Mining plc. It is a volcanogenic massive sulphide deposit with several zones of mineralisation that has been worked intermittently for hundreds of years, although large-scale mining from open pit workings commenced in the middle of the eighteenth century. Underground production was predominant in the nineteenth century, but by 1900 virtually all mining activity had ceased.

The deposit contains a total historical resource, only part of which is JORC compliant, of about 7.76 million tonnes at 9.3% combined zinc, lead and copper, with minor gold and silver values. Commercial production came close to restarting in 1990, following the sinking of the 300m deep Morris Shaft, but a sharp fall in metal prices curtailed development at that time. However planning permission for a 1,000 tonne per day mine, which was granted in 1988 and reviewed in 2006, remains valid.

Coal

Deep and shallow coal (MPF 2010)

Almost all onshore coal resources in Britain occur in rocks of Carboniferous age (300–330m years old). In England and Wales coal-bearing rocks are almost entirely confined to the Pennine and South Wales Coal Measures groups of Upper Carboniferous (Westphalian) age. Coal seams occur at fairly regular intervals, interbedded mainly with claystones, siltstones and sandstones. However, in parts of northern England, and notably in the Midland Valley of Scotland, older coals also occur in strata beneath these Westphalian aged successions. In Scotland these occur principally in the Limestone Coal and Upper Limestone formations, with locally thick coals present in the Passage Formation. Coal-bearing strata occur at the surface in a number of discrete 'exposed coalfields' but also dip beneath younger rocks to form 'concealed coalfields'.

Coal has been mined intensively in Great Britain for the past 160 years and much of the resource has been heavily depleted, however, considerable resources remain at depths readily accessible by underground mining. Significant resources amenable to surface extraction also exist which has the advantage of extracting coals that were either too thin to be extracted by underground methods, or were only partially extracted due to the need to leave supporting pillars in the workings.

Very large resources of Carboniferous coal remain at depths greater than 1200 metres (the normal limit of conventional mining). This is particularly the case in the eastward extension of the East Pennine Coalfield, both within the UK land area and, in particular, below the North Sea. Here, and in other parts of the UK Continental Shelf, there exist large resources of coal, as yet not quantified in detail, in Carboniferous, Mesozoic and Palaeogene strata. However, much of this is lignite rather than bituminous coal.

In England and Scotland the coal raised is almost entirely used as steam coal, which is for use chiefly in steam-raising boilers at power stations. Only a very small proportion is coking coal, for coke manufacture. Coal from deep mines contains varying amounts of deleterious elements, in particular, sulphur and chlorine. Coal from surface mine operations contains, as a rule, lower amounts of these elements and blending is often undertaken in order to minimise the sulphur and chlorine content of coal delivered to power stations. In the South Wales Coalfield coal rank increases from the east to the northwest, where anthracite occurs, the only source in Britain. It is sold to industry, domestic customers and specialised local power stations. Lignite is produced in minor quantities as a by-product of ball clay extraction in the Bovey Basin in Devon. No lignite has been produced commercially in Northern Ireland, although in the vicinity of Lough Neagh, there are large resources that have been evaluated for power generation.

Coalbed methane (CBM) and underground coal gasification (UCG)

The UK has very large deep coal resources which may be accessible using technologies including coalbed methane from 'virgin' coal seams and underground coal gasification. There is also potential for recovering gas from active and abandoned coal mines. In England and Wales coal-bearing rocks are almost entirely confined to the Pennine and South Wales Coal Measures groups of Late Carboniferous (Westphalian) age. However, in parts of northern England, and notably in the Midland Valley of Scotland, older coals also occur in strata beneath the Westphalian.

Gases produced during the formation of coal are either adsorbed onto the coal or dispersed into pore spaces within the coal. Immediately after the plant material is deposited, it is biodegraded by bacterial action, producing methane. This is known as 'primary biogenic production' and the gas is likely emitted to the atmosphere or trapped in overlying sediments. Most of the methane that is now found within the coal seams was produced later as the depth of burial increases; this is known as 'thermogenic' methane. Most of the gas is attached to the coal surface in micropores. The amount of gas given off depends on the gas content, rate of coal extraction from coal mines, permeability and total thickness of the coal seams present.

The prime requirements for CBM prospects are unworked coal seams thicker than 0.4m at depths of between 200 and 1200 metres. Low permeability and high drilling costs currently make deeper targets unattractive. Good prospects should have adequate levels of methane (>7m^3/tonne), which generally increase with maturity of the coal. However, permeability, rather than seam gas content, is the most critical factor and varies inversely with gas content and maturity. In general, UK coals exhibit low permeabilities, which limits their potential for CBM.

