# CILT Level 6 Advanced Professional Diploma

# Strategic supply chain management

## CASE STUDY

**INSTRUCTIONS FOR CANDIDATES**

You will be expected to demonstrate your knowledge and understanding of relevant theoretical principles, concepts and techniques; to apply these appropriately to the particular situation described in the case study; and above all, to make sound decisions. You will not gain marks by writing a general essay on the topic.

***Please note that all work should be your own. Copying or plagiarism will not be tolerated and could result in no marks being awarded. If quotes or short extracts are used they should be attributed or the source of the information identified.***

You should acquaint yourself thoroughly with the case study.

## CASE STUDY – 'FRACKING' FOR GAS

*This case has been produced for assessment purposes only. It has been sourced from the articles indicated within the reference list, which are available in the public domain. It contains a number of direct extracts and quotations which have been referenced within the text.*

*The views and opinions expressed within the case are those of the authors of the reference material and are not necessarily the views or opinions of NIRTC or the companies mentioned. The case may not reflect the actual situations of the specific companies mentioned.*

*The case was written in January 2015 and may not reflect the current situation. Candidates are advised to base their answers on the situation depicted in the case.*

**A glossary of the terms used can be found at the end of the case study.**

## INTRODUCTION

Barrack Obama, 44th President of the United States of America, made the following remarks in his State of the Union Address delivered to the American Congress in January 2012.

> *"... with only 2 percent of the world's oil reserves, oil isn't enough. This country needs an all-out, all-of-the-above strategy that develops every available source of American energy. A strategy that's cleaner, cheaper, and full of new jobs.*
>
> *We have a supply of natural gas that can last America nearly 100 years. And my administration will take every possible action to safely develop this energy. Experts believe this will support more than 600,000 jobs by the end of the decade. And I'm requiring all companies that drill for gas on public lands to disclose the chemicals they use. Because America will develop this resource without putting the health and safety of our citizens at risk.*
>
> *The development of natural gas will create jobs and power trucks and factories that are cleaner and cheaper, proving that we don't have to choose between our environment and our economy. And by the way, it was public research dollars, over the course of 30 years, that helped develop the technologies to extract all this natural gas out of shale rock – reminding us that government support is critical in helping businesses get new energy ideas off the ground"* (25).

In the USA from 1986 until 2006, consumption of natural gas far exceeded domestic production, whereas in the past, the country had managed to more or less produce sufficient for its needs without having to rely on imports from Canada. Innovations and engineering advances in the extraction of natural gas from previously inaccessible deep shale beds resulted in a very dramatic shift from 2006 onwards, as companies moved rapidly to exploit the massive supplies of natural gas and other hydrocarbons locked in these rock formations. The change in the market dynamics was very rapid, with natural gas extracted from these sources increasing to 30% of overall production in 2010 from only 10% in 2007(11). Much of the gas extracted from deep shale beds is recovered through a controversial process known as 'fracking', the fracturing or creating of fissures in the shale beds through which gas and other hydrocarbons can be released.

The impact of this increase in domestic production on market prices for natural gas has been equally dramatic, with the spot price (New York Mercantile Exchange) hitting a record low of $1.82 per MBThU on 20 April 2012 compared to $12.69 in June 2008 – a drop of 86%. This now makes natural gas prices in the USA lower than diesel and petrol (11) and a third of what they are in Europe (10).

It is not hard to imagine the effect that this reduction in price and increased supply of domestically produced natural gas has had on the economy of the United States. Half the homes in the USA are supplied with natural gas and this accounted for 21% of natural gas consumption; 14% of consumption went to commercial buildings; energy generation consumed a further 30% and is the largest user, and around 27% of natural gas was used by industry both as a raw material[1] and as a source of heat. It is worth noting at this stage the strategic significance of natural gas as a raw material in the production of fertiliser, antifreeze, plastics, pharmaceuticals and fabrics. It is also used to manufacture a wide range of chemicals such as ammonia, methanol, butane, ethane, propane and acetic acid. (3) There is also significant future potential for the development of vehicles fuelled by natural gas which produce 60–90% less smog-producing pollutants and 30–40% less greenhouse gas emissions than vehicles running on diesel or petroleum (3). It is not difficult to see how the impact of much lower prices and an abundant supply of natural gas affects the whole economy and where and how some of the increased number of jobs referred to by President Obama may be generated.

