Creating markets for recycled resources

Report: Plasterboard

Review of Plasterboard Material Flows and Barriers to Greater Use of Recycled Plasterboard

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Executive Summary

The research for this report was carried out by AEA technology Environment for WRAP between September and November 2005. The report describes, and quantifies (where possible) the UK materials flow for gypsum, with a particular focus upon opportunities for, and barriers to, the recycling of plasterboard.

Interviews and discussions were held with key industry sectors, and existing references on the subject were used. Commercial confidentiality was citied in some cases as a reason why information could not be supplied or verified. Where this was the case, existing data and reports were used to construct estimates.

Projections show a trend of increasing gypsum consumption over the next 5 years. The majority of the additional demand arises from increased consumption of plasterboard in the construction sector, driven mainly by demand for new and renovated housing.

Of the uses for gypsum identified in this report, the plasterboard industry is identified as the most significant potential user of recovered gypsum. Growth in the plasterboard sector is predicted, and has the potential to provide a market for large quantities of recycled gypsum. However, there are barriers to this,which must be addressed for it to happen on a significant scale (see Table 1 below).

The main potential arisings of gypsum are from construction and demolition sector wastes, although, despite legislative changes, these continue to mainly be sent to landfill.

Barriers exist in relation to the arisings of recyclable gypsum (mainly these relate to the need to divert more waste plasterboard away from landfill), and to the use of the material recovered (mainly quality and supply issues in the plasterboard industry).

Based upon the findings of this report, the main issues that appear to require addressing in order to increase recycling of gypsum are summarised in the table below:

Table 1 Assessment of main issues impacting upon UK gypsum recycling rates

Issue	Options	Comments
Decreasing landfill	Lower the current "10%" permissible sulphate content of mixed waste loads, that is given in regulatory guidance	Stimulates alternatives including recycling Increases cost of landfill
	More bulking centres	Improves availability of alternative waste management facilities Decreases cost of material transport
Increase use in plasterboard industry	"Eco- labelling" scheme to improve visibility of product environmental performance	Needs to be industry wide to overcome competition issues
	Development of quality standards for recycled gypsum	To overcome current quality concerns
	Increase volume / availability of recovered material (see also "bulking" above)	To provide consistent supply to the plasterboard industry (or other users)
Reduce cost of recovered material cf. other sources	Transport costs may be reduced by provision of "bulking centres" e.g. at materials recycling facilities?	Investment in local infrastructure required.
	Tax the use other sources (e.g. virgin, desulphogypsum (DSG))	DSG is already a reused by-product

The main findings of this report are as follows:

Overview of materials flow

The overall demand for gypsum in the UK for all uses in 2004 is estimated to be 4.6 – 5 Mtpa.

It is predicted that by 2010 the plasterboard sector alone will have grown to utilise approx 5 Mtpa.

It is estimated that, by 2010 the overall demand for gypsum in the UK will rise by 2 – 2.5 Mtpa, to a reach an overall total of 6.6 – 7.5 Mtpa.

Other uses of gypsum (e.g. agricultural, etc) are relatively small and the main UK supply market for recycled gypsum is the plasterboard industry.

It is estimated that by 2010 the market for recycled gypsum in the plasterboard industry could grow from the current rate of approximately 0.1 Mtpa to as much as 0.4 – 1.1 Mtpa.

The estimated current quantity of gypsum waste arising in the construction and demolition industries and sent to landfill is in the order of 1 Mtpa.

The main information is displayed diagrammatically in Figure 1 and Figure 2.

Quality and availability of the recycled material

Current UK supply of recycled gypsum is estimated to be 0.07 Mtpa. Current capacity for recycling is estimated to be 0.175 Mtpa. The industry currently reports that it intends to expand capacity to a total in the region of 0.4 Mtpa.

The development of a quality assurance regime (including standards, testing, etc) may help address quality assurance concerns expressed by the plasterboard industry, and help to increase recycling rates.

The ability of post-consumer gypsum (i.e. not desulphogypsum) recyclers to provide sufficient volumes of material of reliable quality is highly influenced by factors affecting diversion from landfill - the continued availability of low cost landfill of gypsum waste is a key issue (see below).

Supply and cost of other competing gypsum sources

Relatively good supplies of (both UK sourced and imported) mined and synthetic gypsum compete with recovered gypsum in terms of sales of gypsum to the plasterboard sector.

There are three plasterboard manufacturers in the UK - both Lafarge and Knauf use imported sources, whereas British Gypsum use mainly UK sources. Both Lafarge and Knauf reported some difficulty in sourcing UK material.

Synthetic gypsum mainly arises from the use of flue gas desulphurisation in the electricity generation sector. Because of continued downward pressure on emissions from industry, and the expansion of these requirements in an enlarged Europe, it can be expected that European arisings of desulphogypsum will continue to rise.

Legislation & Disposal price

In England and Wales, Environment Agency guidance has been issued that permits the deposit of wastes with up to 10% sulphate content waste loads with other biodegradable wastes. This appears to have hindered the anticipated increase in availability of segregated gypsum wastes by effectively permitting continued mixed landfill.

With the continued availability of lower cost mixed landfill, it is likely that the majority of the estimated 1 Mtpa of gypsum that is being landfilled in the UK, will continue to be landfilled rather than segregated for either mono-cell disposal or for recycling.

Supply & demand for, and price of, recycled gypsum

The current situation of plasterboard recycling in the UK is one of an emerging market. A number of recycling operators have started to enter the UK market and are indicating that they anticipate increased business. However, the recycling market currently sees lower than expected arisings of segregated gypsum wastes. The consequences of this have been that the recycling industry has experienced some initial difficulty demonstrating its ability to meet the quality and supply requirements of the plasterboard industry (see below).

Other issues

Plasterboard manufacturers report that product and raw material quality issues limit their ability to incorporate of recycled plasterboard. Tolerances vary from product to product, and certain types of specialist plasterboards (e.g. foil backed) cannot be recycled using today's technology.

Plasterboard manufacturers using desulphogypsum require the particle size of the recycled material to be more tightly controlled than those that whose main raw material is natural gypsum. Therefore, there is an indication

that it is not possible to incorporate as much recycled gypsum where desulphogypsum is used as the main feedstock.

The main potential source of recyclable gypsum is the construction and demolition industry. However, despite the large arisings, the difficulties in managing potential contamination mean that demolition waste is seen as a less desirable source. Plasterboard wastes from construction particularly suited to recycling are:

- over-ordered material
- segregated off-cuts

Barriers to increasing the segregation of gypsum in construction waste include practical and economic factors, whilst the present lack of a clear legislative environmental driver to reduce the quantities being landfilled is also key.

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1 Introduction

1.1 Purpose of this Report

This work was carried out for WRAP (the Waste & Resources Action Programme) in order to provide background information and examine the options for increasing the recycling of gypsum, and its main product plasterboard, in the UK.

The report identifies (and quantifies and projects where possible):

- The UK materials flow for gypsum
- Sources of the gypsum used in the UK
- UK uses of gypsum
- UK waste management practice, including recycling
- Barriers to change.

The report has the following outline structure:

Table 2 Outline structure of report and chapter hyperlinks

Subject	Section (and hyperlink)
Introduction	1
UK Sources of gypsum	2
UK Uses of gypsum	3
The plasterboard industry	4
UK Waste management of gypsum and plasterboard	5
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1.2 What is Gypsum?

Gypsum is a very soft mineral composed of calcium sulphate dihydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$.

1.2.1 Chemical structure

Heating gypsum to between 100°C and 150°C partially dehydrates the mineral by driving off 75% of the water contained in its chemical structure. The temperature and time needed depends on ambient partial pressure of H_2O. Temperatures as high as 170°C are used in industrial calcination, but at these temperatures anhydrite begins to be formed. The reaction for the partial dehydration is:

$CaSO_4 \cdot 2H_2O$ + heat = $CaSO_4 \cdot ½H_2O$ + $1½H_2O$ (steam)

The partially dehydrated mineral is called calcium sulphate hemihydrate or calcined gypsum (commonly known as Plaster of Paris, $CaSO_4 \cdot ½H_2O$).

The dehydration (specifically known as calcination) begins at approximately 80°C, although in dry air some dehydration will take place at 50°C. The heat energy delivered to the gypsum at this time (the heat of hydration) tends to go into driving off water (as water vapour) rather than increasing the temperature of the mineral, which rises slowly until the water is gone then increases more rapidly.

The endothermic property of this reaction is exploited by plasterboard to confer fire resistance on residential and other structures. In a fire the structure behind a sheet of plasterboard will remain relatively cool as water is lost from the gypsum, thus preventing (or substantially retarding) damage to the framing (through combustion of wood members or loss of strength of steel at high temperatures) and consequent structural collapse.

In contrast to most minerals, which when re-hydrated simply form liquid or semi-liquid pastes, or remain powdery, calcined gypsum has an unusual property: when mixed with water at normal (ambient) temperatures, it

quickly reverts chemically to the preferred dihydrate form, while physically "setting" to form a rigid and relatively strong gypsum crystal lattice:

$CaSO_4 \cdot ½H_2O + 1½H_2O = CaSO_4 \cdot 2H_2O$ (This reaction is exothermic)

This phenomenon is responsible for the ease with which gypsum can be cast into various shapes including sheets (for plasterboard), sticks (for blackboard chalk), and moulds (to immobilize broken bones, or for metal casting). Mixed with polymers, it has been used as a bone repair cement. Small amounts of calcined gypsum are added to earth to create strong structures directly from cast earth, an alternative to adobe (which loses its strength when wet). The conditions of dehydration can be changed to adjust the porosity of the hemihydrate, resulting in the so-called alpha and beta hemihydrates (which are more or less chemically identical).

The anhydrous form, called anhydrous calcium sulphate (sometimes anhydrite), is produced by further heating to above approximately 180°C and has the chemical formula $CaSO_4$. Anhydrite reacts slowly with water to return to the dihydrated state.

1.3 Occurrence

Gypsum occurs in nature as flattened and often twinned crystals and transparent cleavable masses called selenite. It may also occur silky and fibrous, in which case it is commonly called satin spar. Finally it may also be granular or quite compact. In hand-sized samples, it can be anywhere from transparent to opaque. A very fine-grained white or lightly-tinted variety of gypsum is called alabaster, which is prized for ornamental work of various sorts. In arid areas, gypsum can occur in a flower-like form typically opaque with embedded sand grains called desert rose.

Gypsum is a very common mineral, with thick and extensive evaporite beds in association with sedimentary rocks. The largest deposits known occur in strata from the Permian age. Gypsum is deposited in lake and seawater, as well as in hot springs, from volcanic vapours, and sulphate solutions in veins. Hydrothermal anhydrite in veins is commonly hydrated to gypsum by groundwater in near surface exposures. It is often associated with the minerals halite and sulphur.

The word gypsum is derived from the aorist form of the Greek verb μαγειρεύω, "to cook", referring to the burnt or calcined mineral. Because the gypsum from the quarries of the Montmartre district of Paris has long furnished calcined gypsum used for various purposes, this material has been called “Plaster of Paris”.

Commercial quantities of gypsum are found in Germany, Italy, England, Spain Canada, Australia and in the United States.

A growing source of gypsum is from flue gas desulphurisation, which scrubs the sulphur emissions from fossil fuel burning power stations and other combustion plants. This involves the addition of limestone, which reacts with the sulphur dioxide to produce high purity gypsum as a by-product.

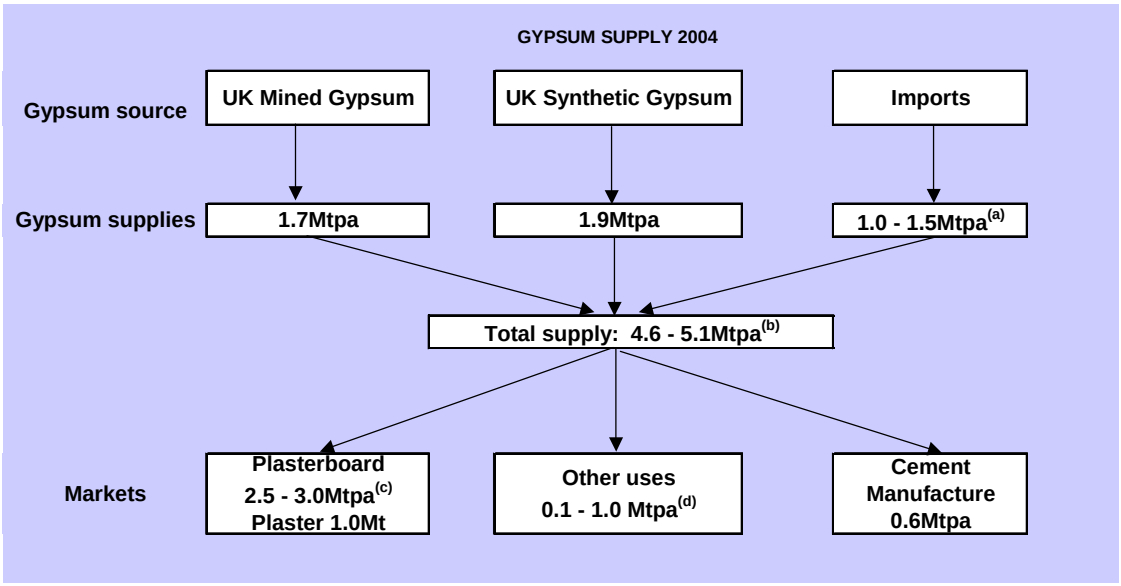
Global consumption of gypsum in all its forms was estimated at 149 Mt in 2003. The main global market for natural gypsum is as a retarder in Portland cement, especially in industrialising economies where production of calcined gypsum products is much smaller than the developed economies. Globally, in 2003, cement production consumed an estimated 76 Mt of gypsum. Plasterboard and plaster production was estimated to have accounted for 58.5 Mt, and the other main market for gypsum was in agriculture, where an estimated 6.5 Mt was used. Globally, cement is expected continue to be the main market for gypsum, despite the recent increases in plasterboard capacity in North America, Europe and Asia. Over the next five years consumption of desulphogypsum is expected rise at a faster rate than most other forms of gypsum. [1]

As the supply of gypsum in developed economies grows, the recycling of gypsum waste generally becomes more common. An estimated 4 Mtpa of waste in the USA is recycled, and increasingly significant amounts are recovered in the EU and Japan. [2]

1.4 Summary of UK Materials Flow for Gypsum

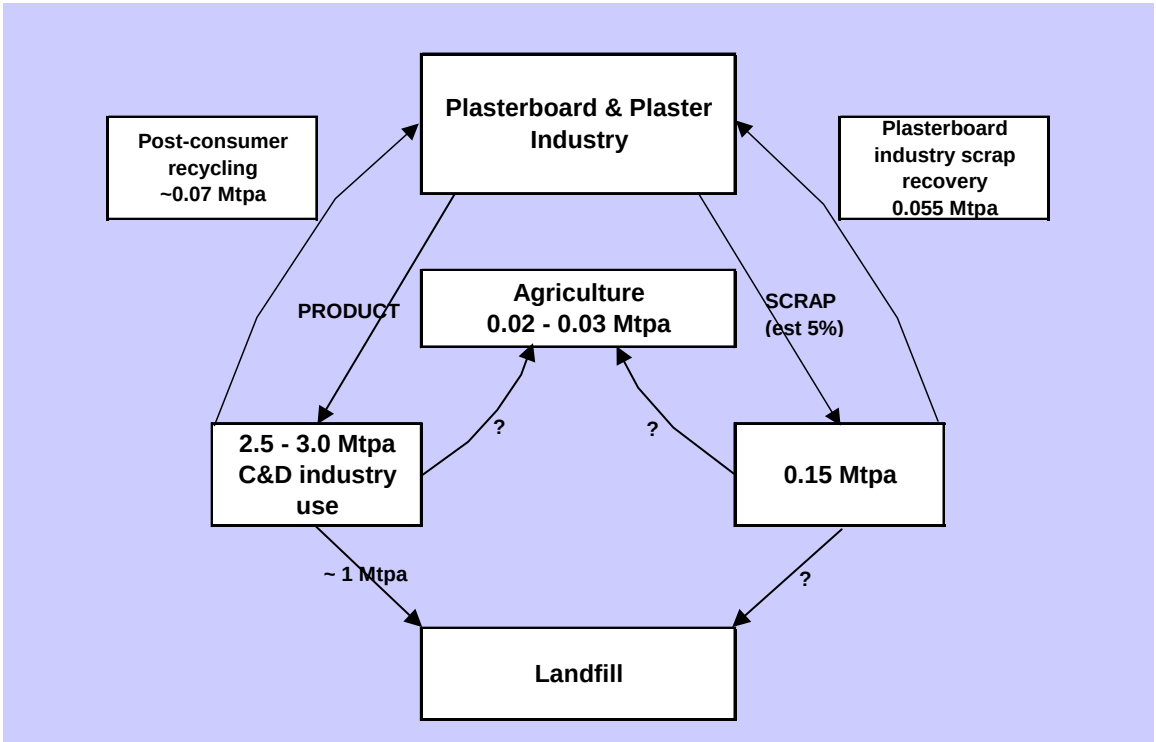
The diagrams below provide an overview of the main materials flows for gypsum in the UK.

Figure 1 Calculated UK Gypsum supply materials flow (2004)



Notes to figure 1:
a) An estimated 1.3 Mtpa of natural and synthetic gypsum are imported. Error of 20% has been allowed for data deficiencies.
b) Total varies dependent on import figure.
c) Industry figures reported plasterboard production at 300 Mm^2 per annum equating to 2.5 Mtpa of gypsum usage on an assumption of 9 kg/m^2 and 95% gypsum content. National statistics reported plasterboard consumption at 3.0 Mtpa.
d) Estimated quantity of gypsum not used in main markets.