Resource criteria for UCG require coal seams more than 2 metres thick at depths of between 600 and 1200 metres. There is also a need to have standoffs from operational and abandoned mine workings, urban areas, dense faulting and major aquifers. Although onshore areas with theoretical potential are extensive and occur in a number of coalfields including Yorkshire, Lincolnshire and Warwickshire, central Scotland and South Wales, the first conditional licence awards in the UK have been made offshore (e.g. Firth of Forth, Solway Firth, off west Cumbria, off NE England, Humber Estuary, off East Anglia and Swansea Bay).

APPENDIX 2
OIL AND GAS

The domestic production of oil and gas reached a peak in 1999, and has since been on a sharp declining trend. By 2013, production of oil and gas had fallen by 65% compared to 1999, and the UK became a net importer in 2005. Onshore oil and gas represented only about 1% of the total UK production in 2013. The British Geological Survey has identified a number of prospective areas where it may be possible to extract unconventional oil and gas, but the practical potential of this indigenous supply remains uncertain.

Overall, the UK produced 90m tonnes of energy minerals in 2013 at a total value of £29bn.

UK energy minerals - shale gas, prospective areas (Source: BGS)

Areas surveyed in detail for shale gas/oil resource

Areas underlain by shales considered prospective for shale gas

Areas underlain by shales considered prospective for shale oil

Conventional onshore oil and gas (MPF 2011)

Evidence of oil, both at surface and in mines and boreholes, is known in many areas of Britain. However, oil and gas have only been discovered and produced in commercial quantities from specific sedimentary basins onshore. These are where the required reservoir rocks and source rocks that gained adequate maturity were deposited and where trapping structures now exist. The age of mature source and reservoir rocks, and the type of hydrocarbons found (oil or gas) varies and many of the basins also extend offshore.

Wessex-Channel (including the Weald) Basin, southern England

This basin covers the Weald and Wessex areas in southern Britain, across which, oil and gas occurrences have long been known. Prospective sequences also extend offshore beneath the English Channel. A number of oil seeps have been documented inland, but most occur along the Dorset coast, from near Osmington in Weymouth Bay to Durlston Head and include the famous Mupe Bay oil seep and the occurrences of gas bubbling on the seabed between Durlston Head and Anvil Point. Many oil and gas seepages are also known from East Sussex, the first discovery of which was in a water well in 1836.

These oil and gas seepages and occurrences provided the early impetus for exploration in the area. Though results were initially disappointing, the Kimmeridge Oilfield was discovered in 1959 and the giant Wytch Farm Oilfield was discovered in the early 1970s. Production from this latter field has dominated onshore oil output. Ten other oil and gasfields have subsequently been discovered in the Wessex-Channel Basin.

East Midlands Province, England

The East Midland oil province comprises a series of major Carboniferous rift basins, within which sequences containing important source and reservoir rocks were deposited during Namurian and Westphalian (late Carboniferous) times. Historically, the East Midlands province, comprising Lincolnshire, Nottinghamshire and the northern part of Leicestershire, has been one of the most prospective areas for onshore oil and gas in Britain. It has been subjected to only minor folding or tilting and faulting in post-Mesozoic times, such that hydrocarbon accumulations emplaced in post-Carboniferous times have not been greatly disturbed.

Early exploration led to the oil discovery at Kelham in the 1920s and many important discoveries have been and continue to be made, including Gainsborough/Beckingham, Welton, Saltfleetby and Keddington. However, many of the older fields such as Eakring, Bothamsall, Egmanton and Kelham Hills are now shut down due to exhaustion of recoverable reserves and increasing water production. One or two oil discoveries have yet to be developed, including those of Broughton and Brigg.

North West England

The Formby Oilfield was discovered in 1939. The occurrence of oil had long been known in the vicinity, but the oilfield proved difficult to locate, being sealed by superficial deposits. The oilfield, which probably results from seepage of oil from a deeper accumulation, was shut down in 1965. The only other success in the region was the discovery, in 1990, of the still operating Elswick Gasfield.

North East England (including the Cleveland Basin)

In 1937 drilling was carried out at Eskdale and discovered gas from the Permian Upper Magnesian Limestone, which was extracted in the 1960s. Subsequently, a number of other gasfields have been discovered along an E-W structural trend. The gas originates from Carboniferous (Westphalian) Coal Measures and has been trapped in fractured Permian limestones to create the closed Eskdale and Lockton gasfields and the still producing Malton, Kirby Misperton, Marishes and Pickering gasfields.

Midland Valley of Scotland

The small Midlothian oilfield was discovered in 1937 and for a few years produced small amounts. A few months later a discovery of gas was made at Cousland along the same structural trend.