There has also been an environmental benefit according to some analysts, with a shift from the use of coal to gas in the production of electricity. This has resulted in a very significant reduction in the emission of carbon dioxide ($CO_2$). $CO_2$ emissions from burning coal are more than twice those caused from burning gas, and the US Energy Information Administration (EIA) (1) reported that domestic emissions in 2012 (1st quarter) of $CO_2$ fell to the lowest level recorded since 1992. Because of the switch from coal to gas fired power stations and the laying idle of some of the older less efficient coal-fired power stations, levels of sulphur dioxide (primary cause of 'acid rain') have also sharply fallen (11).

Opponents of shale gas extraction point to the fact that methane (natural gas) contributes far more to the greenhouse effect and global warming than carbon dioxide. One of the main environmental concerns is the danger of methane escaping during the extraction of shale gas. However, regulatory bodies in the USA are also concerned to ensure that standards are developed and maintained so that such escapes are prevented at oil and gas wells.

Ironically, the historically low prices of natural gas in the USA could have an impact upon production, since the cost of shale gas extraction is quite high, and the break-even price for profitable extraction was estimated in October 2012 to be at around one-and-a-half times the spot price for natural gas. In order to remain economically viable, therefore, prices and revenue would need to increase. That can either be achieved by reducing the amount of gas extracted, in effect cutting back on the amount of drilling, or by increasing the sales revenue. The latter may be achieved domestically if the use of compressed natural gas (CNG) for transportation becomes more widespread, but a bigger and more immediate impact may come from exports, especially since the price of natural gas in Europe and Asia can be five to seven times higher than in the USA (11). However, at the time of drafting this case, companies are not allowed to export liquid natural gas (LNG) from the USA to countries with which it does not have a free trade agreement. This would, therefore, exclude countries with potentially very high demand, such as Japan, members of the European Union, and fast-growing markets in Asia, such as China and India. Only one licence has been granted to export to such countries so far, but already there are nineteen further licence applications lodged with the Energy Department, and Barack Obama has stated that by 2020 the US is likely to be a net gas exporter (12). It has been estimated that companies are investing as much as $120 Billion in North American export projects, with 31 proposed export facilities applying for federal approval (27).

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[1] e.g. fertiliser, antifreeze, plastics, pharmaceuticals and fabrics. It is also used to manufacture a wide range of chemicals such as ammonia, methanol, butane, ethane, propane and acetic acid. (Geology.com)

In an article in the Daily Telegraph on the 11 August 2013, David Cameron, the UK Prime Minister, stated that:

> *"Fracking has real potential to drive energy bills down. ... It's simple – gas and electric bills can go down when our home-grown energy supply goes up. We're not turning our back on low carbon energy, but these sources aren't enough. We need a mix. Latest estimates suggest that there's about 1,300 trillion cubic feet of shale gas lying underneath Britain at the moment – and that study only covers 11 counties. To put that in context, even if we extract just a tenth of that figure, that is still the equivalent of 51 years' gas supply.*
>
> *This reservoir of untapped energy will help people across the country who work hard and want to get on: not just families but businesses, too, who are really struggling with the high costs of energy. Just look at the United States: they've got more than 10,000 fracking wells opening up each year and their gas prices are three-and-a-half times lower than here. Even if we only see a fraction of the impact shale gas has had in America, we can expect to see lower energy prices in this country.*
>
> *Secondly, fracking will create jobs in Britain. In fact, one recent study predicted that 74,000 posts could be supported by a thriving shale-gas industry in this country. It's not just those involved in the drilling. Just as with North Sea oil and gas, there would be a whole supply chain of new businesses, more investment and fresh expertise"* (2).

Substantial shale gas basins have been identified in Europe (see exhibit 1) and access to this local source of natural gas could be very significant for Germany, for example, where the country is switching from nuclear power generation to coal-fired power and imported gas. In addition to the obvious benefits of lower gas prices and abundant domestic supplies, industry is also concerned that failure to exploit the shale gas deposits in Europe could widen the competitive gap with the United States.