Figure 2 Calculated UK materials flow for gypsum waste and recycling (2004)



2 UK Sources of Gypsum

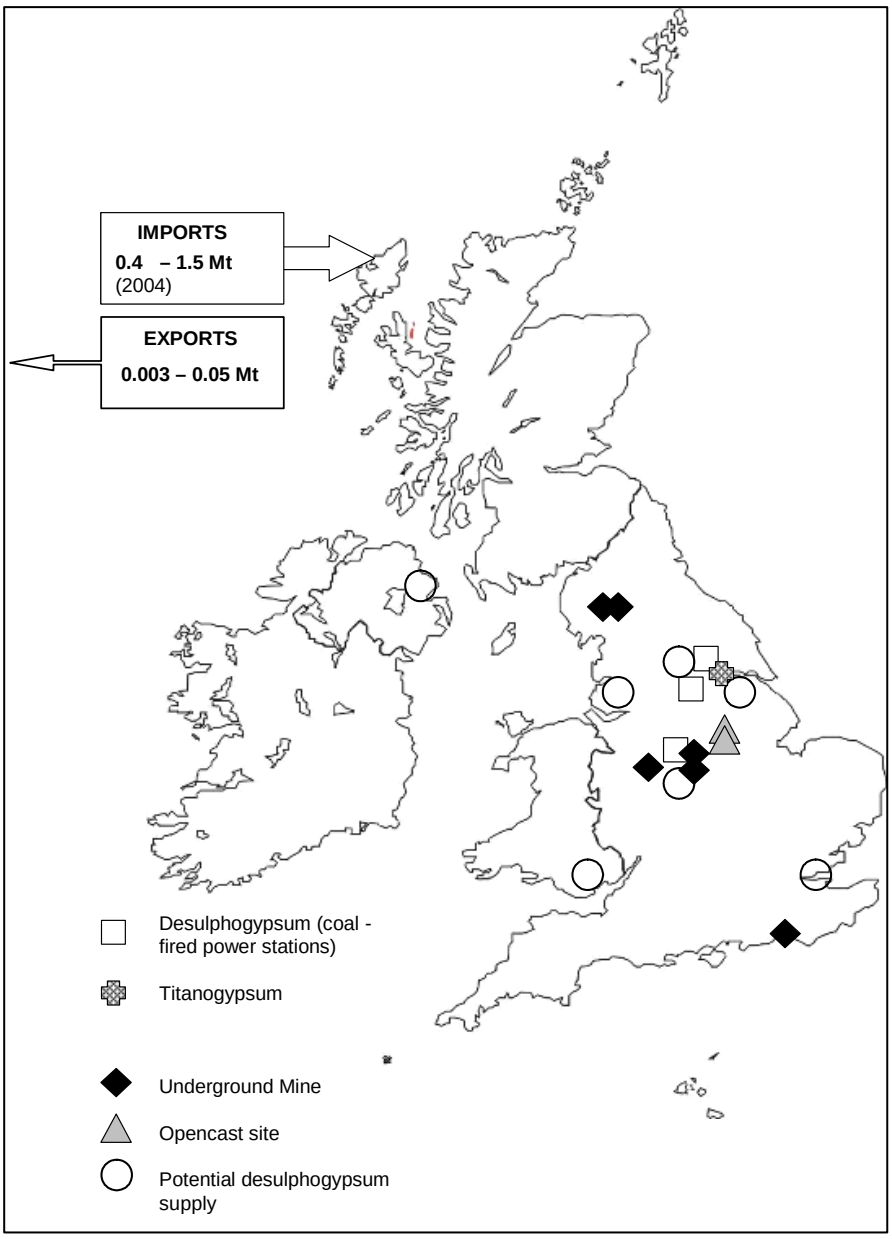
2.1 Overview of UK Sources

The gypsum used within the UK arises from three sources:

- Natural gypsum - mainly from underground mining
- Synthetic gypsum – a by-product of production processes
- Import of both natural and synthetic gypsum.

The diagram below summarises the main UK sources of gypsum. It includes mines, and the main current and potential synthetic supplies.

Figure 3 UK Gypsum Production sites, imports and exports



2.2 Mining of Natural Gypsum

2.2.1 General description of UK activity

British Gypsum Ltd is the only company mining natural gypsum in the UK. They have 6 underground mines and 1 opencast mine, the largest being in Leicestershire and East Sussex.

2.2.2 Quantification of UK activity

From 1999 to 2003 imports of gypsum and plaster (combined) are reported to have risen from an estimated 0.42 Mtpa to approximately 0.9 Mtpa (a figure of up to 1.5 Mtpa is calculated from company reported information). By comparison, exports for the period were generally in the order of 0.05 Mtpa, and mainly comprised plasters. [3]

Exact figures for the quantity of natural gypsum mined in the UK were not provided, although it is estimated to be in the order of 1.7 Mtpa. The table below shows the change in hectares used for mining gypsum.

Table 3 Area of underground mining and pithead in 1994 and 2000

	Underground mining			Areas of pithead		
	Area in 1994 (ha)	Area in 2000 (ha)	Change in area (ha)	Area in 1994 (ha)	Area in 2000 (ha)	Change in area (ha)
Gypsum/Anhydrite	38,215	14,894	-23,321 (61%)	117	125	+8

The data indicates a decrease in hectares of underground gypsum mines by 61% between 1994 and 2000. This may indicate a reduction of natural gypsum being mined within the UK over the period. This is likely to be due to the increased use of desulphogypsum in place of mined material in the plasterboard industry.

The table below provides information concerning UK gypsum reserves:

Table 4 UK gypsum reserves

Site name	Location	Reserves (Mt)	Reference source
Barrow Mine	East Leake, Loughborough Leicestershire LE12 6HX	18-19	BGS Mineral Planning Factsheet. Nottingham council website
Marblaegis Mine	Nottinghamshire	4	BGS Mineral Planning Factsheet
Faul Mine	Staffordshire	4	BGS Mineral Planning Factsheet
Newbiggin	Kirkby Thore	Not known	BGS Mineral Planning Factsheet
Birkshead	Kirkby Thore	6	BGS Mineral Planning Factsheet
Brightling	East Sussex	15-20	BGS Mineral Planning Factsheet. East Sussex and Brighton & Hove Mineral Local Plan
Kilvington Quarry	Newark	10 (only half of this has planning permission for extraction)	BGS Mineral Planning Factsheet. Nottingham Council website
Bantycock Quarry	Newark	Predicted stores until 2015	Nottingham Council Website
Total		**> 57**	

The data in the above table is incomplete and therefore does not allow for an accurate summation of total UK gypsum reserves. However, it may be stated that these are in excess of 57 M tonnes. At current mining (1.7 Mtpa) and consumption rates, it is estimated that UK reserves are sufficient for in excess of 30 years. It should however be noted that this report predicts an increase in annual demand for gypsum in the order of 2 M tonnes. It is probable that this demand would not be met solely from UK mined gypsum but it can be expected to increase pressure on UK reserves.

2.3 Synthetic Gypsum

2.3.1 Types of synthetic gypsum

A growing source of gypsum within the UK is synthetic gypsum. There are three main types of synthetic gypsum:

Desulphogypsum (DSG) – is formed by the removal of sulphur dioxide from the flue gases of coal-fired power stations using Flue Gas Desulphurisation (FGD). Finely ground limestone reacts with released sulphur in flue gas cleaning equipment, creating gypsum. It is possible for desulphogypsum to have purity levels of 96%, compared with 80% for natural gypsum sourced within the UK. FGD equipment can also be fitted to cement kilns, or other combustion processes.

Current UK production of desulphogypsum is approximately 1.4 Mtpa. (See Table 5 for details of UK production sites)

Titanogypsum – is a by-product from the manufacture of titanium dioxide. Huntsman Tioxide Ltd at Grimsby produces Titanogypsum, which is used in the plasterboard industry. (See table 7 below for details)

Current UK production of titanogypsum is approximately 0.48 Mtpa.

Fluorogypsum – is a by-product from the manufacture of hydrofluoric acid from fluorspar and sulphuric acid, which is used in many industries, for example in the manufacture of products containing fluorine organic compounds such as teflon and refrigerants.

Current UK production of fluorogypsum is approximately 0.04 Mtpa.

Gypsum is also produced as a waste product from the manufacture of salt during the brine purification process. This is only true for those salt manufacturers that utilize sulphate rich streams for the evaporation process. No figures on the quantity of gypsum produced in this process could be obtained. It is understood that the gypsum is mixed with other compounds from the purification process and disposed of to a brine cavity[4].

2.3.2 Current and future UK activity

Synthetic gypsum (desulphogypsum) is produced at three UK coal-fired power stations:

- Drax (Drax Power Ltd), N. Yorkshire
- Ratcliffe-on-Soar (Powergen) Nottinghamshire
- West Burton (EDF) Nottinghamshire

It is reported that British Gypsum owns exclusive rights to buy this product from all three locations.

Several more coal-fired power stations are reported to be planning to fit flue gas desulphurisation plant, including Eggborough, Cottam and Rugeley and will potentially be producers of desulphogypsum in the future.

Details of current and possible future UK desulphogypsum arisings are given in the 3 tables below. The tables show that:

- Current UK desulphogypsum production is approximately 1.4 Mtpa
- Potential additional UK desulphogypsum production is approximately 1.1 Mtpa (i.e. total 2.5 Mtpa)
- UK Titanogypsum production is approximately 0.48 Mtpa

Table 5 Current UK desulphogypsum production at large combustion plants

Name	Location	User of Gypsum	Power plant capacity	Gypsum arisings	Comments	References
Drax Power Ltd	AES Drax Power Station PO BOX 3, Selby, North Yorkshire, YO8 8PJ	All the gypsum is sold under a contract with British Gypsum and is used for making plasterboard and related products	4 GW	0.65 Mt (2004)	Any gypsum that is produced below specification is mixed with pulverised fuel ash and disposed of under license at Barlow Mound	BGS Mineral Planning Factsheet. DRAX Website. Yorkshire and Humber Assembly, Coal: The Future
EDF Energy, West Burton	Retford, Nottinghamshire, DN22 9BL	All the gypsum is sold under a contract with British Gypsum and is used for making plasterboard and related products	2.0 GW	0.4 Mt (2004)		BGS Mineral Planning Factsheet. Environment Agency. Yorkshire and Humber Assembly, Coal: The Future
E.ON, Ratcliffe-on-Soar	Ratcliffe-on-Soar, Nottingham, NG11 OEE	All of which is sold on for the manufacture of gypsum based products	2.0 GW	0.35 Mt (2004)		BGS Mineral Planning Factsheet. EON Website. Yorkshire and Humber Assembly, Coal: The Future
Total current UK desulphogypsum production = 1.4 Mtpa						

Table 6 Potential Desulphogypsum production capacity at UK Large Combustion Plants

Name	Location	Project status	Installation size	FGD capacity and estimated gypsum arisings (see note a below)	References
RWE Npower, Fifoots Point	South Wales	FGD yet plant in administration, potential to reopen in winter months 100% FGD as a percentage of plant capacity	0.4 GW	FGD: 0.4 GW Gypsum ~0.068 Mtpa	Welsh Assembly Government, Energy Wales. Yorkshire and Humber Assembly, Coal: The Future
Scottish and Southern Energy's, Fiddler's Ferry Power Station	Widnes Road, Cuerdley Warrington, Cheshire, WA5 2UT	FGD S36 Consent granted	2.0 GW	FGD: 0.5 GW Gypsum ~0.085 Mtpa	Yorkshire and Humber Assembly, Coal: The Future. Global Gypsum Magazine, June-July
RWE Npower, Aberthaw Power Station	The Leys, Barry, South Glamorgan, CF62 4ZW	Applied for consent, favoured position on grid	1.5 GW	FGD: 1.5 GW Gypsum ~0.255 Mtpa	Innogy, Aberthaw Power Station, proposed FGD plant. Yorkshire and Humber Assembly, Coal: The Future
British Energy, Eggborough	Eggborough, Goole, North Humberside, DN14 OUZ	FGD under construction	2.0 GW	FGD: 1.0 GW Gypsum ~0.17 Mtpa	Yorkshire and Humber Assembly, Coal: The Future. Environment Agency
EDF Energy, Cottam	PO BOX 4, Retford, Nottinghamshire, DN22 OEU	Under construction, further 1 GW under consideration 100 % FGD by the end of 2007	2.0 GW	FGD: 2.0 GW Gypsum ~0.34 Mtpa	Yorkshire and Humber Assembly, Coal: The Future. Environment Agency
International Power, Rugeley	Armitage Road, Rugeley, Staffordshire, WS15 1PF	FGD applied for consent under S3, considered unlikely	1.0 GW	FGD: 1.0 GW Gypsum ~0.17 Mtpa	Yorkshire and Humber Assembly, Coal: The Future. Coal Research Forum
Additional desulphogypsum supply if further FGD equipment installed: 1.1 Mtpa					

Note a) Additional desulphogypsum supply was calculated using existing plant data showing that each 1 GW of FGD applied capacity produces approximately 0.17 Mtpa of gypsum. This figure should be viewed with caution due to varying technology and fuel used.
Not all plants plan to use FGD for the entire installation capacity e.g. Fiddlers Ferry.

Table 7 Other current UK synthetic gypsum production

Name	Location	User of Gypsum	Annual arisings	Utilisation	Comments	References
Desulphogypsum (from cement process)						
Castle Cement Limited	Ribblesdale Works, Clitheroe, Lancashire. BB7 4QF	The gypsum is put into the cement making process mixed with natural gypsum	No data	No data	Other plants in Ketton, Rutland & Padeswood, Flintshire	Castle Cement Website
Total = Unknown						
Titanogypsum						
Huntsmans Tioxide Ltd	Titanium Dioxide Manufacturing Tioxide Europe Ltd, Moody Lane, Grimsby, N.E. Lincolnshire. DN31 25W. Tel. 01472 355335	Supplied to Knauf at Immingham for plasterboard manufacture and for local landspreading	0.48 Mtpa	Majority utilised, approx. 0.05 Mtpa to landfill		Roskill Report. Huntsman Environment, Health and Safety Report
Titanogypsum Production = 0.48 Mtpa						
Fluorogypsum						
INEOS Fluor	The Heath, Runcorn, Cheshire. WA7 4QX	Used in cement and floor screed	0.04 Mtpa	No data		Roskill Report
Fluorogypsum Production = 0.04 Mtpa						
Note: Rhodia, Avonmouth may also produce some fluorogypsum but this was not confirmed.						

2.3.3 Drivers for desulphogypsum production

The production of desulphogypsum results from the use of lime and limestone in flue gas desulphurisation (FGD) equipment at combustion plants. The additional capital and revenue costs of installing and operating FGD mean that combustion plants only use such equipment when required to do so. Obligations are generally legislative, and arise where:

- Fuels contaminant levels are high (e.g. sulphur in coal)
- Required emission limit values are low

The following legislation describes the restrictions currently in place on emissions and air quality that impact on the coal-burning industry, the primary source of desulphogypsum. The current net effect of these drivers can be seen in Table 6.

The Revised EC Large Combustion Plants Directive (2001/80/EC)

The Directive requires a reduction in total Sulphur Dioxide emissions from existing combustion installations, which have an annual thermal input of over 50 megawatts. The revised directive takes into account the advances in combustion and abatement technologies that exist[5]. The Directive was transposed into UK law as:

- The Large Combustion Plants (England and Wales) Regulations 2002
- The Large Combustion Plant (Control of Emissions) (Scotland) Regulations 1991

The Integrated Pollution Prevention and Control (IPPC) Directive (EC/96/61)

Implemented in the UK primarily by the Pollution Prevention and Control (England and Wales) Regulation 2000. The Pollution Prevention and Control (PPC) regulation controls pollution from certain industrial activities (including large combustion plants). Permits are required for such installations to operate and emission limit values set based upon the concept of Best Available Techniques (BAT). Guidance on BAT is given in European and UK guidance.

In general it may be expected for the BAT requirement to result in greater use of FGD in the UK, and thus greater arisings of DSG.

Ambient Air Quality Assessment [1999/30/EC]

This directive contains threshold values for a number of air pollutants including sulphur dioxide. For this pollutant the directive states that necessary measures must be taken to ensure defined ambient concentrations do not exceed the limits.

The United Nations Economic Commission (UNECE) for Europe's Second Sulphur Protocol

The following targets have been set in this protocol, using a baseline of 1980:

- 50% SO2 reduction by 2000
- 70% SO2 reduction by 2005
- 80% SO2 reduction by 2010

A target of 75% had already been reached by 2000. The remaining portion is thought to consist largely of power station emissions.

EU National Emissions Ceiling Directive 2001/81/EC (EU NECD)

The directive sets an upper limit on production of sulphur dioxide, with the aim of reducing acidification[6].

The UK Climate Change Programme and UK Energy Policy

The climate change programme aims to reduce UK green house gas emissions. A trading scheme is being implemented to achieve the UK reduction targets. The currently reported renewed interest in nuclear generation in the UK could result in a decrease in desulphogypsum production as electricity generation shifted away from coal.

2.4 Imported Sources of Gypsum

Gypsum is being imported into the UK in increasing amounts since the 1980s. The main supplies are from Germany and Spain. As described in section 2.2.2, from 1999 to 2003 imports of gypsum and plaster (combined) rose from an estimated 0.42 Mtpa to approximately 0.9 Mtpa.

The main consumers of imported gypsum are the plasterboard and plaster products industries. Lafarge currently imports mainly natural gypsum from Spain, while Knauf imports mainly desulphogypsum from Europe, principally Germany – where there are significant arisings owing to high use of flue gas desulphurisation technology.

The table below provides data for imports of gypsum to the UK. It is not clear from the source information whether the figures quoted (1997 – 2003) relate only to mined gypsum imported, or whether they include imported desulphogypsum. Discussions with the industry concerning their importation activities lead to the higher figure calculated for 2004.

Table 8 UK gypsum import data 1997 – 2004

Year	Quantity (tpa)	Reference
1997	528,921	Roskill Report
1998	331,785	Roskill Report
1999	403,470	Roskill Report
2000	497,402	Roskill Report
2001	484,170	Roskill Report
2002	235,572	Roskill Report
2003	56,228 (note a)	Roskill Report
2004	1,300,000 (note b)	Estimated imports
Average Imports = 480,000 tpa		

a) the source indicated that this figure may be falsely low
b) the 2004 figure is derived from reports that Lafarge and Knauf rely almost exclusively upon imported gypsum, and that their combined UK market share is approximately 50%. However, Knauf import DSG not mined gypsum. It is not clear whether the Roskill figures relate to imports of mined gypsum only or include DSG imports.