Northern Ireland

In Northern Ireland prospective Carboniferous and Permo-Triassic sequences occur beneath the Antrim basalts in the north east of the province. Here exploration continues but no commercial discoveries have been made onshore, although shows have been encountered in the near offshore areas.

Unconventional fossil fuels (MPF 2011, with modifications by E Hough of BGS)
Shale gas and shale oil

Shale gas comprises methane and other hydrocarbons recovered from mudrocks and shales which have previously been considered too impermeable ('tight') to allow economic recovery of hydrocarbons. Unlike conventional hydrocarbon systems, which collect in permeable rocks and can be released simply by drilling boreholes into those rock formations, shale gas/oil is locked in the matrix of less permeable rocks. Commercial flows of hydrocarbons can be accessed by combining directional drilling and stimulation, called hydraulic fracturing or 'fracking'. Shale gas/oil is formed by thermal maturation (heating within the Earth) of organic (carbon) rich shales. The characteristic temperature range required to form this 'thermogenic methane' within the shale is known as 'gas window', with lower temperatures over geological time forming oil. Rock properties such as Total Organic Carbon (TOC) and mineralogy together with estimates of thermal history give a good indication of the gas/oil resource potential of a shale formation. Due to a current (2014) lack of production data in the UK and Europe, the amount of hydrocarbons that could be commercially exploited (reserve) is not known.

Shale gas/oil prospects in the UK exist in a number of different basin settings. Estimates have been made of the amount of gas and/or oil in place within three areas of the UK; estimates are given as broad ranges, which reflect geological uncertainty associated with the calculations. The principal exploration target comprises thermally mature Carboniferous basinal shales of the Pennine Basin (Namurian to Tournaisian age) in northern England and the English midlands. There is an estimated range of 822 - 2281 trillion cubic feet (Tcf) of gas-in-place (central estimate of 1329 Tcf) within the Bowland-Hodder geological unit in this area, and other Carboniferous-aged shales may have potential.

Elsewhere, Carboniferous shales in the Midland Valley of Scotland are thought to hold 49.4 - 134.6 Tcf (central estimate of 80.3 Tcf) of gas and 3.2 - 11.2 billion barrels (bbl) of oil in place (central estimate of 6.0 bbl). There may also be a shale gas/oil potential in parts of south and north-east Wales, and south-western parts of Northern Ireland.

Clays of Jurassic age (145 - 199m years old) including the Lias Group, the Oxford Clay Formation and the Kimmeridge Clay Formation of the Weald area in south-east England are thought to hold a shale oil resource of 2.2 - 8.5 bbl (central estimate of 4.4 bbl), with no shale gas potential. There may be further potential for both thermogenic and biogenic shale gas in addition to shale oil in the Wessex and and Cleveland basins.

DEFINITIONS AND DATA SOURCES

Definitions

UK mineral extraction industry

Extraction of raw minerals, including coal, construction and industrial minerals.

UK minerals industry

Extraction of raw minerals and mineral products manufacture such as cement, glass, basic chemicals etc.

First use markets

Direct markets for minerals and mineral products.

Gross value added (GVA)

Value of all goods and services produced in an area, an industry or a specific sector of the economy. It is the value of total output net of any intermediate consumption.

Recycled and secondary aggregates

Materials recovered from either demolition and construction waste, mostly used as aggregates and fill, or as by-products from industrial and other extractive activities, including colliery spoil (used for bulk fill), china clay waste (used as mortar and concreting sands), power station ash (used as a cement substitute within ready-mixed concrete and for block making), blast furnace slag from the iron and steel industries (used as aggregates and cementitious materials) and slate.

Trade balance

The difference between the value of a country's exports and imports of goods and services. Where the value of exports exceeds imports, the country has a trade surplus, which contributes positively to aggregate demand and GDP. If a country's value of imports exceed its exports, it would result in a trade deficit, which negatively contributes to aggregate demand and GDP.

Data sources

Office for National Statistics (ONS)
www.ons.gov.uk

Annual Business survey (ABS)
www.ons.gov.uk/ons/rel/abs/annual-business-survey/index.html

Mineral Products Association (MPA)
www.mineralproducts.org

British Geological Survey (BGS)
www.bgs.ac.uk

Labour Force Survey (LFS)
http://discover.ukdataservice.ac.uk/series/?sn=2000026

Annual Minerals Raised Inquiry (AMRI) **Survey**
www.gov.uk/government/collections/minerals

Union Européenne des Producteurs de Granulats (UEPG)
www.uepg.eu

Department for Business Innovation and Skills (BIS), **Building Materials and Components statistics**
www.gov.uk/government/collections/building-materials-and-components-monthly-statistics-2012

HM Revenue and Customs (HMRC), **Trade statistics**
www.uktradeinfo.com/Pages/Home.aspx