*"I think it's simply irresponsible to declare that we don't need [shale gas] and we don't want [shale gas] here in Europe".* Kurt Bock, CEO of BASF

*"Energy-intensive industries, such as the petrochemical industry, may soon begin to leave Europe for the U.S. because of the abundance of cheap energy there".* Gerhard Rois, COE of OMV, (cited in 17)

In their article, 'Europe's shale gas competitiveness challenge and consequences for the petrochemical sector', (2013) Philippe & Cool (17) point to the fact that, although exploitation of shale gas reserves in Europe will cost more than in the USA, it would still produce a marked downward shift in the price of gas and narrow the competitive gap with the USA. Failure to do so, they suggested, could result in petrochemical companies re-locating to the United States in order to remain competitive. This view has, however, been challenged on the basis that such gas wells show a marked decline in output over a shorter space of time than for conventional oil or gas wells and that this could eventually have an upward effect on gas prices. However, in the USA, industry leaders, such as Taylor Robinson and Graham Brisben – president and CEO, respectively, for PLG Consulting are talking of something they call 're-shoring' – basically the return of manufacturing businesses from off-shore back to the United States, fuelled by the cheap energy prices arising from shale gas production.

In Poland and Russia, tax incentives have boosted gas exploration and, although there is no published estimate for shale gas reserves in Russia and no production, it is estimated that the shale beds in Western Siberia may be the world's richest. Russia is the world's largest producer of natural gas, and much of Poland's requirements are fulfilled by importing from Russia. Poland's Finance Minister has stated that the country will invest 50Bn Zlotys ($16Bn) by 2020 in shale gas exploration with the hope that this could provide a more beneficial economic and political alternative to importing. In Hungary, a joint venture was created in 2007 between ExxonMobil Hungarian Gas and oil company MOL to explore and evaluate potential for unconventional oil and gas. Potential target areas also include the Baltic, Bulgaria, France and The Ukraine.

**'FRACKING AND PROPPANTS'**

The term 'Fracking' is a shortened version of 'Hydraulic Fracturing'. This is a process whereby hydrocarbons such as natural gas (methane) that are tightly bound into deep layers of shale can be released by 'fracking' or fracturing the shale bed. This process involves what is known as 'horizontal drilling' and fracking wells are often described as 'horizontal wells' (see Exhibit 2).

According to Geology.com, shale is:

> *"A fine-grained sedimentary rock that forms from the compaction of silt and clay-size mineral particles that we commonly call 'mud'. This composition places shale in a category of sedimentary rocks known as 'mudstones'. Shale is distinguished from other mudstones because it is fissile and laminated. 'Laminated' means that the rock is made up of many thin layers. 'Fissile' means that the rock readily splits into thin pieces along the laminations"* (3).

Drilling for shale gas involves sinking a drill vertically to around a kilometre (but can be much deeper) or until it reaches the shale bed. The drilling then takes another direction and turns horizontally to run along the shale bed where the gas or oil is trapped. It has to be remembered that methane is not only an explosive and highly flammable gas (as is ethane, which is also present), but it is also a more powerful contributor to the greenhouse effect than carbon dioxide, so every effort has to be made to ensure that it does not escape into the environment. Hence, before the fracking commences, the well is first lined with a steel casing which is cemented into place. Only then is the horizontal section of the well perforated by explosives and water pumped down under very high pressure, which creates fissures in the shale bed that expand rapidly and through which the gas is released. At these depths the pressure of the rock is enormous, and in order to prevent the fissures from simply closing again and trapping the gas, something is needed to keep them 'propped' open. This is known as a 'proppant' and supplies of this material are essential to the whole process, as is the supply of large amounts of liquid. This liquid is water treated with a cocktail of chemicals to produce a viscous gel that can carry the 'proppant' particles in suspension. The chemically treated water, together with thousands of tons (for each well) of proppant particles, are pumped down the well and into the fissures at very high pressure. The fluid flows back to the surface and is collected in storage facilities, leaving the proppant particles behind 'propping' open the fissures created in the shale rock formation. Usually around 40% of the water flows back to the surface within the first few weeks after the well starts to function but most of it returns during the lifetime of the well. Another good reason for casing the well in steel and cement is to prevent the proppant fluid from leaking into the aquifer[2] and contaminating the water supply, either when it is forced into the well, or on its return.

The proppant can be either in the form of silica or 'frac-sand', as it is commonly known, which occurs naturally and is mined, or can be ceramic beads manufactured from kaolin or sintered bauxite or sand coated in a hard resin. When the water pressure is released, the fissures created in the shale start to close, but they are prevented from doing so by the particles of sand or other proppant that keep them open and create pores through which the gas and petroleum fluids can flow into the well. This will only happen if enough of the proppant particles have been delivered at pressure through the well and into the fissures in the shale bed.