3 UK Uses of Gypsum

3.1 Overview of Uses

Gypsum is the hydrated form of calcium sulphate. It is economically more important than the anhydrous form, known as anhydrite. Possible applications of gypsum depend on the origin of the material. UK gypsum originates from three main sources:

- Mining of natural gypsum in the UK;
- Production of synthetic gypsum (an industrial by-product or waste material, mainly "desulphogypsum" from flue gas desulphurisation equipment);
- Import of both natural and synthetic gypsum.

The table below shows UK consumption of gypsum from each of the main UK sources in 2002 and 2004:

Table 9 Estimated UK gypsum consumption in 2002[1] and 2004

Origin	Mass in Mt 2002	Mass in Mt 2004
Natural gypsum (UK mined)	1.7	1.7
Synthetic gypsum (UK produced)	0.8 - 1.2	1.9
Net imports	0.6 - 0.8	1.0 –1.5
Totals	**3.1 - 3.7**	**4.6 – 5.1**

The most significant use of gypsum in the UK is for plaster products and plasterboard for use in the construction industry.

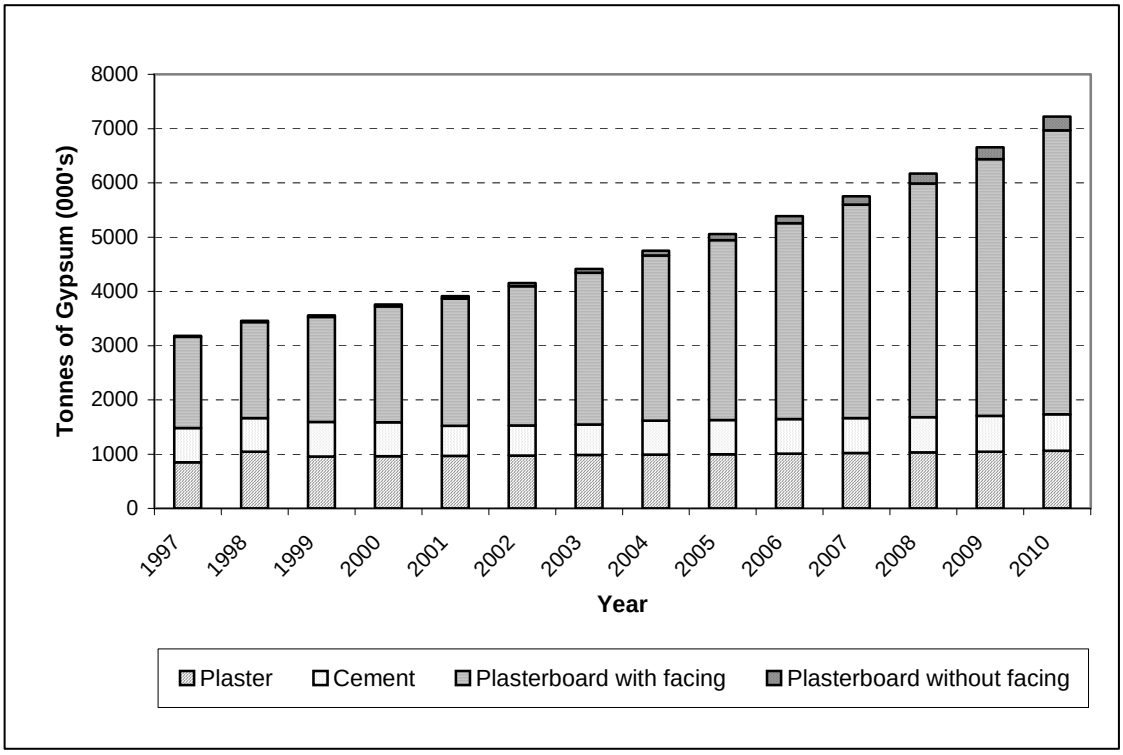
It is reported that, in the UK, synthetic rather than natural gypsum is more widely used to manufacture plasterboard[7]. In 2002 1.8Mt of gypsum was supplied for use in plasterboard manufacture. Gypsum plasterboard is increasingly used in the construction of new buildings rather than plastering walls and ceilings. Plasterboard has a number of beneficial properties, which include; fire resistance, sound and heat insulation properties, durability and ease of use. Detailed information on the plasterboard industry is provided in Chapter 4.

Natural gypsum contains clays making it particularly suitable for the manufacture of building plasters, since they increase the malleability of the plaster. In the UK approximately 1.0 Mt of gypsum was used in plaster production in 2004.

Use in cement manufacture is also significant, and globally is the most significant user. The UK cement industry uses approximately 0.6 Mtpa of gypsum in the manufacture of 12.5 Mtpa of cement.

The figure below provides a projection for the use of gypsum in construction products:

Figure 4 Projected UK use of gypsum in construction products[8]



The above projection uses UK housing growth rates to predict gypsum consumption levels in a variety of relevant construction products. It can be seen that projected growth is significant. From 2005 to 2010 the construction market is predicted to consume an additional 2 Mtpa, resulting in a demand for gypsum of over 7 Mtpa. This represents an increase over the period of 20 %.

3.2 The Plaster Products Industry

3.2.1 The plaster production process

The following[9] provides an example of a current UK plaster production process. The details of the production process will differ to some degree from manufacturer to manufacturer and from plant to plant.

Raw gypsum ($CaSO_4.2H_2O$), whether it is a natural mined gypsum or synthetic desulphogypsum, is delivered to site where it is first ground to the required particle size and dried to remove the vast majority of its free moisture. The dried, ground gypsum is then fed into a calciner, or kettle, where it is heated to a temperature of around 175°C. This will remove ¾ of the gypsum's chemical, or bound water, and transforms the gypsum into stucco ($CaSO_4.½H_2O$).

Once cooled, this stucco is ready to be used in plasterboards, plasters and gypsum based jointing compounds.

The stucco and other minor additives are transported via screw conveyors to a series of weigh scales, where the required amounts of the individual components are metered out according to a specific formulation. Once all the ingredients have been weighed out correctly, the batch of powder is transferred into a batch mixer, where all of the ingredients are combined together to produce the final product.

The product is then bagged off using an automatic bag filling system, stacked onto pallets, and then either placed in the warehouse, or loaded onto trucks for distribution.

3.2.2 Use of plaster

The main use of plaster is as a building material where it is used as a finish, typically over brickwork. Thickness varies from around 12mm as a base coat or 2mm as a final skim finish. Plaster starts as a dry powder that is

mixed with water to form a paste, which then hardens. Plaster may also be used to create complex detailing for use in room interiors.

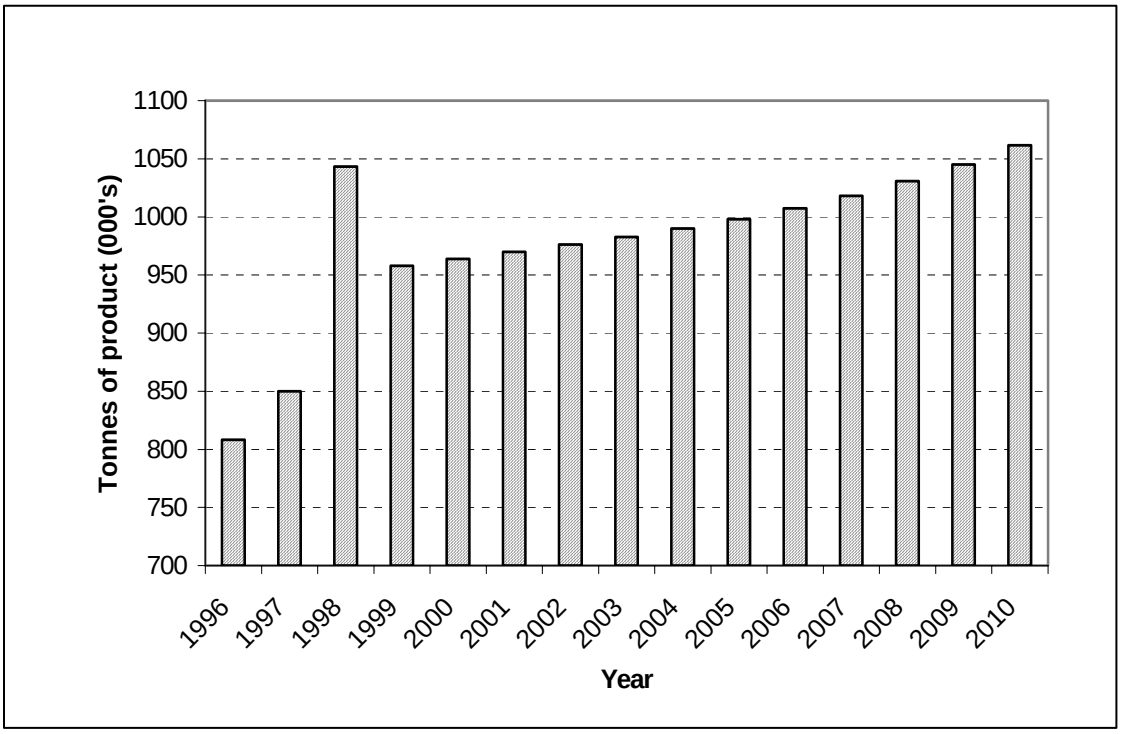
Plaster expands while hardening, and then contracts slightly just before hardening completely. This makes plaster excellent for use in moulds, and it is often used as an artistic material for casting. Plaster is also commonly spread over an armature (form), usually made of wire, mesh or other materials. In medicine, it is also widely used as a support for broken bones.

In 2002 approximately 1.0 Mt of gypsum was used in plaster production[10].

3.2.3 Projected UK gypsum use for plaster

The graph below provides projections for the use plaster in the UK market. The projection is based upon predicted household growth[11].

Figure 5 UK predictions for gypsum use in plaster



It can be seen that the trend is one of slight growth. The quantity of gypsum supplied as plaster increases by around 10% from just under 1 Mtpa to close to 1.1 Mtpa from 2004 to 2010.

3.3 The Cement Industry

3.3.1 Introduction

The UK cement industry currently supplies 90% of the UK market.

The cement industry uses approximately 0.6M tonnes[12] of gypsum per year for the production of a total of 12.5 M tonnes of cement per year. There are four main manufacturers:

- Lafarge Cement
- Castle Cement
- Cemex UK Cement (formerly Rugby Cement)
- Buxton Lime Industries

There are a total of 15 major plants operating in the UK. The plants are distributed across the UK, with 11 plants in England, 2 in Wales, and one each in Scotland and Northern Ireland.

3.3.2 The cement production process

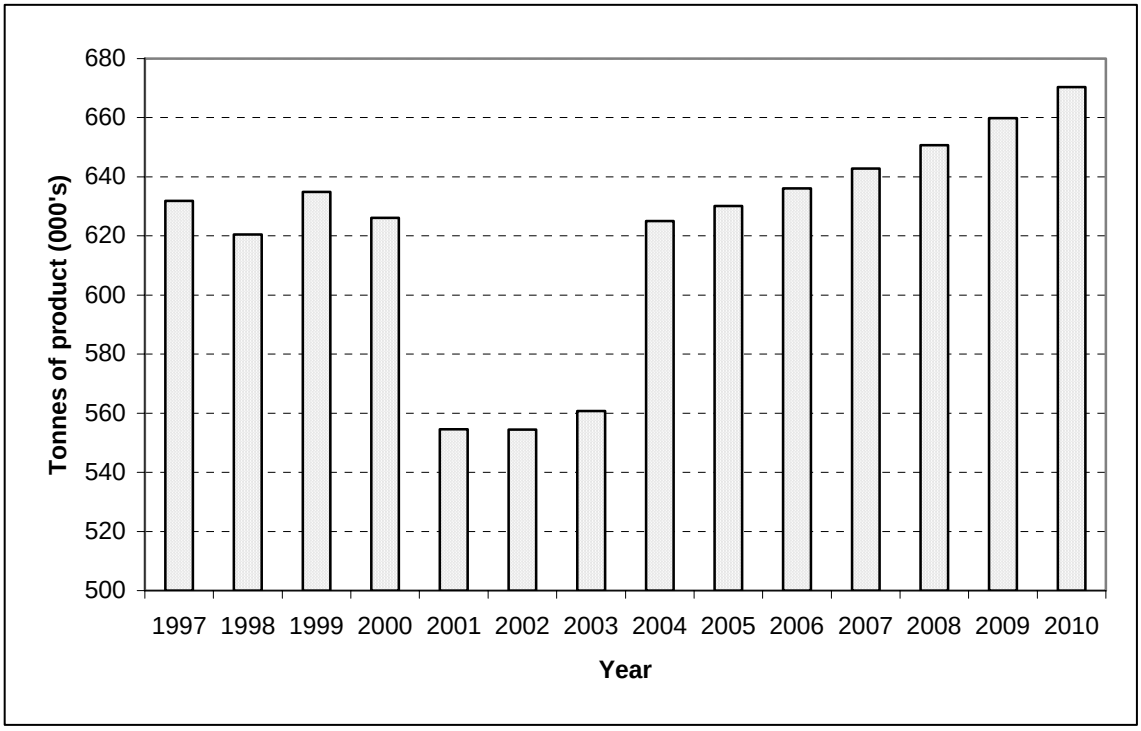
Cement production involves the burning of limestone or chalk with finely ground clay or sand in a kiln to produce clinker. Gypsum is added to the clinker to control the rate at which the cement sets and to strengthen the final product. The end product contains 5% gypsum.

Both natural gypsum and desulphogypsum are used in this process, as well as gypsum from old moulds used in the Potteries in Staffordshire.[13].

3.3.3 Projections for gypsum use in the cement industry

The graph below provides projections for the use gypsum in cement in the UK market. The projection is based upon predicted household growth[14] and recent trends in the plasterboard industry[15].

Figure 6 Predicted UK use of gypsum in cement



It can be seen that the trend is one of steady growth. The quantity of gypsum supplied for cement manufacture increases by 8% from approximately 0.63Mtpa in 2005 to 0.68 Mtpa by 2010. However, the British Cement Association do not currently predict a change in the UK cement market in the near future.

3.4 Agricultural Sector

3.4.1 Introduction

Gypsum is used in the agricultural sector as a soil conditioner, especially for heavy clay soils. It also adds sulphur and calcium and has a catalytic effect maximising fertilizer utilization. Gypsum can reduce the harmful effects of sodium salts.

Environmental considerations mean that levels of contaminants are key issues for all land spreading applications, particularly when wastes, by-products or recycled materials are used.

Traditionally, virgin natural gypsum has been used for agricultural uses. However, in recent years the cost of this material to farmers has increased, encouraging them to seek alternatives.

Titanogypsum and desulphogypsum are also used for agricultural soil conditioning. These are considered to be less contaminated than phosphogypsum and therefore preferable.

It has been reported that a small number of farms in the UK have been using ground waste plasterboard from construction, refurbishment and demolition sites, although in the absence of any published studies on aspects such as the environmental impacts or optimum application rates. Research and robust trials to evaluate the environmental and economic factors would be beneficial in supporting the use of recycled gypsum from waste plasterboard in agricultural applications.

3.4.2 Legislative restrictions on land spreading

In line with UK and European legislation, in general the deposit of wastes on land requires the activity to have an authorisation. In England and Wales waste management licences are issued by the Environment Agency, in Scotland this is carried out by SEPA. However for certain activities with a lower pollution potential exemptions from the requirement to have a full licence are permitted, in favour of a "registered exemption". This system requires that the activity be carried out in an environmentally sound way. Such exemptions may be issued for certain agricultural activities provided certain conditions are met (see 5.1.2 for further details of waste management legislation).

Other legislation:

In addition to the above, the following pieces of legislation are already or may in the future have an impact on the amount of gypsum used within this sector.

Towards a Thematic Strategy for Soil Protection [COM (2002) 179]

One of the objectives for the Sixth EU Environmental Action Programme is the protection of soils against the eight threats to soils identified by the European commission. This thematic strategy is working towards producing comprehensive policy into the protection of soil[16].

The Common Agricultural Policy Single Payment Scheme (set-aside) (England) Regulations 2004

This regulation came into force on the 15th January 2005 and only applies in England. It concerns the application of fertiliser, waste, lime and gypsum to the land set-aside from production. Gypsum can only be applied to land set-aside from production only in accordance with the following:

- "A farmer may apply fertilisers to the land set-aside from production if prior to such application he satisfies the Secretary of State that the land is situated in an area known to be used as a feeding area by geese in winter and is to be managed as such an area
- Throughout the set-aside period a farmer may apply organic waste to the land set aside from production provided that it -
  (a) is applied only where there is an existing green cover on the set-aside land;

  (b) is applied in amounts which will not destroy that green cover; and

  (c) in the case of manure and slurry, is not applied -

    (i) within 10 metres of any watercourse; or
    (ii) within 50 metres of any boreholes.

- A farmer may apply lime or gypsum to the land set aside from production where that land is to be cropped in the following year"[17]

3.4.3 Quantities of gypsum used and projections

Landspreading

During the past 2-3 years the price of gypsum has increased and farmers have sought to use alternatives for soil conditioning. The price per tonne has increased from £12-13 per tonne 5 years ago to £39-40 per tonne currently[18]. Velcourt, the largest farm management company in the UK, reported that the price increase means

that they now use lime instead of gypsum. The company previously used gypsum by-product from the building trade.

The National Farmers Union (NFU) was unable to provide any figures for the tonnage of gypsum and plasterboard used in agriculture annually in the UK.

ADAS stated that they spread between 20 - 30 ktpa of plasterboard on land for agricultural or ecological improvement purposes[19]. Their waste management arm collects waste plasterboard, mainly from construction and demolition operations. In future they are looking to spread 50 ktpa of plasterboard waste on land.

Fertilisers

Gypsum is also used as a raw material in the manufacture of artificial fertilisers (ammonium sulphate). In fertilisers the gypsum is a source of sulphur and acts as a filler.

In 2003/4 1.8 Mt of fertiliser nutrients (nitrogen, phosphate and potash) were consumed in the UK. The Agricultural Industries Confederation (AIC) stated that less than 8920 tonnes (0.5%) of this total would represent the annual tonnage of gypsum used in fertilisers in the UK[20]. The low percentage use is reported to be due to gypsum being difficult to spread evenly[21].

Others

Gypsum is also used in growing media (such as compost), and as a bulking and enriching agent adding sulphur and calcium and reducing the harmful effects of sodium salts. It is also reported that there will be an increase in the use of gypsum as use of peat substitutes in growing media increases[22].

3.5 Other uses

The gypsum uses described below are believed to be generally minor. In the majority of cases it has not been possible to quantify the use.

3.5.1 Food and drink industry

Gypsum is used in a number of different foods including tofu, flour, white bread, ice cream, blue cheese and in canned vegetables. It is also used in pet food.

A small amount of very pure gypsum is used in confectionary and as a processing aid for bakeries and pre-blends.

It is used to control the tartness and clarity of wine, as a clarifier in the brewing industry, and in sugar beet refining. Approximately 400 tonnes of gypsum are used annually in the UK in the brewing industry[23].

Changes in the following regulations could have implications for use of gypsum in the food industry:

Miscellaneous Food Additive Regulation 1995

Gypsum is part of additive E220, the additive is used within products such as; vinegar, wine, cordials, beer, soft drinks, dried fruit, juice and potato products. The maximum limits to the amount of SO_2 allowed in particular products are listed in schedule 2, part b of this legislation. Changes and amendments to this legislation may affect the quantities of gypsum used in this additive[24].

The Food Supplements (England) Regulations 2003

The regulation determines the substances that can be used as a source of vitamin/mineral in the manufacture of food supplements. There are currently 112 substances on this list; one of these is the use of calcium (gypsum is a potential source of calcium)[25].

3.5.2 High purity gypsum

High-purity natural gypsum is used to make special plasters, such as those used for dental and surgical work and for use in moulds in the pottery and metal casting industry[1].

13 Ktpa of gypsum is used in ceramic moulds. 12 Ktpa of gypsum ceramic moulds are recycled (94% of total used p.a.) into cement manufacture.

3.5.3 Road Building

The Highways Agency was unable to provide data for the tonnage of gypsum used in road building annually.

3.5.4 Floor paving applications

Lanxess (formerly Bayer) manufacture fluoric acid and produce gypsum as a by-product, which they use in floor paving applications. The company would not disclose the details of their operations for reasons of commercial confidentiality, although they stated that they do not market their gypsum product for the plasterboard industry[26].

3.5.5 Glass manufacture

Natural gypsum can be used as an oxidising and fining agent in the manufacture of container glass. Quantities used are unknown but believed to be low.

3.5.6 Paint, plastics and chemicals

Gypsum is used as a pigment mineral or filler in the paint industry.
The British Coating Federation, the Chemical Industries Association, and the Royal Society of Chemistry were all contacted directly but were unable to provide a figure for the annual tonnage of gypsum used in paint fillers.

3.5.7 Pharmaceuticals

Gypsum is used in toothpaste and in medicinal tablets as a filler, and also as a colour additive for drugs and cosmetics[27]

Toothpaste manufacturers were contacted but were unwilling to disclose the tonnage of gypsum used annually in their product for commercial confidentiality reasons.

3.5.8 Other UK applications

Gypsum is also reported to be used for:

- Gesso, a preparation of Plaster of Paris and glue used as a surface for painting.
- Settling dirt and clay particles in turbid water, particularly ponds, without injury to aquatic life.
- As cat litter, and as an oil absorbent.
- In blackboard chalk.

3.5.9 Other non-UK applications

The list below provides ideas of how recycled gypsum has come in useful in other countries:

- **Sludge Drying –** Research is being undertaken in New York involving the mixing of recycled gypsum with sludge for bulking and drying.
- **Water Treatment –** New York State is funding a study into whether recycled gypsum may help settle the dirt and clay particles in turbid water.
- **Salty Soil Treatment –** Spreading of salt during winter along the roadside restricts the flora that can grow, recycled gypsum can be used to leach out the sodium in the soils.
- **Manure Treatment –** To reduce smell, recycled gypsum can be added to animal wastes to reduce the ammonia odour. Similar tests within the United States have shown varied results.
- **Animal Bedding –** The paper fraction recovered from gypsum recycling has been used as a component of animal bedding.
- **Flea Powder –** 90% of the inert material in some flea powders is gypsum.

- **Grease Absorption –** Recycled gypsum can be sprinkled on work floor spaces to absorb grease.
- **Athletic Field Marker –** Used as a marker on sports fields[28].

3.5.10 Waste Exchanges

Waste exchanges allow the advertisement of materials that may be a waste to one but are a potential product to another. They offer a mechanism for the avoiding waste, and for both regular and novel users of materials (including gypsum) to obtain materials at competitive costs. Waste exchanges also permit requests for material to be posted.

The waste exchange databases are updated periodically. A review of the following active waste exchanges carried out in November 2005 showed some (but relatively few) examples relevant to plasterboard and gypsum:

Table 10 Examples of UK waste exchanges (Nov 2005)

Example	Description	Examples
Waste-Exchange	Lists materials that are available, wanted and for sale. The service provided on this website is free and confidential, it is supported by the Environment Agency Wales[29].	Plasterboard off cuts – 10 tonnes per week – Bridgend Limestone / Gypsum powder mixed – 15 tonnes every 30 days – Skelmersdale
Waste Exchange UK	A database allows businesses to access the material available and also a space to advertise the material they may be trying to dispose of[30].	Plasterboard - Gloucestershire
Recycled Products Guide	The guide is produced by WRAP and is a directory of recycled products within the UK[31].	No relevant examples
CIRIA	A database of construction related recycling sites within the UK that accepts or sells materials[32].	No relevant examples
The Bedfordshire Waste Exchange	Detailing the materials wanted and available[33].	No relevant examples
Waste Matchers	Like that of the Bedfordshire Waste Exchange, both of which are managed by Linden Consulting Partnership[34].	No relevant examples
The Waste Exchange	A service hosted by Northern Disposal services. It is a free service providing details on available material and material wanted by businesses[35].	No relevant examples
WASTECHANGE	A European provider of specialist waste exchange services - a free commercial service.	No relevant examples
National Industrial Symbiosis Programme (NISP)	A programme run on a national scale to introduce links between industries from different sectors to create sustainable commercial operations, such as the diversion of waste from landfill for use in other markets[36].	No relevant examples

The relatively low number of examples of exchanges of plasterboard is likely to be due to the "high-volume, low-cost" nature of plasterboard, and the availability of inexpensive disposal. Together low disposal costs, high transport costs, and a high volume product that is relatively inexpensive to purchase, all act as disincentives for re-use in this way.

4 The Plasterboard Industry

4.1 General Overview of the Industry

There are three plasterboard manufacturers in the UK: Knauf, Lafarge and British Gypsum. All use gypsum as their principal raw material.

The entry of Knauf and Lafarge to the UK market has increased competition over the last 10 –15 years. However, British Gypsum remains the dominant manufacturer, with approximately 50- 60% (from over 80% in the early 1990s) of the market share in the UK, and a capacity to produce 170.10 Mm^2 of plasterboard per annum. At an average of 9 kg/m^2, this gives an approximate figure for British Gypsum of 1.53 Mtpa of plasterboard, requiring (at 95% gypsum) approximately 1.45 Mtpa of gypsum.

British Gypsum, Knauf and Lafarge all report plans to expand their operations in the future. Further details for each company can be found later in this section. The table below provides summary information for UK plasterboard manufacture:

Table 11 Location and estimated annual gypsum throughput capacity of UK plasterboard plants, 2004

Company	Location	Plant	Capacity (Mm^2 pa) [37]	Capacity (Mtpa)[38]
BPB	Penrith, Cumbria	Kirkby Thore Line 1	21.1	0.19
		Kirkby Thore Line 2	39.2	0.35
	Loughborough, Leicestershire	East Leake Line 1	31.4	0.28
		East Leake Line 2	39.2	0.35
	Robertsbridge, East Sussex	Robertsbridge	39.2	0.35
		Approximate Total	**170.1**	**1.53**
Knauf	Immingham, Lincolnshire	Immingham	27.9	0.25
	Sittingbourne, Kent	Sittingbourne	48.0	0.43
		Approximate Total	**75.9**	**0.68**
Lafarge	Bristol, Avon	Bristol Line 1	29.1	0.26
		Bristol Line 2	21.7	0.20
		Approximate Total	**50.8**	**0.46**
Approx. Overall Total			**296.8**	**~2.7**

The Plasterboard Production Process

The following[39] provides an example of a current UK plasterboard production process. The details of the production process will differ to some degree from manufacturer to manufacturer and from plant to plant (see section 3.2.1 for information concerning plaster production).

Plasterboard is made from plaster obtained from the crushing and calcining of gypsum. It is manufactured in a continuous production process. A gypsum slurry is made up from stucco, or plaster of Paris, water and other additives, in a continuous mixer. The calcining of gypsum is a process of removing some of the water of crystallisation by the application of heat.

The gypsum slurry spreads, in a uniform stream, from multiple outlet hoses onto a moving sheet of paper. Where the board is produced upside down, this paper will form the front face of the plasterboard. Discs 'score' this paper allowing it to be easily folded at the edges. The 'back face' paper, fed from above the production line, is applied to the slurry via a forming head set to the desired board thickness. At this point the front face paper is folded at the edges, producing an enclosed envelope of paper slurry.

Once formed, the board travels the length of the production line on a series of setting belts, and sections of rollers to the shear. The production line may be in the order of 300m in length. During this journey, the plaster core has time to set, or harden, and the required product information (including: product name and type, relevant British Standards, date and time of manufacture) is printed on the boards.

At the shear, the long train of board is cut into panels of specific length. These smaller boards are then turned over and passed into a multi-level dryer. During the drying period, the excess water, which was required to form the initial slurry, is gently evaporated off. Drying must be well controlled to ensure product quality.

After the boards have dried, they are trimmed and stacked to form pallets. These pallets are then placed in a warehouse after which they will be loaded for distribution.

4.2 Restrictions and Drivers for the use of Plasterboard

Factors affecting the construction industry are of great relevance to plasterboard and hence gypsum consumption. Currently plasterboard production and consumption is rising by 3-4% per year. In 2000, UK consumption of plasterboard was 388 Mm^2. This is expected to nearly double by 2020 to 768 Mm^2, as a result of the predicted housing construction rate[40]. From 1988 to 1999 there was a direct correlation between the slump in UK property sales and a decline in demand for plasterboard[41].

Due to changes in UK building construction practice, since 1990 there has been an estimated 20% increase in plasterboard use in housing. UK demand for plasterboard and for gypsum is also increasing because of changes in the UK Building Regulations, mainly fire proofing and sound insulation, which have lead to the development of thicker plasterboard products to meet the requirements.

In terms of the sources of gypsum that will supply this demand:

1. It is generally anticipated that demand will rise in the plasterboard sector for desulphogypsum. This is because desulphogypsum is purer than most natural gypsum, making it stronger and lighter – weight.

2. The demand for natural gypsum for bagged plasters and cement has also increased, and is expected to continue to reflect activity patterns for the construction sector.

4.2.1 Policy Drivers for the Construction Industry

There are a number of Government and European policies, which are governing the long-term development the construction industry and its products. The main areas that most significantly influence the use of gypsum are described in the table below:

Table 12 Construction policy drivers influencing gypsum use in the UK

Policy Area	Description
Sustainability	Environmental criteria, length of use, recyclability, energy efficiency, and source emissions are all key criteria; With the current particular focus on energy efficiency the construction of all buildings is coming under scrutiny. In particular the design of elements such as walls has a huge influence on thermal performance both as heat is transmitted through elements and air finds route to leak out of the building.
Health and safety	Regarding installation and use; health and safety covers many different facets of the construction industry. From the safe installation of a product to the subsequent use of the building. Areas such as operational lifting and safe installation need to be considered as well as the fire integrity of the completed building. Not only do gypsum products such as cement, blocks and plasterboard need to be lifted onto site and in place, but they also have a role to play in fire protection.

Both of these key areas of policy influence the amount, type and size of the gypsum products that are used throughout buildings.

4.2.2 European legislation of relevance to the Plasterboard Industry:

At a European level the policies described above have lead to the following legislation of relevance to the plasterboard industry:

The Construction Products Directive (CPD)

The main aim of this legislation is to ensure the quality of any product intended for the permanent incorporation into a building or civil engineering works. The main factors influencing products containing gypsum are:

- Safety in case of fire,
- Hygiene, health and the environment,
- Safety in use,
- Sound insulation; and
- Energy economy and heat retention.

As part of the CPD mandate harmonised CEN standards are being developed ensuring consistency across Europe on products. This is a lengthy ongoing process as the old BS standards are converted. It is due to be completed by 2012.

Completed influencing standards of relevance to plasterboard are listed in the table below:

Table 13 Completed standards of relevance to plasterboard

Reference	Name / subject
BS EN 197-1:2000 Cement – Part 1	Composition, specification and conformity criteria for common cements.
BS EN 459-1:2001 Building Lime- Part 1	Definitions, specifications and conformity criteria.
BS EN 520:2004 Gypsum Plasterboards-	Definitions, requirements and test methods.
BS EN 934-2,3&4:2001 Admixtures for concrete, mortar and grout- Part 2 Concrete admixtures-	Definitions requirements, conformity, marking and labelling.
BS EN 12859:2001 Gypsum blocks	Definitions, requirements and test methods.
BS EN 12860:2001 Gypsum based adhesives for gypsum blocks	Definitions, requirements and test methods.
BS EN 13813:2002 Screed material and floor screeds	Screed material – properties and requirements.
BS EN 13279-2:2004 Gypsum binders and gypsum plasters.	Test methods.
BS EN 13279-1:2005 Gypsum binders and gypsum plasters.	Definitions and requirements.
BS EN 13963:2005 Jointing materials for gypsum plasterboards.	Definitions, requirements and test methods.
BS EN 14195:2005 Metal framing components for gypsum plasterboard systems	Definitions, requirements and test methods.
BS EN 14190:2005 Gypsum plasterboard products from reprocessing.	Definitions, requirements and test methods.

These standards have replaced the old BS standards, though not necessarily word for word. In many cases the levels required may have changed slightly, but the aim remains to ensure that products are manufactured and installed to a safe minimum level.

There are still many other standards undergoing or due for review but until then the BS standards remain current.

The EU Energy Performance in Buildings Directive (EPBD)

The EPBD looks at the energy efficiency of new and existing buildings. A key element of this is reducing heating losses by air-tightness which is intrinsically linked to the building construction and standard details. Therefore there may be an influence on installation details for plaster and plasterboard.

Implementing programmes and legislation in the UK are described in the table below:

Table 14 UK legislation and programmes with an influence on energy drivers for plasterboard use

Reference	Description
The Energy White Paper (2003)	The EWP was published in 2003 and provided details of the Governments targets for reducing carbon emissions. It provides the high-level policy statements and announced the bringing forward of the revision of key drivers for improvements in the built environment energy efficiency.
Energy Efficiency the Governments Plan for Action (2004)	This was the second paper published which provided more details on how carbon reduction was going to be achieved. Energy efficiency in buildings again being a large facet.
Sustainable Task Group and Sustainable Code for Buildings	In 2003 a Sustainable Task Group was formed to investigate ways in which sustainability could be improved. One of the recommendations in their report was for a Sustainable Code for Buildings to be developed. The aim of the code will be to provide inspirational non-mandatory requirements. The code is due to be published April 2006 but its contents are relatively unknown. It is expected that there will be details on thermal performance of walls and air tightness - both of which are influenced by the materials selected for the construction including plaster and plasterboard.

4.2.3 Current UK Policy and Practice

Current UK policies, practices and legislation are already in-place and are affecting the use of gypsum products. These include:

The Health and Safety Executive (HSE)

The HSE is responsible for UK regulation of health and safety. Amongst this, it deals with construction activites in the UK. The remit covers all areas including lifting operations both manual and mechanical. This includes advising industry on the maximum lifting loads (25kg) and frequency. In essence this has an influence on the maximum manufactured size of plasterboard sheets restricting them to the size that an individual builder can handle on his own. The HSE's remit also extends to fire risk, where they advise on the fire-rating requirement for a space and the possible methods that the rating can be achieved. This fire rating can be achieved in a number of ways; one of the recognised methods is the doubling of plasterboard sheets to provide a higher rating. The HSE therefore has an influence on the amount of plasterboard is used in two ways:

- The areas that typically have to be fire rated and
- The method in which they advise the space is fire rated.

British Standards

Those relevant to plasterboard specifications are currently undergoing a harmonisation process. Outstanding standards include:

Table 15 British Standards relevant to plasterboard use awaiting harmonisation

Reference	Name / subject
BS 4022:1970 panels	Specification for prefabricated gypsum wallboard
BS 1230-1:1985	Gypsum plasterboard. Specification for plasterboard excluding materials submitted to secondary operations
BS 7364:1990	Specification for galvanized steel studs and channels for stud and sheet partitions and linings using screw fixed gypsum wallboards
BS 1191-2:1973	Specification for gypsum building plasters. Premixed lightweight plasters
BS 1191-1:1973	Specification for gypsum building plasters. Excluding premixed lightweight plasters
BS 3958-6:1972	Thermal insulating materials. Finishing materials; hard setting composition, self-setting cement and gypsum plaster
BS 5270-1:1989	Bonding agents for use with gypsum plasters and cement. Specification for polyvinyl acetate (PVAC) emulsion bonding agents for indoor use with gyp sum building plasters
BS 8212:1995	Code of practice for dry lining and partitioning using gypsum plasterboard

The Buildings Act (1984)

This legislation provides Government with powers to set out minimum requirements for different elements of construction. These are detailed in the Building Regulations (England and Wales) 2000, and are designed to secure the health and safety of persons in and around buildings, and to conserve energy. Parallel legislation exists in Scotland and Northern Ireland.

Each of the different elements is set out as a different Approved Documents, or "Parts", several of which affect the use and application of gypsum products.