Hydraulic fracturing (Fracking) uses substantial volumes of water in the process. In the USA it is estimated that there can be up to 25 stages in a single well site, with each stage in the fracking process requiring around four hundred thousand gallons of water – that could mean a possible total of more than 10 million gallons of water in order to bring the well into operation. It is absolutely imperative that the supplies of proppant and liquid to the well sites are uninterrupted and continuous once fracking has commenced. This key strategic requirement underpins all aspects in the design and management of the supply network.

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[2] "An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well" (en.wikipedia.org)

Water returning to the surface is contaminated with chemicals from the process itself and also from the rock formations (this may include some radioactive elements in certain rock formations), so great care has to be taken to ensure that the water does not come into contact with the aquifer layer during the process of fracking itself or when returning to the surface. The returned water can be stored in lined ponds or tanks and is either treated on site to remove chemicals or sent away for treatment (11). In the United Kingdom, Cuadrilla, a gas exploration and recovery company, discloses all chemicals used in treating water for this process and these additives are approved by the UK Environment Agency (UKEA). Returned water is also tested by the UKEA and is removed for treatment at an UKEA approved plant (4). In order to protect groundwater from accidental spillage, for example, Cuadrilla in the UK prepares its drilling sites with a thick impermeable membrane prior to the commencement of operations.

In the USA, petrochemical companies involved in fracking have been reluctant to disclose the chemicals and gelling agents added to the water in the fracking process, claiming that this is proprietary information and commercially sensitive. However, under proposals outlined in the President's State of the Union address, this may become a legal requirement. Caudrilla asserts that the UK Environment Agency has declared the chemicals it uses in the fracking process present no danger to human health and the list of chemicals and concentrations is published on its web site (4).

Research suggests that there is no danger of gas or chemicals from the shale beds themselves contaminating the aquifer, since these shale beds are many thousands of meters below the aquifer and separated by very wide and dense formations of impermeable rock. The main danger lies in contaminated fracking water escaping through fractured or improperly sealed well casings or spillage and leakage from on-site containment facilities.

**PROPPANT QUALITY AND SPECIFICATION**

Proppant may be in the form of powdered bauxite, ceramic material or silica (sand).

> *"Powdered bauxite can be fused into tiny beads at very high temperatures. These beads have a very high crush resistance and that makes them suitable as a proppant. They can be produced in almost any size and in a range of specific gravity. The specific gravity of the beads and their size can be matched to the viscosity of the hydraulic fracturing fluid and to the size of fractures that are expected to develop in the rock. Manufactured proppants provide a wide selection of grain size and specific gravity compared to a natural proppant known as frac sand.*
>
> *World bauxite resources are adequate for decades of production at current rates. Other materials could be used instead of bauxite for alumina production. Bauxite is found in abundance at many locations around the world. In 2010 the ten leading bauxite producing countries were: Australia, China, Brazil, India, Guinea, Jamaica, Russia, Kazakhstan, Suriname and Greece. Each of these countries has enough reserves for many years of continued production. Some have reserves for over 100 years of production"* (3).

Unlike frac-sand or silica, sintered bauxite and ceramic proppants are mainly imported into the United States from countries in Asia.

There is a growing market for essential supplies – notably the water and proppant necessary for the fracking and extraction process.

Industry and news media reference to the use of frac-sand may suggest that the main proppant is sand that can be gathered from beaches or any sand mine anywhere. However, this is not the case. The sand itself must be high purity quartz (silica) and this can only be obtained from sand deposits that have been formed in a particular manner. The sand itself can vary in quality but the industry requires frac-sand to be highly weathered so that it has achieved a high degree of uniform roundness. The rounder and more uniform the sand grains, the more they can withstand the forces exerted upon them by the rock during the fracking process.

The return on investment (ROI) of wells depends on the speed and rate of extraction. Put very basically: the more gas or oil you can get out of the well and the quicker you can extract it, the higher your ROI would be. There are however, other variables to take into account, one of which is the cost of the proppant and the associated supply chain and logistics costs. A harder and more uniform ceramic proppant will be more costly and would almost certainly need to be imported and these increased costs would have to be balanced against the efficiency gains and other variables associated with the geology of the well. One company has estimated that the use of ceramic proppant in field trials produced an increase in productivity in excess of 20% and also resulted in an increase of more than 20% in the total amount of oil or gas recovered from the well than the use of sand-based proppants.