- **Part B Fire Safety** - similar to the HSE the Building Regulations have a remit to ensure that a building is designed and constructed to a minimum fire rating. One of the methods for achieving this fire rating is to add additional layers of plasterboard to achieve a 1-hour fire rating.

- **Part E Resistance to the passage of sound** – sets out the requirements for sound insulation. Increased insulation requirements are prompting plasterboard manufacturers to alter plasterboard design – this is resulting in increased gypsum use as boards of greater thickness are used. The latest version (2003, as amended) of Part E introduced compliance by the use of "Robust Standard Details" (see below).

- **Part L Conservation of fuel and power**, it was announced in 2003 that Part L would be revised to achieve a 25-27% improvement in energy efficiency in all new buildings. The draft versions have now been published. It provides minimum requirements for U values and air leakage for buildings, which influence the construction materials used. Increased plasterboard thickness provides a means of increasing thermal insulation – this can increase gypsum consumption per square metre of board.

- **Part F Ventilation**, is very much written in conjunction with Part L to dictate minimum levels of air leakage allowed. One method of compliance is to use "robust details" (see below)

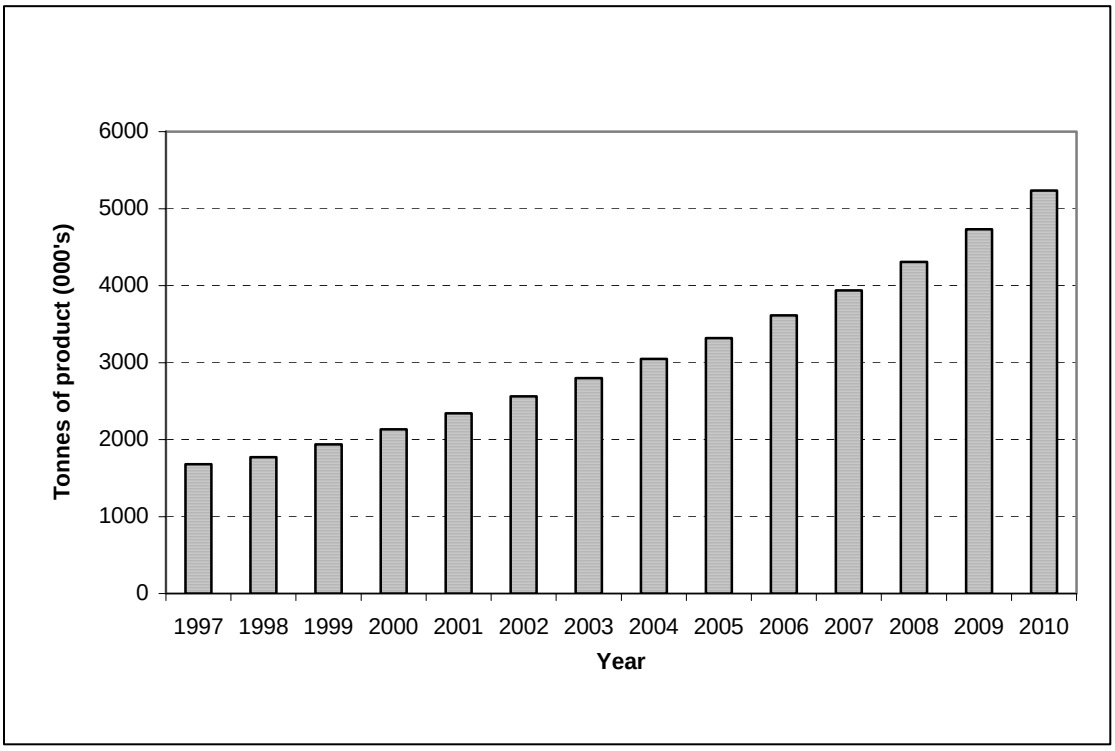
- **Robust Details** This is a new facet to the Building Regulations that is still under development. The aim is to provide the construction industry with standard details for all elements of construction to ensure that buildings are built with better air tightness, thermal performance and acoustic performance amongst others. The details provide industry with instructions on how to build using the specific materials listed in each detail. It can therefore have some influence on what and how each material is used, including on plasterboard.

- **Sustainable and Secure Buildings Act (2005)** Whilst this Act is relatively new it has the potential to have a sizeable impact on the construction industry. It gives the Government new powers under the Building Act to determine and dictate the materials, water and waste efficiency. At present it is still unclear how the powers are going to be applied.

4.3 Summary of Projections for Plasterboard Use

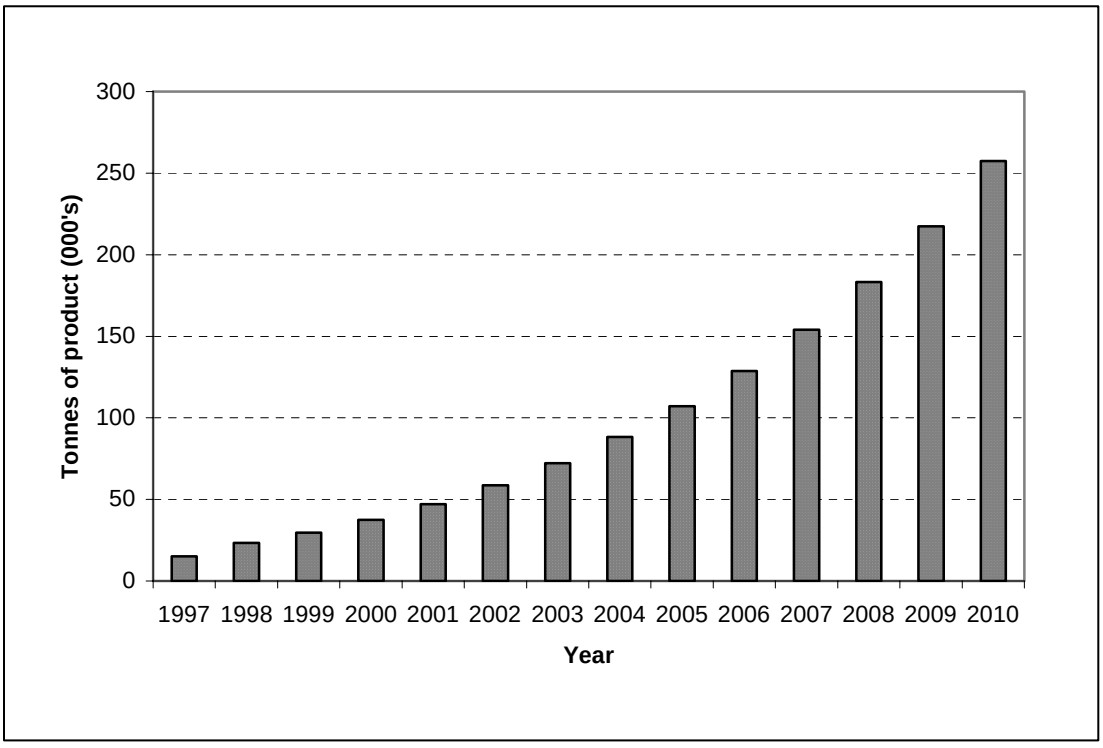
The graphs below provide projections for the use gypsum in the production of plasterboard (with and without facing) for the UK market. They are based upon predicted household growth[42] and recent trends in the plasterboard industry[43].

Figure 7 Projected UK gypsum demand for plasterboard (with facing)



It can be seen that the trend is one of significant growth. The data shows that the quantity of gypsum supplied as plasterboard with facing increases from approximately 3 Mtpa to over 5 Mtpa from 2004 to 2010. This is an increase over the period of 66%.

Figure 8 Projected gypsum demand for plasterboard (without facing)



The trend shows significant growth in gypsum demand, increasing from approx 0.1 Mtpa to approx 0.25 Mtpa from 2004 to 2010. This represents an increase over the period of 150%. However, the gypsum mass increase

over the period of 0.15 Mtpa is small compared to the additional 2 Mtpa predicted as required for plasterboard with facing.

4.4 Company Specific Information: British Plasterboards

Description of company activities

BPB is a leading company in the global supply of plasterboard and gypsum plasters. It is also a major supplier of insulation, ceiling tiles and related products for interiors, serving markets for building systems in over 50 countries. It supplies approximately 50-60% of the UK market, representing approx. 1.5 Mtpa of plasterboard. British Gypsum has five production sites (for plasterboard and / or plaster) at:

- Kirkby Thore, Cumbria
- Sheburn-in-Elmet, North Yorkshire
- East Leake, Nottinghamshire
- Barrow-upon-Soar, Leicestershire
- Robertsbridge, East Sussex

The East Leake site is also the head office site of British Gypsum. Each of the British Gypsum sites is located close to the UK gypsum reserves.

British Gypsum is a wholly owned subsidiary of BPB plc. During November 2005 the French company, Saint-Gobain SA, agreed to buy BPB plc for £3.89 billion (775 p per share). Saint-Gobain, based near Paris, is already Europe's biggest distributor of building materials.[44]

Types of gypsum used

British Gypsum is the only company that extracts natural gypsum/anhydrite in the UK. It does so from one quarry and six mines.

Although this has not been confirmed independently, British Gypsum has been reported to have contracts with all three of the UK major DSG producers. DSG is believed to currently represent a significant proportion of their raw material.

Total consumption of gypsum is currently estimated to be in the order of 1.4 – 1.6 Mtpa. Growth in the UK market is predicted – based on current market share this is anticipated to result a further increase in consumption of approx 1 Mtpa by 2010.

It is understood that British Gypsum operates a "take-back" scheme for the recycling of plasterboard. No details of the scheme were supplied.

4.5 Company Specific Information: Lafarge

Description of company activities

Lafarge are a multinational building materials company located in 75 countries. The main activities of Lafarge are in the cement, roofing, aggregates, concrete and gypsum products and services. This includes the manufacture of plasterboard and other gypsum based products, supply of fixings and metal stud for plasterboard applications.

The company has two UK manufacturing sites:

- Easton-in-Gordano, Bristol (plasterboard manufacture)
- Frampton, Gloucestershire (compounds for plasterboard manufacture)

Nine different boards are produced, each with different weights.

During interview[45] the total plasterboard production was quoted as 500 Mm^2/yr. However, other sources[46] indicate the figure to be closer to 50 Mm^2/yr. At an average weight of 9 kg/m^2 and a gypsum content of 95% w/w, the lower figure represents an approximate annual gypsum consumption by Lafarge of 0.43 M tonnes of gypsum. This compares well with the estimated market share of Lafarge of 25% of the total UK gypsum consumption of approximately 2.5 – 3.0 Mtpa.

Lafarge reported that they offer a recycling solution to their own customers' through a third party waste management company who provide the transport back to their Bristol site. Lafarge also offer a general solution to the industry through New West Gypsum who operate a gypsum recycling facility. (See section 5.2.4 for further information)

Types of gypsum used

Lafarge reported that they use two sources of gypsum:

- **Imported -** mined gypsum is imported from Spain and represents the main production supply. A price of £10-30 per tonne of virgin gypsum was indicated.

- **Recycled –** off-cuts from own production and, post-consumer material comprising mainly construction off-cuts (see also section 5.2.4)

Lafarge reported that in the order of 15-18% recycled material could be utilised without impact upon final product quality requirements. Actual annual amounts of recycled material used were not disclosed.

Paper separation during the recovery process was identified as a key issue. Paper fibre contamination of > 5% was reported to decrease the proportion of recycled material that could be incorporated. Demolition derived gypsum was reported to be generally more difficult to incorporate owing to greater contamination and quality assurance issues.

Table 16 Approximate quantities derived from take-back incorporated in the production stream

Source	Approximate current quantity arising / imported (ktpa)	Approximate current quantity utilised (ktpa)	Approximate projected quantity utilised (ktpa)
Own production scrap	20	20	20
Imported construction off-cuts	12	12	30
Demolition waste	0.5	0.5	2
TOTALS	**32.5**	**32.5**	**52**
Note: Approximately 5 % of recovered plasterboard is paper that goes to agriculture (mainly animal bedding).			

The table above shows that Lafarge:
- Currently incorporate 32.5 ktpa of recycled product (approx 5% of production capacity)
- Anticipate this will grow to 52 ktpa (approx 10% of production capacity)
- Current levels are below the 15-18% they consider possible

See section 5.2.4 for further details of the recycling technologies employed.

Projections

Lafarge representatives reported that:
- a recent slow-down in UK economic performance had slowed demand in the commercial and industrial sector
- government funded housing policies (replacement of old housing) supported growth in plasterboard demand

Lafarge reported that a greater availability of recycled product was anticipated as a result of the implementation of the European Landfill Directive. Lafarge felt that Environment Agency guidance, permitting up to 10% high sulphate bearing wastes (including plasterboard) to be co-disposed with other non-hazardous wastes, was a reason for the predicted quantities of gypsum not arising i.e. the level allowed continued deposit in landfill at a low price, thus undermining the incentive to segregate gypsum bearing wastes including plasterboard.

Based upon reported gypsum consumption data and estimates for the quantity of recycled material that can be incorporated, the current market for recycled gypsum at Lafarge is estimated to be in the order of 0.1 Mtpa. Depending on the assumptions made, market and production factors, this could vary from 0.05 to 0.16 Mtpa.

4.6 Company Specific Information: Knauf

Description of company activities

Knauf is a multinational producer of building materials and construction systems. From its origins as a producer of conventional gypsum, Knauf has developed into a group of companies in the industrial sectors of dry wall installations, insulation technology and plastering. Another extensive segment is moulded and injection moulded parts as well as other related activities. Globally Knauf provide products and services in the following fields:

- Building materials and systems based on gypsum and gypsum-related products.
- Thermal insulating and sound insulation materials.
- Limestone and lime products.
- Chalk and cement related products
- Plant engineering

Development of UK based operations started in 1988 with the construction of its first plasterboard plant in Sittingbourne, Kent. A second plasterboard plant at Immingham, N.E. Lincolnshire, and a plaster plant (1993) at Sittingbourne have also been put into operation. The UK business was reported[47] to comprise the production and supply of:

- Gypsum based products
- Plasterboard
- Bagged plaster

UK market share is estimated at 25 - 30%. Production capacities at Knauf UK plants are reported in Table 11. Combined UK gypsum consumption for plasterboard manufacture is estimated to be 0.7 Mtpa.

Types of gypsum used

Knauf reported that they currently use the following types of gypsum:

Table 17 Types of gypsum used by Knauf (2005)

Type	Use(s)	Notes
UK Mined gypsum	Not used	Not used
Desulphogypsum	Plasterboard	Europe (Italy, Germany, Poland) 100% (unless short supply when natural gypsum is used - this might happen 8-10 weeks of year)
Imported sources	Bagged plaster	100 % natural from Spain
Recycled own production scrap	Plasterboard	1-3% of production stream (i.e. approx 7 –21 Ktpa in UK)

Factors affecting their decision were reported as:

- Desulphogyspum has a higher purity [than mined gypsum] and weighs less. The lighter weight has production benefits, allowing more plasterboard to be made in less time. Its disadvantage is that higher moisture levels (8-12% free moisture) mean more energy is required for drying.

- Desulphogypsum is sourced from Europe. Knauf reported that they cannot buy it here as British Gypsum has the rights to all UK desulphogypsum.

- Natural gypsum is sourced from Spain. Knauf reported that restricted access to UK sources meant that this was the only option.

Use of recycled gypsum

Knauf do not currently operate a "take-back" scheme, but at the time of writing, it is understood that a number of options are under consideration and that negotiations with third party gypsum recycling companies are ongoing.

Knauf reports[48] that:

- it is able to take back "production ready" plasterboard waste to be used again in their production process

- to make waste plasterboard "production ready" it needs to be re-processed using specialist equipment
- the paper liners are returned to the Paper Industry for recycling.

Knauf report[49] the following issues in respect of the recovery of plasterboard for use in its own production:

- **On site [of use]** The waste plasterboard should be segregated and loaded into dedicated "tipper skips" situated conveniently adjacent to the work area. These skips can then be emptied into larger dedicated skips for collection by waste contractors.

- **Waste Transfer Station** All plasterboard waste should be segregated and free from contamination. Should this not be the case it will be necessary to transport the waste plasterboard to a Waste Transfer Station to be sorted.

- **Plasterboard Recycling Station** Knauf Drywall has entered into a partnership with New West Gypsum at Immingham, and reported to be in discussion with GRI at Sittingbourne, to manage and recycle waste plasterboard. The waste plasterboard will firstly have the paper liner removed and separated ready for recycling. The next stage is to crush the gypsum core to a suitable particle size ready for inclusion into the manufacturing process.

Knauf reported[50] that, mainly for quality reasons, they are currently unsure of the quantity of post-consumer recovered gypsum that could be incorporated in their production stream. The barriers to the incorporation of recovered gypsum were cited as:

Table 18 Barriers to use of recovered gypsum reported by Knauf (2005)

Issue	Description
Technology related	• Current technology able to process post production scrap but difficulties reported with construction derived. • Cannot treat some plasterboard e.g. foil backed
Quality related	• Lower and unreliable quality of post-consumer waste (includes product quality impact and health and safety concerns e.g. asbestos) • Particle size differences with desulphogypsum (main supply) • Quality concerns regarding other manufacturers board leads to a reluctance to take it • Lack of a recycled material quality standard and QA testing
Supply related	• Supply rates (and quality) would be required to be consistent to improve confidence that the material would not interrupt production

Land spreading:

Knauf reported that farmers use recycled gypsum from the Immingham plant as a soil conditioner. Knauf pay the farmers to take the material.

By contrast Knauf report that at Sittingbourne, where there is also reported a demand for the product from local farmers, the Environment Agency (EA) requires such activity to have a waste management licence. It was reported that this was because the paper content of the gypsum was too high. Knauf have reduced the paper content from 5% to 0.6% and continue discussions with the EA. Knauf report that a common standard would help them to decide what they can do.

Projections

Knauf reported that they expected the use of recycled gypsum (from construction and demolition) to increase, and that a scheme had been considered involving the addition of a small fee to the price of plasterboard sold to allow take-back of waste.

Should the quality and other concerns expressed by Knauf be overcome, based upon reported gypsum consumption data (~0.7 Mtpa) and estimates for the quantity of recycled material that can be incorporated (i.e., at Lafarge, 15-18% of production), Knauf may have capacity to incorporate in the order of: 0.1 Mtpa. However, this figure should be regarded with caution owing to the reported[51] particle size incompatibility with the dominant desulphogypsum raw material.

5 UK Waste Management of Gypsum and Plasterboard

5.1 Restrictions and drivers for change in the management of gypsum wastes

5.1.1 General barriers to change in waste management practice

The general barriers to changes in waste management practice for any material can be classified under four headings:

- Educational and Behavioural
- Market and Organisational
- Legislative and Technical
- Financial and Economic

Educational and Behavioural barriers are those that relate to the way in which activities are undertaken and how individuals respond to challenges or uncertainties. They include failings such as lack of information and knowledge of processes and equipment. Other behavioural barriers exist due to uncertainties around the expectations of markets, technology and policy. These often lead to a cautious approach to policy implementation to minimise the associated risk. Mistrust provides another behavioural barrier arising, for example, from the cost of recycling construction products.

Market and organisational barriers are those that exist due to the nature, structure and attitude of an organisation. For example, these may include barriers around lack of qualified personnel, the discontinuity of support and support mechanisms for the various stages or a lack of knowledge transfer within an organisation. All of these can present challenges to how readily an organisation can seize an opportunity.

The market and organisational culture and environment can provide barriers, particularly where new thinking is required around processes or operations, where there is precedent set, industry standards and policy to comply with or ties to existing technology though organisational requirements.

They range from simple lack of awareness through to the requirement to adapt new techniques or codes of practise. Often the existing practises can be 'locked-in', for example where the infrastructure and institutional arrangements are adapted to the incumbent technologies but are ill suited to the new practises.

Economic barriers are some of the most common and most quoted. The economic barriers closely interact with the other types of barrier often providing the justification to accept the less tangible behavioural or organisational barriers.

Other Economic barriers include the failure of the market to value the abatement of landfill availability, risk aversion and uncertainty as to nature and scale of economic risk, and a lack of competition in the market place producing monopoly issues.

Legislative barriers are detailed in the section 5.1.2 below.

5.1.2 Legislative drivers – waste management

This section provides a table that summarises information about the main legislation that influences the management of gypsum and plasterboard wastes. Further details are also provided in the text sections.

Table 19 Summary table of legislation relevant to gypsum products

Legislation	Requirements	Implications for management of gypsum waste
The waste management licensing (England and Wales) (Amendment and related provisions) (no. 3) Regulations 2005	Provided certain conditions are met, the landspreading of gypsum waste from specific sources is exempt from waste management licensing controls as a waste recovery operation.	The Environment Agency must be informed in advance. It must result in benefit to agriculture or ecological improvement, and no more than 250 tonnes per hectare should be spread in any 12 months period.
The Landfill (England and Wales) (Amendment) Regulations 2004	From 16 July 2005 these specify detailed waste acceptance criteria and procedures for acceptance of waste for each class of landfill replacing the existing criteria and procedures in the Landfill (England and Wales) Regulations 2002 ("the 2002 Regulations")	Waste is pre-treated prior to disposal e.g. physical sorting and dewatering. Waste containing more than 10% sulphate must be disposed of in a separate cell, but below this content may be disposed of in a non-specific cell.
The List of Wastes (England) Regulations 2005	The List of Wastes, which replaced the "European Waste Catalogue", provides for the classification of wastes and determines whether they are hazardous wastes.	If the waste is hazardous it must be disposed of in a landfill permitted for hazardous waste disposal. In general plasterboard waste is not considered hazardous by EA (see EA guidance)
The Environmental Protection (Duty of Care) Regulations 1991 (as amended)	Waste must be disposed of or recovered legally. A record should be kept of all waste received or transferred through a system of signed transfer notes.	As left.
Controlled Waste (Registration of Carriers and Seizure of Vehicles) Regulations	Registration with environmental regulator and issue of licence for transport of waste.	Registration with environmental regulator for carriage of producer's own construction or demolition waste.

<u>The waste management licensing (England and Wales) (Amendment and related provisions) (no. 3) Regulations 2005</u>

Under the Waste Management Licensing (England and Wales) (Amendment and Related Provisions) (no. 3) Regulations 2005, the landspreading of gypsum waste from specific sources is exempt from waste management licensing controls as a waste recovery operation. The arisings must be from:

(1) the manufacture of cement, lime and plaster and articles and products made from them,
(2) power stations and other combustion plants.

The exemption applies if certain rules are complied with. The Environment Agency must be informed in advance of the proposed landspreading of the waste, which must result in benefit to agriculture or ecological improvement, and no more than 250 tonnes per hectare should be spread in any 12 months period.

Under the Waste Management Licensing Amendment (Scotland) Regulations 2004, the spreading of gypsum waste to land is no longer an exempt activity, meaning that such activities are required to have a full waste management licence.

Under the Waste Management Licensing (Northern Ireland) Regulations 2003, there are no exemptions for the spreading of gypsum waste for ecological improvement.

<u>European Council Decision 2003/33/EC</u>

This required Member States to limit the disposal of non-hazardous 'gypsum-based material' to landfill cells where only non-biodegradable wastes are deposited. It also placed limits on the organic content of any other (non-biodegradable) wastes that may be landfilled in the same cell as gypsum-based material.

In England and Wales, the Council decision is being implemented via the Landfill Amendment Regulations 2004. These extend the scope of the Council Decision's requirement, to include 'other high sulphate bearing material'. This broader scope acknowledges the UK observations in some of the cases referred to above, that sulphate in

many different forms, not just specifically gypsum, is capable of leading to problems with hydrogen sulphide formation and release.

For the practical implementation of the new Regulation, it was seen as necessary to stipulate a minimum concentration of sulphate to which the Regulation applies. As the intention of the new Regulation is (implicitly) to avoid problematic emissions of hydrogen sulphide, it is necessary to determine, through theoretical and experimental study, a sulphate concentration in waste, below which the risk of such emissions is acceptably small, when that waste is co-disposed with biodegradable waste. This is believed to be the driver for the derivation of the, so called "10% rule" (see UK legislative amendment below).

The Landfill (England and Wales) Regulations 2002 (Amended 2004)

In the UK most waste plasterboard is currently disposed to landfill.

The Landfill (England & Wales) Regulations 2002 implemented Council Directive 99/31/EC on the landfilling of wastes. This legislation set out strict operational and technical requirements for landfill disposal designed to reduce the negative effects of landfill. The regulations also changed the definition of waste being disposed of to landfill. Landfills may no longer accept waste types such as tyres and liquid wastes and new waste acceptance criteria (WAC) must be used for material classifications.

Landfills themselves will now be classified as either Hazardous, Non-hazardous or Inert and traditional UK co-disposal methods can no longer be used.

From 16 July 2005, the Landfill Regulations implemented a further change by requiring specific waste acceptance criteria for gypsum wastes and high-sulphate bearing wastes, stable non-reactive hazardous wastes, and asbestos wastes. Gypsum wastes includes all plasterboard waste.

A significant element of these waste acceptance criteria are given in Schedule 1 paragraph 15 of the Regulations which states that "gypsum based and other high sulphate bearing materials may only be disposed of in landfills for non-hazardous waste in cells where no biodegradable waste is accepted".

The Environment Agency (EA) have published documents giving interpretation of and guidance on the waste acceptance requirements of the Landfill Regulations:

- Regulatory Guidance Note 11 (RGN11) [52];
- Guidance for waste destined for landfill – Interpretation of the Waste Acceptance Requirements of the Landfill (England and Wales) Regulations 2002 (as amended) [53];
- Waste - can you handle it? Gypsum wastes and high sulphate bearing wastes[54].

Reference 52 describes the type of engineered high-sulphate mono-cell required to meet the requirements of the Regulations.

References 53 states that the EA considers 'gypsum-based and other high sulphate-bearing materials' to be wastes with more than 10% sulphate in any one load. This interpretation is based upon investigations and consultation at two landfill sites in Wales.

Reference 54 gives guidance on the disposal of these wastes:

> "If the waste is not hazardous it must be disposed of in a non-hazardous landfill, where there are two options:
> 1) If the content of the load contains significant amounts of high sulphate bearing waste it must be disposed of in a separate cell where there is no biodegradable waste … we consider that this relates to both gypsum and other forms of sulphate containing waste with a content of more than 10% sulphate per load.
> 2) If the content of the load contains small amounts of high sulphate bearing waste, e.g. less than 10%, it may be deposited in a non-specific cell" [ie in a general non-hazardous landfill with other wastes including biodegradable wastes].

This is the guidance which has become referred to as the "10% rule". Unfortunately, due to subtle variations in the wording in Reference 53, the "10% rule" has been variously interpreted as 10% sulphate per load, and 10% high-sulphate material per load.

Importantly, Reference 54 also gives guidance plasterboard waste is classified in general as NON-hazardous.

Designated mono-cells for high-sulphate waste are expensive to construct and licence, and high sulphate waste is less profitable for landfill operators than asbestos. The result is that there are currently believed to be very few (see 5.2.2) landfill sites in the UK with designated mono-cells and licensed to accept this kind of waste, and consequently disposal costs have increased significantly.

The result of the "10% rule" is that there is an incentive NOT to segregate plasterboard waste from other wastes (eg, on a construction site), so it remains less than 10% of the waste load and can be disposed of to general landfill at lower cost. It has even been reported that segregated plasterboard waste is being 'diluted' with other wastes to come under the 10% threshold.

The further effect of this is it depressing the economic driver for recycling plasterboard waste.

While the 10% threshold for segregated disposal exists it is unlikely that the number of landfills licensed specifically to accept loads of high sulphate waste will increase. It has been proposed that if the Environment Agency were to revise their interpretation of the Landfill Directive, and a lower (than 10%) threshold for segregated disposal were enforced, the segregation of gypsum waste from other waste would most likely increase and demand rise for mono-cell landfill of such sulphate wastes. This would be expected to lead to increased recycling of waste plasterboard. This proposal is currently being debated within the related industry sectors.

The Northern Ireland Environment and Heritage Service and the Scottish Environment Protection Agency do not currently require high sulphate waste to be deposited in a mono-cell, as specified by the Environment Agency in England and Wales.

The Environmental Protection (Duty of Care) Regulations 1991 (as amended)

These Regulations require gypsum product manufacturers to handle waste safely and in accordance with the law. This is the 'Duty of Care' and it applies to anyone who produces, imports, carries, keeps, treats or disposes of controlled waste such as gypsum waste from business or industry.

The waste producer is responsible for ensuring the safe and proper disposal or recovery of the gypsum waste they produce, even after it has been passed on to another party such as a waste contractor or recycler.

The Duty of Care has no time limit, and extends until the waste has either been finally and properly disposed of or fully recovered.

Waste should only be handled by individuals or businesses authorised to deal with it.

A record should be kept of all waste received or transferred through a system of signed transfer notes.

Control of Pollution (Amendment) Act 1989 and the Controlled Waste (Registration of Carriers and Seizure of Vehicles) Regulations 1991, (as amended)

In England, Scotland and Wales, the carriage of waste is regulated under the Control of Pollution (Amendment) Act 1989 and the Controlled Waste (Registration of Carriers and Seizure of Vehicles) Regulations 1991, (as amended).

Gypsum manufacturers that wish to transport, or arrange the disposal or recovery of controlled waste such as gypsum waste, may be required to register with their Environmental Regulator. The carriage of an organisation's own wastes does not usually require registration, unless it is construction or demolition waste.

5.1.3 Construction and demolition industry

It is worthwhile considering the construction and demolition industry as a whole before looking at the particular barriers.

- It is a very competitive industry normally using a closed tendering process so costs are driven and kept down, with minimal profit margins.
- In the UK it is the largest industry and employs a huge number of skilled workers. It also employs many unskilled workers.
- It is slow to change, still retaining many conservative attitudes.
- The industry comprises many small (even single-person) enterprises, working both directly and as sub-contractors for larger companies.

Barriers to change in waste management practice

The key barriers for the building industry are as follows:

Educational barriers include:

- **Lack of knowledge amongst professionals.** Professionals within the industry may feel that they lack the knowledge on how to minimise waste arisings and increase materials recycling. For example, an architect may not have learnt techniques to design buildings in such a way as to optimise the use of whole sheets of plasterboard, so reducing waste off-cuts.
- **Site Training.** The construction industry includes thousands of skilled and unskilled workers, in many cases sub-contacted by the main contractor. Their time on the site could be relatively short and though an induction may be carried out on health and safety issues, it is rare for inductions to given on good site waste management, such as the importance of segregating waste into the correct skips.
- **Hassle factor.** With many sub contactors on sites it is difficult to ensure that everyone is carrying out their work as instructed. It is often not possible to ensure that the correct waste materials are placed in the correct skips, rather than 'the closer' skip, without overseeing them all day.

Market barriers include:

- **Client specification.** The construction industry is very competitive, with projects being priced and submitted in a closed tender process. Therefore, unless minimum levels of recycling are specified as a requirement by the client or other body, it is unlikely that a construction company will include it in their project.
- **Contractual.** There is generally no fiscal incentive within the standard contract for lesser amounts of material to be used than specified. In particular, dry lining is usually undertaken by specialist contractors who price jobs, and are paid, by the area installed. The time element of a contractor's costs are greater than the material costs for plasterboard, so standard practice is to work quickly by using whole sheets and cutting out window and door openings rather than fitting off-cuts to shape.
- **Market uptake and public perception.** Reducing the amount of construction waste on a new building has limited marketing value; however investing in a renewable technology or other more visible sustainable measures may bring attention to a project. Therefore a construction company may be more likely to invest in these areas rather than in recycling.
- **Architects and Quantity Surveyors (QS) playing safe.** The calculations done by Architects and QS provide the construction companies with a bill of quantities to price against. This will be based on measured amounts of products plus a factor to account for part pieces etc. Unless this is reduced then the contactor will provide a similar amount of the product to site, any un-used is normally wasted. Architects and QS will not reduce their safety factor as this could mean additional costs to the agreed price and delays in programme. This is exacerbated by the contractual arrangement with the dry lining contractor, as discussed above.

Financial barriers include:

- **Economics.** Many construction clients will have concerns about the environment and may specify some sustainable elements for their construction. Construction waste management costs are largely dependent on the size of the project. The recyclability depends on quantity, quality, and the inherent value of the waste material. The issues for builders centre on the relative cost and "bother" factor of recycling (collection, separation, and transportation), against landfill tipping fees, and transportation. For plasterboard, at present material costs are low and costs of disposal to landfill are low, so there is little economic incentive to segregate and recycle plasterboard waste.
- **Economics.** For high volume low cost materials such as plasterboard it is more economically viable to dispose of unused material at the end of the construction project, and re-order for the next project, than to store and carry unused materials over.
- **Sub-contractors.** A contactor brought onto site to carry out a specific job will want to complete their work in the minimum time, get paid and move on. Unless they are contractually obliged to recycle their waste they will not bother.
- **Sector diversity.** The construction sector includes many single-person operations as well as some very large operators. Commonly smaller operators work as sub-contractors for the larger organisations. While large organisations have sufficient economy of scale to incorporate and implement environmentally advantageous procedures in a cost effective manner, the burden upon small operators is generally disproportionately large. Therefore the larger organisations, and those letting contracts, hold the key to specifying recycling where it may result in added costs.

Legislative barriers include:

- **Lack of legislation.** Buildings are generally constructed to minimum requirements (such as to meet but not exceed the requirements of the Building Regulations), with few exceptions looking to higher aspiration levels. This provides an equal basis for the industry to price each job competitively. Therefore the current ethos within the much of the industry is to not react to anything unless clear **mandatory** legislation is in place.
- **Lack of legislation.** Although waste management legislation applies, there is currently no legislation to require main contractors to recycle the waste materials on their sites. However, The DTI are considering the introduction of mandatory Site Waste Management Plans (SWMPs) as part of the Clean Neighbourhoods & Environment Act 2005. SWMPs are an important tool for construction companies and their clients, of all sizes, to improve their environmental performance, meet regulatory controls and reduce rising costs of disposing of waste.
- **Lack of direct action.** There is no legislation currently in place to make each individual responsible for his or her actions on site, with respect to waste management. Individual control occurs at site level, and will depend on the attitude and degree of control by the site management.
- **Lack of clear policy.** Current guidance from the Environment Agency on the Landfill Regulations effectively allows a continuation of co-disposal of plasterboard with other wastes. There is therefore little incentive for construction companies to reduce the production of plasterboard waste, or segregate plasterboard waste from other wastes.

Summary

In summary there are many barriers preventing the construction and demolition industry from adopting greater recycling of plasterboard and gypsum products. They are associated with cultural market and organisational barriers, economics and a lack of education. Whilst these barriers are real, change would be possible by introducing clear mandatory legislation or an agreed industry code of practice to require the construction and demolition industry to change its practises.

5.2 Current UK Practice

5.2.1 Summary of current UK arisings and fate of gypsum and plasterboard waste

There are three main waste management outlets:

- Landfill
- Recycling
- Land spreading

Owing to its low organic content, plasterboard is not generally suited to incineration. Indeed the presence of large amounts of plasterboard has been reported to have an adverse impact upon the performance of some waste incinerators.

In the UK the main gypsum waste flows are currently estimated as indicated in Table 20.

Table 20 Estimated UK arisings and destinations for scrap and waste gypsum

Source	Type	Quantity arising (Mtpa)	Destination	Comments
Combustion plants	Desulphogypsum from FGD	1.4	Plasterboard manufacture (BPB)	DSG is also imported to the UK (by Knauf)
Other DSG	Synthetic gypsum (mainly from Tioxide)	~ 0.5	Plasterboard manufacture (Knauf)	Knauf also report some land-spreading
Construction & Demolition waste. (notes a & b)	Plasterboard and plaster waste	~ 1 (note c)	Recycled to plasterboard 0.07 Mtpa (note d) Landfill ~ 0.9 Mtpa 0.02 – 0.03 Mtpa for agricultural land spreading	Landfill figure calculated from estimated total minus reported recycling ADAS report intention to increase to 0.05 Mtpa Knauf also report some from Immingham
Plasterboard industry	Plasterboard off cuts	0.15 (note e)	0.055 Mtpa re-used in plasterboard production process (note d) Separated paper to agricultural bedding	0.055 Mtpa is calculated from Knauf estimate was that 1-3% of total production was recycled to the process.