> *"Some have said that the ideal proppant is lighter than water, stronger than diamonds and cheaper than dirt. In short, it does not exist"* (28).

So in summary; the more uniform and stress resistant proppants are more costly but can be more productive[3]. This tends to be the case where the wells are deeper and the pressure and temperatures are greater. Where the wells are shallower, such as in the UK, for example, the less costly and often more readily available frac-sand is more likely to be used than imported resin coated or ceramic proppant. It is estimated that the UK has abundant recoverable shale gas deposits at depth, and this, together with other complex geological conditions will almost certainly require the use of a wider range of proppant in the future. In fact, choices of proppant types are becoming wider as more knowledge is gathered and more testing under field and laboratory conditions is conducted. Choice of the ideal proppant may be finalised only after the first fracking has taken place and test results indicate the best proppant type for the particular conditions. Some economic modelling which balances the costs of the proppant supply, likely gas market prices and the productivity of the well is also required as part of the selection process in order to ensure a satisfactory ROI.

**SUPPLY and LOGISTICS**

As the commercial and geo-political realities of the massive oil and gas reserves locked up in deep shale rock formations are realised throughout the world, global extraction of these valuable hydrocarbons will rapidly increase. The worldwide demand for proppants, such as silica, may well follow the trend experienced in the USA, where more than 13 million tons of silica proppant are now being used annually for hydraulic fracturing, a ten-fold increase over a ten year period. Clearly, in such a situation, the companies that develop competence in strategic management of the global proppant supply network will have a definite competitive edge over their rivals.

The main issue is always the balance between the cost of extracting the shale gas and the spot price of the natural gas or oil and other hydrocarbons recovered by the wells. In Argentina, where there are substantial shale gas basins in desert areas and where the cost of doing business is much less than the in the United States, this is a major issue. A recent congress held by the industry to focus on this highlighted the following challenges:

> *"For those that have drilled and completed pilot wells, the main difficulties have been importing sufficient proppant to complete the wells on time and identifying where to get the water required for fracking in the middle of the desert – at low enough costs. It is no secret therefore, that proppant supply and water management, will play an integral role in the future development of … major shale basins"* (24).

[3] This is a broad generalisation for the purposes of this case and it is appreciated that the whole process of selecting the best proppant for a particular well is highly complex and dependent on a number of variables, some of which are not known until the performance of a particular proppant within a fracture has been analysed.

By now it should be apparent that very substantial bulk quantities of frac-sand (or other proppant) and water are required for each well. According to a recent KPMG study (9) comparing shale gas extraction in the USA with the European Union (EU), water usage can strain a project's rate of return, given the substantial additional costs of water supply from distant sources. In the USA, the water is either extracted from lakes and rivers, or purchased from utility companies, or flow-back water that is recycled. Delivery is by a combination of tanker truck and pipeline (if the water is available within two to three kilometres of the well site).

In the UK so far, all of Cuadrilla's water has been sourced from the mains water supply – from water utilities companies. This is, however, a much smaller exploratory operation compared with the United States, but even the relatively small scale operation at Preese Hall in Lancashire used 8,400 cubic metres of water (approximately 2 million gallons).

This water requirement represents a major problem for some countries such as India, Australia and Argentina, where the shale beds are often in areas of desert or semi desert, where plentiful water supplies are a major problem.

In the UK and mainland Europe the distances between the shale bed formations and population centres is shorter than in the USA and the competition for water is likely to be greater, and this could cause an upward pressure on prices of water. It is necessary, therefore, to develop cost effective and safe solutions for the sourcing, disposal and treatment of water during hydraulic fracturing operations (9).

The issue is not just the cost of proppants and water but also the availability – 'can frac-sand be obtained locally or does it need to be imported?' – is a key question, as is the understanding of the supply chain and the logistics involved, and how the total cost of ownership is structured. For example, the oil and gas industry in the USA consumes more than half the value of all commercial grade silica mined there, with the glass industry the second largest consumer with nearly 20%.