Notes:
a) It has not been possible to separately quantify C&D waste.
b) The plasterboard industry report greater quality concerns respects demolition waste than construction waste
c) The figure of 1 Mtpa arisings is an estimate based on personal communications with WRAP and available statistics for national waste arisings.
d) 0.07 derived from reported current operations of UK recyclers (see also 5.2.3). Because some recyclers operate on the site of plasterboard manufacturers, there may be overlap between the 0.07 Mtpa reported to be recycled by UK recyclers and the 0.055 Mtpa that is calculated to be recycled in the plasterboard industry.
e) Based on 5% production scrap

The above table shows that:

- Large quantities of DSG are used by the plasterboard industry
- Construction and demolition waste give rise most of gypsum waste that is landfilled
- Recycling to the plasterboard industry is currently in the region of 0.07 Mtpa

Figure 2 in section 1.4 shows the main UK waste and recycling flows.

5.2.2 Current UK Landfill outlets for gypsum and plasterboard waste

Historically the UK has landfilled a high proportion of waste. The implementation of new legislation from 16 July 2005 was expected to significantly change UK landfill practice. From that date, the Landfill Regulations required landfills to have specific waste acceptance criteria for waste, including gypsum wastes.

As discussed in Section 5.1.2 the Environment Agency (the waste management regulator in England & Wales) has issued guidance on the disposal of gypsum wastes and high sulphate bearing wastes. The main consequence of this guidance in respect of gypsum and plasterboard wastes is to determine whether the waste can continue to be landfilled with other non-hazardous wastes. The guidance states that, in general, the EA considers that:

- plasterboard is not hazardous waste
- waste loads containing greater than 10% sulphate require landfilling in a separate "mono-cell"

These mono-cells must be designed specifically for sulphate containing wastes and will not be able to accept biodegradable waste. In Scotland and Northern Ireland there is currently no requirement for high sulphate waste to be disposed in a designated cell.

Although information was received regarding the UK landfills that have applied for licences in response to these changes in legislation, owing to the classification of many sites applying for a "wide range" of wastes, the data does not provide a clear picture of which applicants have specific plans to receive gypsum wastes. Therefore, it is unclear how many sites in England & Wales are licensed to accept such high sulphate waste loads.

Two sites were identifiable as having a designated cell for high sulphate waste:

- Winterton Landfill, North Lincolnshire - Waste Recycling Group;
- Harmondsworth Landfill, Sipson, Middlesex - SITA

Waste Recycling Group stated that the following limits per day applied according to their Waste Management Licence:

- 100 tonnes plasterboard
- 100 tonnes of gypsum
- 40 tonnes of metal sulphates
- 60 tonnes of contaminated sulphate
- 50 tonnes barium sulphate sludge.

As the table below shows, material containing less than 10% high sulphate waste can be disposed of as non-hazardous waste for a much lower fee of £42.50 per ton, than material consisting of 100% high sulphate waste, which costs £113 per ton to dispose of.

Table 21 Reported prices for disposal of plasterboard at the Winterton Landfil[155]

Waste	Route and requirement	Cost £/t
Plasterboard	100% plasterboard waste into mono-cell in Winterton landfill site	113 (includes landfill tax @ £18 /t)
Plasterboard	<10% plasterboard mixed with other non-hazardous waste	42.50 (includes landfill tax @ £18 /t)
Plasterboard	Recycling	25[56]
The above costs are for dry waste disposed as a one-off disposal.		

Waste Recycling Group were unable to provide the capacity of the mono-cell designed to receive high sulphate waste, and was unable to forecast the life span of the cell. They stated that since 16 July 2005, the rate of deposition of high sulphate waste had risen markedly. It was reported that the cost for mono-disposal of high sulphate wastes will increase to more than £125 per ton over the next few years[57]. However, escalating costs for this service would appear unsupportable if the practice of dilution with other waste continued.

The continued practice of lower cost mixed landfilling for gypsum wastes appears to be inhibiting the development of specific waste management for these wastes.

5.2.3 Summary of UK Recycling outlets for gypsum and plasterboard

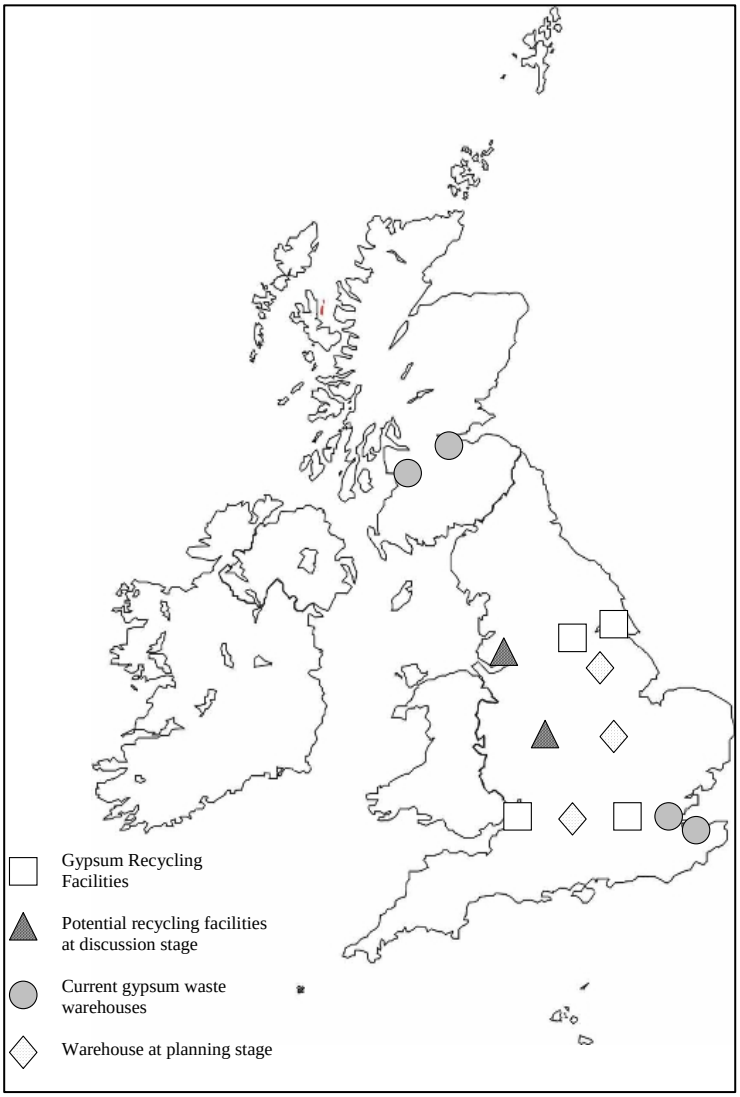
Table 22 below provides a guide to the amount of gypsum waste which is currently being recycled, the capacity of the current facilities and the potential planned recycling capacity in the future.

Table 22 Summary of current and proposed UK gypsum recycling capacity

Company	Current throughput (Ktpa)	Current UK capacity (Ktpa)	Indicated future UK capacity (Ktpa)
New West Gypsum	~ 55 (reported 50% of current capacity)	~ 110	~ 220 (i.e. investigating 2 new plants)
Gypsum Recycling International	Not known	2 UK warehouses capacity not known	~ 90
Plasterboard Recycling UK	~ 10 (reported 0.8 / month)	~ 15 (current plant reported not at full capacity)	~ 45 (i.e. investigating 2 new plants)
Roy Hatfield	~ 6	~ 50 (new plant opened Sept 05)	~ 56
Totals	**~ 70**	**~ 175**	**~ 400**
Note: Capacities are estimates calculated on the basis of 1 shift, 5 days per week			

It can bee seen that, despite the fact that current recycling appears to be below the present UK capacity, the recycling industry is investigating further expansion.

Figure 9 **Locations of current and reported potential recycling facilities / transfer stations for gypsum waste within the UK (excludes new NWG plants as location not revealed)**



5.2.4 UK Plasterboard and Gypsum Recycling - Company Information

5.2.5 New West Gypsum Recycling

The first New West Gypsum Recycling (NWGR) facilities were founded in 1985 in Canada and the United States. The sites that NWGR is currently working at within the UK are at Easton-in-Gordano, Bristol and Immingham, Lincolnshire. The equipment used at these sites is a Gypsum Waste Recycling Unit; this is a portable unit capable of recycling either wet or dry plasterboard. On average 25 tonnes per hour can be processed.

The conditions of input material into the recycling unit are that waste is:

- Clean of contaminants e.g. wood and metals
- Gypsum only waste, mixed waste is not accepted

Recycling technology was reported to use:

- a hammer mill to crush the product,
- a series of sieves for grading and a further milling process to render the gypsum down to the desired size
- magnets to remove any stray metal objects and
- an extraction system for paper separation.

The recycled gypsum is used by the plasterboard manufacturer, combined with natural or synthetic gypsum. NWGR studies have shown that plasterboard can incorporate up to 25% recycled gypsum into new board without affecting quality[58]. (Note that 15-18 % was quoted by Lafarge)

There are a variety of options for the paper fraction removed when plasterboard waste is treated, these can include:

- returning to the pulp mill to make new paper
- composting
- use as animal bedding.

NWGR facilities are on the site of Lafarge at Easton-in-Gordano, near Bristol. The majority of NWGR product is plasterboard. NWGR take plasterboard manufacture off-cuts from Lafarge, as well as having other contracts within the construction industry.

The gypsum recycled within this process is fed back into the Lafarge plasterboard manufacturing process. NWGR are not currently working at capacity at their Easton-in-Gordano site. The company estimates that they can recycle around 100 percent more gypsum each month. They are looking to open two other plants within the UK to manage the expected growth in demand.

NWGR facilities at Immingham are on the site of Knauf. The recycling unit at this site is of the same type as that at Easton-in-Gordano. Again NWGR use plasterboard from Knauf as well as other plasterboard waste brought onto the site. The gypsum that is produced is fed back into the Knauf plasterboard manufacturing process.[59]

5.2.6 Gypsum Recycling International

Gypsum Recycling International (GRI) is a Danish company who began their operations in 2001. They are interested in branching out into different countries and have set up an International Franchising Programme as a means to do this. Within the UK, GRI operates as Gypsum Recycling UK (GRUK) and the venture works by having warehouses located within the UK and a portable recycling unit which travels to these transfer stations. At present there are two UK warehouses:

- Sittingbourne – Adjacent to the Knauf plasterboard manufacturer
- West Thurrock

GRUK report interest in opening three more warehouses in the near future in the following locations:

- Sheffield
- West Midlands
- Swindon

Research is being undertaken to locate a further two sites near:

- Manchester
- West London

At present a portable recycling unit is brought in from Scandinavia or Ireland to process the gypsum waste collected within the UK warehouses. Due to the limited supply of gypsum waste, it is considered that there is not currently the need for a full time recycling unit within the UK. GRI are however currently building a portable recycling unit for use within the UK in anticipation of increased demand, which should be ready for operation in early 2006. The machine will have the capacity to recycle 50 tonnes per hour.

GRUK report the potential to recycle all kinds of gypsum/plasterboard waste. They accept waste from new construction as well as production scrap, demolition material and that collected from CA sites. They state that they have the technology to separate out impurities such as nails and screws from the gypsum waste. Waste not accepted is plasterboard with insulation, foiled back or with attached aluminium frames[60].

GRI operations within Europe have already been successful with market share in[61]:

- Scandinavia
- Holland
- Germany

5.2.7 Plasterboard Recycling UK

Plasterboard Recycling UK (PBR UK) was established in 2004[62]. Their recycling outlet is based in North London, with transfer stations in Edinburgh, Glasgow, Rotherham and Bristol.

PBR UK only take plasterboard waste from the construction industry and waste management industries. This waste must be pre-segregated, and mixed loads are rejected. The PBR UK service includes, organising skips, compactors and the transfer of waste from site.

At present PBR UK take 800 tonnes of plasterboard a month, which is reported to be below their plants potential capacity. Like New West Gypsum they also researching into opening two more recycling plants. They are looking to situate north of Birmingham[63].

5.2.8 Roy Hatfield Limited

Roy Hatfield Limited began its gypsum recycling programme in May 2003 with a custom made plant for recycling waste gypsum moulds from the pottery industry. Around 11,000 tonnes of moulds are processed each year. The precise quantity of gypsum this represents was not supplied.

At the end of September 2005 Roy Hatfield Limited extended their operations and opened a new plasterboard recycling plant, with a capacity of 50,000 tpa. The plant accepts waste from waste management companies, demolition and construction contractors.

UK waste management press reports suggest that this plant is running at capacity, but this could not be confirmed directly. Roy Hatfield Ltd also manufactures decorative concrete products in which some of the recycled gypsum is used. [64]

Due to the commercial sensitivity associated within the industry Roy Hatfield Ltd would not comment on their current operations.

6 Summary and Conclusions

This section presents observations and conclusions in respect of the key issues that need to be addressed in order to allow for increased recycling of gypsum in the UK. The conclusions are presented here under the two main headings that commonly impact upon recovery / recycling markets:

- **Material supply and demand factors;**
- **Infrastructure and institutional factors.**

6.1 Material supply & demand factors

6.1.1 Description of the factors

The main factors that influence supply and demand for recycled gypsum in the UK are:

- Overall demand for gypsum - principally from the plasterboard industry;
- Quality and availability of the recycled material, its compatibility with user requirements and suitable quality standards;
- Supply and cost of other competing gypsum sources:
  - Mined gypsum;
  - Desulphogypsum;
- Legislation restricting its disposal;
- Costs of disposal.

6.1.2 Discussion of the factors

Each of these factors are discussed below in the context of the findings of this report:

Overall demand for gypsum

The overall demand for gypsum in the UK for all uses in 2004 was estimated to be 4.6 – 5 Mtpa. The demand arose mainly from the following sectors:

- Plasterboard industry 2.5 – 3 Mtpa
- Plaster products industry 1 Mtpa
- Cement industry 0.6 Mtpa

Growth in these sectors is predicted, mainly as a consequence of anticipated growth in the construction sector fuelled by demographic factors and housing policies. Based upon housing predictions and recent trends in the market for gypsum, **it is predicted that by 2010 the plasterboard sector will have grown to utilise approx 5 Mtpa**.

Demand in the plaster products and cement industries may also rise slightly, although with the majority of additional demand coming from the plasterboard sector this additional increase will be relatively small.

Other uses of gypsum (e.g. agricultural, etc) are relatively small, and while some growth may occur (e.g. by approx. 0.025 Mtpa to 0.05 Mtpa for landspreading, 0.01 Mtpa total for fertilisers), in terms of the overall additional material demand for the manufacture of plasterboard, these are small and in total unlikely to exceed 0.1 – 0.2 Mtpa.

It is estimated that **by 2010 the overall demand for gypsum in the UK will rise by 2 – 2.5 Mtpa, to a reach an overall total of 6.6. – 7.5 Mtpa**.

The plasterboard industry will remain the main UK supply market for gypsum by a significant margin, and therefore will also be the main UK supply market for recycled gypsum.

The size of the demand for post consumer recycled material is largely dependent upon the proportion of material that the plasterboard manufacturers can incorporate into their production; this is very quality, supply and cost dependent (see section below). However, it may be estimated that (see Table 9 below) the projected new market for recycled gypsum in 2010 is:

- 0.4 Mtpa (at 10% production incorporation)
- 0.7 Mtpa (at 15% production incorporation)
- 1.1 Mtpa (at 25% production incorporation)

This may be compared with an estimated current quantity of gypsum waste being disposed to landfill of 1 Mtpa. A 100% materials recovery rate is not achievable (particularly under current market / legislative conditions). However, **there is the potential to incorporate significantly more post-consumer gypsum waste in the plasterboard manufacturing sector.** It should also be noted that efforts to reduce the amount landfilled are unlikely to divert the newly non-landfilled waste wholly to recycling. This is because increased resource efficiency may result in reduced arisings i.e. material re-used instead of recycled.

Table 23 **Estimated additional gypsum recycling capacity in the plasterboard manufacturing industry at various incorporation percentages**

Company	Approximate current gypsum consumption (Mtpa)	Estimated increase in gypsum consumption by 2010 in Mtpa (at current market share)	Estimated current recycling rates (Mtpa)		Projected potential additional recycling capacity in Mtpa (calculated from projected recycling– current recycling incorporated)		
			Own production scrap	Post-consumer sources (not including DSG)	At 10% of total production	At 15% of total production	At 25% of total production
British Plasterboard	1.5	+ 1.25	0.03 (assumed 2%)	No data (assume 0)	0.25	0.38	0.66
Knauf	0.7	+ 0.6	0.014 (reported 1 - 3%)	No data (assume 0)	0.12	0.18	0.31
Lafarge	0.5	+ 0.4	0.02 (reported)	0.01 (reported)	0.06	0.11	0.2
Totals	**2.7**	**+ 2.25** (mid range of projection)	**0.07**		**~ 0.4**	**~ 0.7**	**~ 1.1**

Quality and availability of the recycled material

Current UK supply of recycled gypsum is estimated to be 0.07Mtpa. Current capacity for recycling is estimated to be 0.175 Mtpa. The industry reports that it intends to expand capacity to a total in the region of 0.4 Mtpa.

The difference between the currently reported recycled material and current and future capacity may be a consequence of:

- Lower than expected gypsum waste arisings (e.g. perhaps due to weaker than expected legislation - see supply factors below)
- Quality / technical restrictions currently applied in plasterboard manufacture

Knauf, who almost exclusively use desulphogypsum (mainly for production, quality and economic reasons), report that the particulate size of recycled gypsum gives rise to technical difficulties at the re-processing stage. These difficulties may restrict the use of recycled gypsum to a greater extent where DSG is used as the main feedstock, than where natural gypsum is predominantly used (e.g. at Lafarge).

Lafarge themselves report that, while their own production off-cuts can invariably be incorporated in their process, construction waste, and in particular demolition waste, can raise significant additional quality control (and health and safety) issues. **The development of an industry accepted quality assurance code of practice (standards, testing, etc) may help address these issues.**

As well as quality requirements, large-scale production plants of the type found in the plasterboard sector require the availability of raw material to be of sufficient scale, and of consistent supply. The current relatively small quantities of post-consumer gypsum recycled only partially meet these requirements at present. Although price factors will be key, unless there is a significant increase in the amount of waste plasterboard recycled it may be more likely that increased future demand for gypsum will be met by:

- Increased use of DSG (both UK, if further FGD plants are installed and become producers of DSG, and imported);
- Increased use of mined material (both UK and imported).

The ability of gypsum recyclers to provide sufficient volumes of material of reliable quality is highly influenced by factors affecting arisings, such as the continued landfill of gypsum wastes that appears to be possible using the "10% rule" (see also supply factors below).

Supply and cost of other competing gypsum sources

Key to the demand for any material is competition from other materials. **The competing materials for the intended market for post-consumer recycled gypsum are:**

- **Mined gypsum (UK and imported);**
- **Synthetic gypsum (UK and imported).**

The predicted increased demand for gypsum is likely to lead to an increase in the price of gypsum in general and hence improve the economics of recycling. However, there is also **the potential for gypsum prices to drop if natural gypsum supply increases relative to demand**, should:

- The major UK producer of mined gypsum increase production;
- Additional power stations or other major combustion plants install FGD equipment and become DSG producers;
- The recently generally slow European economy suppress import prices (note: some European regions, notably Spain [a major gypsum producer] have recently experienced a construction boom that has supported construction related material prices).

It is noted that both Lafarge and Knauf use imported sources, whereas British Gypsum use mainly UK sources. Both Lafarge and Knauf reported some difficulty in sourcing UK material. The greater success of British Gypsum, the dominant market player, in securing supply of UK materials appears to be a factor.

Competition from synthetic gypsum is on grounds of both cost and quality. Production benefits are reported (by Knauf), although the greater free moisture content increases energy consumption at the drying stage. Rises in energy prices (which have risen with recent global oil price rises) may therefore act as a disincentive to the use of DSG, and hence could favour other supplies (the moisture content of recycled gypsum is not known and this may therefore be a benefit or dis-benefit).

Because of increasing downward pressure on emissions from industry (the deadline for implementation of major industrial permitting legislation is Oct 2007 for most European Countries), **it can be expected that European use of flue gas desulphurisation use will increase, and that arisings of DSG will rise**.

Waste legislation, and disposal costs

Environment Agency guidance, permitting the deposit of wastes with up to 10% sulphate content with other biodegradable wastes, is widely quoted in the plasterboard production and recycling industries as undermining efforts to increase the recycling of gypsum.

The evidence in this report shows that, in respect of gypsum, **the effect on the waste management industry of the legislation implemented on 16 July 2005 has been relatively minor** – few UK landfills could be confirmed as having a specific cell for high-sulphate wastes. As quoted charges for general landfill are almost one-third the charge for disposal in a high-sulphate mono-cell, there is no economic driver to segregate waste plasterboard from other wastes prior to disposal. The further effect of this is that if segregation is inhibited, then increases in plasterboard recycling will not occur. It is therefore **likely that the majority of the estimated 1 Mtpa of gypsum that is being landfilled in the UK will continue to be landfilled, rather than segregated for either mono-cell disposal or for recycling.**

The 10 % sulphate level in Environment Agency guidance has:

- Resulted in the continued availability of low cost landfill (for the waste loads with < 10% sulphate content, from construction and demolition); and
- **hindered the anticipated increased supply of segregated gypsum wastes.**

6.2 Infrastructure & Institutional Factors

6.2.1 Description of the factors

The main factors that influence the UK capacity for gypsum recycling are:

- Economic viability of investment in recycling infrastructure;
- Technical ability to provide marketable material;
- Ability to obtain sufficient and consistent supplies;
- Market stability;
- Logistics within, and attitude of, the construction and demolition sectors in relation to waste disposal and recycling.

6.2.2 Discussion of the factors

Each of these factors are discussed below in the context of the findings of this report:

Economic viability of investment in recycling infrastructure

Although policies, planning and other legislative restrictions are important, infrastructure tends to develop where a demand exists and it is economic for operators to enter a market. Price and demand factors are discussed in Section 6.1.2 above.

The current situation in the UK is one of an emerging market. A number of recycling operators have started to enter the UK market and are indicating that they anticipate increased business. **The recycling market has been undermined by lower than expected arisings of segregated gypsum wastes** (see legislative factors above) – the consequences of which has been that the recycling industry has experienced some difficulty demonstrating its ability to meet the quality and supply requirements of the plasterboard industry. Confidence in the market is therefore currently fragile, and this could undermine future recycling opportunities.

Technical ability to provide marketable material

The technical equipment currently used in the UK for the recovery of gypsum from gypsum wastes is reported to be successful when treating:

- Production off-cuts;

- Returned un-used board;
- Segregated construction wastes.

Recyclers reported that they can process wet and dry material.

Certain types of specialist plasterboards (e.g. foil backed) cannot be recycled using today's technology, as the foil cannot be separated to a sufficiently high degree to meet plasterboard production requirements.

Plasterboard manufacturers using desulphogypsum require the particle size of the recycled material to be more tightly controlled than those that whose main raw material is natural gypsum. There is an indication that it is not possible to incorporate as much recycled gypsum where DSG is used as the main feedstock.

Demolition wastes give rise to additional concerns because of the difficulties in managing potential contamination with undesirable substances. Examples reported of such substances were asbestos and lead (from old paints). **In general, demolition waste is seen as a less desirable source of recycled gypsum** because:

- Demolition practice often prohibits effective segregation;
- Contaminant levels may be high, resulting in the recycled gypsum being difficult to quality assure;
- Quantities of suitable material may be lower as plasterboard is mainly used in newer buildings while older buildings are most commonly those demolished, and very old plasterboard often being of a much lower quality gypsum than currently required.

However, recyclers reported that they do accept segregated waste plasterboard from demolition and refurbishment sites, and successfully process it to an acceptable quality recycled gypsum.

Ability to obtain sufficient and consistent supplies

The following findings are of interest in respect of the ability of the current recycling infrastructure's ability to deliver increased recycling of gypsum:

- The current quantity of gypsum supplied is estimated to be in the order of 0.07 Mtpa;
- Current capacity for recycling gypsum is estimated at 0.175 Mtpa (i.e. there is already capacity to double current UK gypsum recycling rates);
- At a substitution rate of (only) 10% recycled gypsum into plasterboard manufacture (it was reported that up to 25% may be possible) the additional demand predicted for recycled gypsum would be 0.4 Mtpa;
- The estimated quantity of gypsum waste being landfilled from the construction and demolition industry is approximately 1 Mtpa;
- Plasterboard manufacturers report a degree of concern about the quality of recycled gypsum, but appear to be in a position to take more recycled material than is currently supplied if these concerns can be allayed.

From this it may be concluded that, in this emerging market, quality and quantity of supplies of recovered gypsum do not appear to have been fully demonstrated. Improvements in infrastructure, for example additional investment in collection bins and skips, transfer and bulking stations, and recycling machinery, may be expected to increase the recycling industry's ability to provide sufficient material of the required quality. However, it should again be noted that the risk of investment in such infrastructure is higher while the supply market is undermined by continued low cost disposal.

Market stability

A lack of stability in the market does not sufficiently allow long term planning for the investments in infrastructure that are required.

With the demand for gypsum predicted to grow significantly, **the main factors impacting upon market stability relate to fluctuations in the price of alternative sources of gypsum, and legislative uncertainties impacting upon arisings of segregated plasterboard waste**. These factors are discussed above.

Logistics within, and attitude of, the construction and demolition sectors in relation to waste disposal and recycling

The main potential sources of recyclable gypsum are the construction and demolition industries.

Concerns have been reported about potential contamination of plasterboard from demolition sources, and quality issues with the resulting recycled gypsum.

Plasterboard waste from construction sites is generally cleaner and less contaminated, comprising items such as over-ordered material and segregated off-cuts, and as such is particularly suited to recycling.

Therefore, despite the potentially large arisings of plasterboard waste from the demolition sector, **the construction sector has the greatest potential for the supply of suitable waste plasterboard for recycling.**

The barriers to increasing the on-site segregation of construction wastes that would support additional recycling, were discussed in Section 5.1.3. Project size is a key factor. The segregation of plasterboard waste will be more cost effective on large projects. Small-scale builders often rely on the own transport (or skips) and upon local waste management facilities. The effective segregation of waste gypsum products in such circumstances is significantly more difficult to achieve.

Noting the high levels of inertia and conservative nature of the construction sector, **without a strong legislative and / or financial incentive change in construction industry practice is unlikely, particularly at smaller sites, resulting in continued high landfill rates and reduced supply of recyclable material.**

7 Glossary

Anhydrite	Anhydrous calcium sulphate, $CaSO_4$
BAT	"Best Available Techniques" a term described in the IPPC Directive EC/96/61
Calcination	The process of heating gypsum to produce the hemi-hydrate
Desulphogypsum	Gypsum derived from the use of lime based flue gas desulphurisation
EC	European Commission
EU	European Union
Exothermic	A chemical reaction that releases heat
Flue gas desulphurisation	A technique applied in industry for the reduction of sulphur emissions, often producing gypsum as a by-product
Fluorogypsum	A by-product from the manufacture of hydrofluoric acid
GW, Gigawatt	1 GW = 10^9 Watts. Gigawatts provide a measure of the electricity generation at a power station
Gypsum	Calcium Sulphate Dihydrate, $CaSO_4 \cdot 2H_2O$
IPPC	Integrated Pollution Prevention and Control – title of EC Directive 96/61 on the control of pollution at industrial installations
ktpa	Thousands of metric tonnes per annum
Mtpa	Millions of metric tonnes per annum
Natural gypsum	Mined virgin gypsum
Plaster of Paris	Calcium sulphate hemihydrate or calcined gypsum $CaSO_4 \cdot ½H_2O$
Synthetic gypsum	Gypsum produced as a by-product of industrial processes
tpa	Metric tonnes per annum
Titanogypsum	Gypsum produced a by-product of manufacturing titanium dioxide
Virgin gypsum	Mined gypsum (not desulphogypsum)

8 Annexes

8.1 Annexe 1

UK Companies that when contacted, indicated initial interest in gypsum recycling	Address
ADS	63 Camsley Lane, Lymm, Warrington, Cheshire, WA13 9BY
Alco Waste Management Ltd	Dixon House, Joseph Noble Road, Lilly Hall, Workington, Cumbria, CA14 4JH
Alex Smiles Ltd	Wellington Land, Deptford, Sunderland, Tyne & Wear, SR4 6DA
Amber Services	The Recycling Centre, Dyffryn Business Park, Ystrad Mynach, Caerphilly, CF82 7RJ
Baileys of Norfolk	Brick Kiln Road, Hevingham, Norwich, Norfolk, NR10 5NL
Bardon Recycling - Bordelsley Green Depot	251 Bordesley Green Road, Bordesley Green, Birmingham, West Midlands, B8 1BY
Battleby Landfill Site	Redgorton, Luncarty, Perth, Perthshire, PH1 3EN
Biffa	Head office, Coronation Street, Cressex, High Wycombe, HP12 3TX
Birkenhead Waste Transfer Station	1 Jackson Street, Birkenhead, Wirral, CH41 5DJ
BKP Environmental Services	Casbrook Park, Bunny Lane, Timsbury, Hampshire, SO15 0PG
Bloomfield Recycling	Bloomfield Road, Tipton, West Midlands, DY4 9BS
Bowhill Recycling Facility	B981 Jamphlars Road, Lochgelly
Britannia Crest Recycling	26 Reigate Road, Hookwood, Horley, Surrey, RH6 0HJ
Builders Site UK	23 St Dogmaels Avenue, Llanishen, Cardiff, South Glamorgan, CF14 5PZ
City Centre Commercials Ltd	Tower House, Stopgate Lane, Simonswood Industrial Park, Kirkby, L33 4XY
Cleanaway	The Drive, Warley Business Park, Brentwood, Essex, CM13 3BE
Cockshute Sidings	Shelton New Road, Shelton, Stoke-on-Trent, Staffordshire, ST4 7DL
Comley & Sons	Calf Lane, Calf Lane Quarry, Farnham, Surrey, RG29 1HU
D J Broady	Foster Street Recycling Centre
Day Aggregates Ltd	Transport Avenue, Great West Road, Brentford, Middlesex
Deptford Recycling Centre	Landmann Way, Off Surrey Canal Road, Deptford, SE14 5RS
Eagle Recycling	Headswood Mill, Dennt, Falkirk, Scotland, FK66BL
Eastern Waste Disposal	Morses Lane Industrial Estate, Brightlingsea, Essex, CO7 OSD
Easy Load Ltd	Lees Yard, Old Rochester Way, Dartford, Kent, DA1 3QU
Econ Construction Ltd	The Chalk Pit, Old Maidstone Road, Ruxley, Sidcup, Kent, DA14 5AZ
Envar Ltd	Hollyshaw House, Whitkirk, Leeds, LS15 7BD
Envirowaste	Office 1 Swalesmoor Road, Boothtown, Halifax, West Yorkshire, HX3 6UF
Erith Waste Management Services Ltd	
Four Leaf Enterprises Ltd	Norwich Road, Carbrooke, Watton, Norfolk, IP25 6TJ
Glenside Recycling Ltd (Smethwick)	Victoria Street, Smethwick, West Midlands, B66 2ND

Gypsum Recycling International	Gypsum Recycling International A/S, Leopardvej 2, 7700 Thisted DENMARK
Hassall A & J	Broughton Mill Road, Bretton, Flintshire, CH4 0BY
Hopkinson Reclamation Ltd	Slitting Mill, Waste Disposal Site, Eckington Road, Staveley, Chesterfield, S43 3YG
J A Slater (Bromsgrove) Ltd	George Bayliss Road, Berry Hill Industrial Estate, Droitwich, Worcestershire, WR9 9RB
Ken Hope Recycling Ltd	Hespin Wood, Todhills, Rockcliffe, Carlisle, Cumbria, CA6 4BJ
Knauf Drywall	P.O. Box 133, Sittingborne, Kent, ME10 3HW
L & B Haulage + Civil Engineering Contractors Ltd	Hannah Close, Great Central Way, Neasden, London, NW10 OUX
L A Moore Ltd	Old Railway Yard, Haybridge, Wells, Somerset, BA5 1AH
Lafarge Plasterboard Limited	Marsh Lane, Easton-in-Gordano, Bristol, BS20 0NF
Manchester Tippers & Aggregates Ltd	Upper Wharf Street, Salford, Manchester, M5 4TY
Neales Waste Management	Stanley Street, Waste Transfer Station, Blackburn, Lancashire, BB1 3BW
Onyx	Onyx House, 154a Pentonville Road, London, N1 9PE
Plasterboard Recycling UK Ltd	41-43 Maddox Street, London, W1S 2PD
Premier Waste Management Ltd	Joint Stocks Landfill Site, Coxhoe, Durham, DH6 4RT
Recycled Rock and Aggregate	Warren Farm, Downend Road, Fareham, Hampshire, PO17 6AL
Robin Concrete & Waste Disposal Ltd	Foster Street Recycling Centre, Hull, East Yorkshire, HU8 8BT
Ron Smith Recycling	St Albans Farm, Staines Road, Feltham, Middlesex, TW14 0HH
Roy Hatfield Limited	Fullerton Road, Rotherham, UK, S60 1DH
Saxilby Enterprise Park	Saxilby, Lincolnshire
SBH Crushing & Recycling Ltd	61D Ivy Court, High Street, Nailsea, Somerset, BS48 1AL
Shanks	Frog Island Waste M'ment Facility, Creek Way, Rainham, Essex
SITA	
Skipaway Ltd	Pelican Reach, Clipper Cloase, Medway City Estate, Rochester
Sloyan Doyle Recycling Centre	Simonswood Trading Estate, Stopgate Lane, Simmonswood, Kirkby, West Lancashire, L33
Smiths (Gloucester) Ltd	Alkerton Court, Eastingston, Stonehouse, Gloustershire, GL10 3AQ
Snowie Ltd	Unit 1-4, Abbotsinch Road, Abbotsinch Industrial Estate, Grangemouth, Stirlingshire, FK3 9UX
Southworth Quarry	Winwick Lane, Winwick, Warrington, Cheshire, WA3 7EW
SRM	Customer Service Centre, Middleton Road, Morecambe
T Richard Jones	Betws Industrial Park, Foundry Road, Aimmanford, SA18 2LS
Tarmac Recycling Ltd	Millfields Road, Ettingshall, Wolverhampton, West Midlands, WV4 6JP
Taurus Waste Recycling Transfer Station	Old Bus Depot, Moulsecoomb Way, Moulsecoomb, Brighton, East Sussex
Teesside Waste Management	Normandy Wharf, Dockside Road, Cargo Fleet, Middlesborough, Cleveland, TS3 8AT
Thanet Waste Management	Manston Road, Margate, Kent, CT9 4JW

The Foundry	Common Lane, Wath-upon-Dearne, Rotherham, South Yorkshire, S63 7DX
Todd Waste Management	Rufforth Air Field, Rufforth, Yorkshire, YO23 3QA
Viridor Waste Management	Great Western House, Station Approach, Taunton, Somerset, TA1 1QW
Water Hall Quarry	Lower Hatfield Road, Hertford, Hertforshire, SG13 8LF
Wesley Way	Benton Square Industrial Estate, Newcastle Upon Tyne, NE12 9TA
WM Tracey Ltd Materials Recycling Facility	49 Burnbrae Road, Linwood Industrial Estate, Linwood, Renfrewshire, PA3 3BD
Woods Waste Recycling Plant	Westby Landfill Site, Annas Road, Westby, Blackpool, Lancashire, FY4 5JY
Woolston Recycling Centre Southampton	Willments Shipyard, Hazel Road, Woolsten, Southampton, Hampshire, SO21 7HS
Yorwaste	Harewood Whin Landfill Site, Tinker Lane, Rufforth, York, YO2 3RR

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