The type and size of proppant can vary considerably and the choice of proppant will have a big impact on the productivity of the well. The nature of the geology will help determine whether sand, resin coated sand or light weight, intermediate weight or heavy weight ceramics would be suitable. By volume, sand is by far the most heavily used proppant. Treated sand and other ceramic proppants are more expensive but may be more productive in certain rock formations. The engineers and geologists at the well have to make a choice on proppant type, which will depend on the specific geological conditions encountered in that drilling area – this then has to be communicated to the supply chain in a timely manner, so that there is no delay in drilling, and that the correct, most productive proppant, is supplied.

Most of the ceramic proppant (99%) used in the United States is imported – which further adds to the cost and to issues of conformance and quality. Ceramic proppant and sintered bauxite – although much lower in volume – account for almost the same market share by value as silica in the United States.

The rapid development of oil and gas shale reserves in the USA has driven the requirement for proppant to the extent that the industry has to manage the sourcing and delivery of over 30 million metric tonnes of frac-sand to gas shale drilling sites. Technical developments in the ability to drill further horizontally, faster drilling and the opening of more fracking stages in each well, have contributed to this rapidly increasing demand for proppant.

In the USA the efficiency of logistics is a major factor in whether or not a well is profitable, since a very high proportion of the TCO (Total Cost of Ownership) of proppant is the cost of transportation and storage. Large companies with experience and scale in this type of bulk processing and transportation clearly have an advantage and in the USA they dominate the business. Given the size of the country and the amount of naturally occurring frac-sand deposits, the agreements with railroad companies and the proximity of processing plants and deposits to rail heads are crucial factors in achieving efficiencies in logistics, and these contribute a great deal in bringing down the completion costs for each well. In the United States most of the drilling supplies needed for shale oil and gas extraction, such as proppant (frac-sand and ceramics) and chemicals and even water, are delivered by rail (20).

In the UK, the only dedicated rail link used to transport silica sand is from Kings Lynn on the east coast to glass producers in the north of England. Most of the silica sand production in the UK is transported by trucks and bulk tankers from the quarries and processing plants. However, according to the British Geological Survey – Minerals Planning Factsheet (2009), there is also planning pressure from the government for less damaging alternatives to road transport at sites with a long term future (15).

It has been estimated by PLG Consulting in the USA that only 42% of the total delivered cost of frac-sand to the well site is the actual processed sand and that around 60% of the total delivered cost is driven by logistics.

Significant areas adding to the cost of logistics for proppant in the United States are:

- Sub-optimal logistics network design or infrastructure[4]
- Uncompetitive sand price
- Above market rail rates
- Manifest service[5] vs. Unit train[6]
- Poor planning and execution[7]
- Rail or truck demurrage costs[8]
    - Performance penalties
    - Equipment/driver shortages
- Cost of Poor Quality (COPQ)[9]

It is also worth remembering that once the drilling and fracking start, there must be a 24/7 continuous supply of proppant and water with no interruptions, and this puts pressure on the supply chain and on the logistics, in particular. Running out of proppant during this process would be very costly and could result in the closure of the well.

When comparing the extraction of shale gas by hydraulic fracturing in the USA with operations in the UK and EU, it is worth noting that equipment, technical know-how and services are not developed in the EU to anything like the extent they are in the USA. There are nearly 2,000 land drilling rigs operational in the USA compared with only 72 in Europe, for example. All of the available drilling equipment is currently in use in the USA with little or none spare for export to Europe and the lead time for ordering a new rig is from 9 – 12 months (9).

In the UK a key area of discussion and analysis is the extent to which supplies of good quality frac-sand can be sourced domestically. At a recent conference, 'Proppant Prospects for Europe' (16), Clive Mitchell, BGS (British Geological Survey) Communications Team Leader and Industrial Minerals Specialist, presented his findings from a geological survey into UK silica sand resources for fracking. Not all silica sand is suitable for use in fracking, but the UK does have large reserves.

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[4] The proppant industry in the USA has become highly fragmented with at least 60 vendors supplying one major oilfield.
[5] A manifest service in this context would be a mixed freight train where there would be a number of different consignments with different destinations. The proppant would be another freight consignment on the mixed freight manifest. Not a dedicated service.
[6] Unit trains are groups of rail cars (usually from 40 to 120 rail cars) that move as a solid train from a quarry to a unit train receiving yard. The unit train will be powered by dedicated locomotives and crews.
[7] For further information see; Mawet, P.J., Fleming, A.C. & Nichols, J.H., (2012), Eight Leading Practices for the Proppant Supply Chain, Accenture Research.
[8] Significant storage costs are incurred when proppant is held at a transload facility or in railcars. High volume storage facilities are capital intensive. A typical silo in the USA must be able to store 1,500 tons or the amount needed to tap a single well.
[9] It is important to have exactly the right particle specification for the geology of a particular well. This is by no means always the case and variations can be found especially in imported ceramic proppant from the Far East.

The UK is nearly self-sufficient in silica sand, with 40 quarries producing 4M tonnes annually, although the figure was much higher at around 6.3M tonnes in the mid-seventies. Imports and exports of silica sand are relatively small by comparison, at 198K Tonnes exports and 388K Tonnes imported in 2006 (15). More than 50% of silica glass sand in the UK is produced by Sibelco UK Ltd[10] that also supplies Cuadrilla in its UK exploration operations. Sibelco has silica sand operations in Cheshire, Staffordshire, Surrey, Norfolk, North Lincolnshire and Bedfordshire in England and West Lothian in Scotland.

In the planning application for hydraulic fracturing on the Becconsall site, Cuadrilla pointed out that the depths of drilling are lower than for some higher pressure wells where ceramic proppant is more suitable than the frac-sand supplied by Sibelco from its operations in Cheshire. In the application, Cuadrilla stated that each fracture treatment should use about 50 T (Tons) of sand and that this would be delivered via pneumatic tankers each with a capacity of 27 Tons (18).

**UK FRAC SAND SUPPLY – SIBELCO**

Sibelco, a Belgian mineral and mining company, was founded in 1872, initially supplying silica sand from deposits in Flanders to Belgium's major glass producers. Its association with the clay industry stretches back even further, with UK operations producing world-renowned ball clay in the south west of England for over 300 years.

Sibelco supplies a vast portfolio of specialist minerals for use in a wide range of industries and applications. This family owned and run business places a great deal of emphasis on long term planning and on working in close partnership with its customers so it can better understand and meet their evolving requirements. Innovation is an important aspect of business strategy for Sibelco and the organisation operates 26 specialist technical centres worldwide, each focused on a specific application, but driven by market trends and changing customer requirements.

Sibelco produces silica products from reserves in the UK and also a number of other EU countries, as well as Russia and the Ukraine, and is the world's largest producer of fracturing sands (frac-sands). The substantial experience and investment in this industry in North America has provided a sound foundation on which to build its investment in new infrastructure to support the European shale gas industry.

The company claims that products will be delivered to customers on time via its extensive Europe-wide supply chain, and to the exact specification required. It further claims that its products are manufactured to rigid quality control standards backed by specialist technical support and local customer care.

Sibelco has also been awarded the Carbon Trust Standard for the tenth consecutive year, acknowledging its ongoing activities to reduce energy emissions and commit to sustainable mining. (Sibelco.com)

Frac-sand is not used straight from the ground. It requires processing to optimise its performance. After mining it is taken to a processing plant. There it is washed to remove fine particles.

After washing, the sand is stacked in piles to allow the wash water to drain off. This operation is done outdoors and is restricted to times of the year when temperatures are above freezing. After the sand is drained, it is placed in an air dryer to remove all moisture. The dry grains are then screened to obtain specific size fractions for different customers.

Sand that is not suitable for fracking is separated and sold for other uses. Some frac-sand might be resin coated to improve its performance in the fracking operation. This material will be sold as a premium product. After processing, sand is loaded directly into trucks, or train cars for rail delivery.

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[10] Formerly known as WBB Minerals and part of the multinational Sibelco Group with 288 operational sites, in 41 countries on 5 continents – a truly global company.

In the USA some processing plants are located at the mine site. However, processing plants are very expensive to build and are sometimes shared by multiple mines. These are centrally located to several mines and the sand is delivered by truck, train or conveyer. (Geology.com)

**CERAMIC PROPPANT SUPPLY**

***CHINESE IMPORTS***

Proppant produced outside of North America accounts for 20% of world production, but this proportion is growing as more counties begin to exploit their shale gas reserves. At this point it is likely that any demand for ceramic proppant, including resin coated sand, would need to be imported. China is a major exporter of ceramic proppants and the largest company in China in this market is Yixing Orient Petroleum Proppant Co. Ltd., based in Jiangsu, China. This company supplies the major portion of domestic demand and also 15% of the world market outside China, making it one of the largest exporters of ceramic proppants. A range of ceramic proppants has been developed for different geologies and operating conditions by the company and continuing investment has been made in innovation, technical development and improving quality standards. Yixing has obtained ISO 9001 certification for its quality management system by National Quality Assurance Ltd (NQA) of Great Britain (31).

The exclusive distributor for Yixing Orient ceramic proppants in Europe is a company called Hoben International Ltd, a subsidiary of Goodwin plc, a group that specialises in mechanical and refractory engineering within the energy sector. According to its own publicity, *"Hoben International has been chosen by Yixing Orient as exclusive distributors of their Ceramic Proppants for the UK, Denmark and the North Sea hydrocarbon production areas"* (32). Hoben has experience in supplying silicas for North Sea gas production for the past 15 years.

Importers and distributors of ceramic proppant would need to consider such service requirements as full shipping service, maintenance of inventory in order to meet demand, container or break bulk shipments, adequate loading and transhipment facilities to road and rail, substantial warehousing facilities and suitable seaport facilities (especially with regard to frequency of shipments and transhipment and storage).

***A EUROPEAN OPTION***

> *"Poland based Baltic Ceramics has signed a contract to build the EU's first factory producing ceramic proppants, which are used in the process of hydraulic fracturing. Production is scheduled to begin during second quarter of 2015; management expects to supply up to five percent of worldwide proppant demand"* (33).

Most of the investment required for this facility has been provided by the European Regional Development Fund, Polish Agency for Enterprise Development and The National Centre for Research and Development, with the balance generated via a share issue.

It is intended that production will increase from 60,000 tons initially to a maximum eventually of 135,000 tons from a raw materials supply base which a company spokesman has claimed is sufficient for 80 years of production (34). The strategic location of the facility in the town of Lubsko in the West of Poland will enable it to be used as a hub for the supply of proppant to Europe, Africa and the Middle East. *"In the second half of 2014 we plan to open the only Ceramic Proppants Research and Development Centre in Europe,"* said Dariusz Janus, chairman of the Baltic Ceramics Investments board (33). United Oilfield Services also opened a logistics base in Poland in August last year and a hub for Polish operations is being constructed by the major U.S. company, Halliburton (34). Dariusz Janus, head of IndygoTech Minerals, the holding company controlling Baltic Ceramics Investments, has stated that the locational advantage would enable Baltic Ceramics Investments to supply the rest of Europe with ceramic proppant faster and cheaper than US-based producers such as Carbo Ceramics or Imerys (34).

Above all, it must be appreciated that material prices and availability may change and that this can be quite sudden. The type of drilling site and its location may require changes to the normal modes for transporting proppant and water. These will all have implications for the costs and margins, and it is important that companies are able to model and assess the actual and anticipated changes and any trade-offs they are considering. It is imperative in managing the supply chain and sourcing effectively for companies to understand exactly where and how non-material as well as material factors affect the overall cost.

Earlier it was emphasised that supply and logistics formed as much as 60% of the cost of proppant. It was also emphasised that once fracking has commenced there can be no interruption in the supply of proppant or water propellant. These factors indicate perhaps a focus on lean supply strategies. However, the issues discussed in determining and selecting the most appropriate proppant tend to indicate quite strongly a need to react quickly to changes in proppant requirement at the well-head.

## ENVIRONMENTAL CONCERNS

There are mounting environmental concerns regarding the potential damage to the environment caused by the recovery of shale gas and oil onshore via the process of hydraulic fracturing, and these remain a strong obstacle to the global expansion of the shale gas business (9). Fracking by Cuadrilla in Lancashire at a test site may have caused seismic tremors which were felt near Blackpool in 2011, and this became the subject of concern for many opposed to this process on environmental grounds. The main fear is that widespread use of fracking could cause severe earth tremors that would damage property and prove a danger to life. Other studies have disputed this conclusion.

A further concern raised by environmental opponents to the process involves possible contamination of the water supplies by the proppant fluid pumped down the well and the returning waste water. These fears in the USA have been compounded by the lack of disclosure of chemicals in the proppant fluid by the well operators, who regard the chemical composition of the proppant fluid as commercially sensitive. However, in the UK, disclosure is required by the Environment Agency, which also requires assurances about the safe disposal of the waste water.

The movement of proppant by truck and the mining of frac-sand themselves cause concerns for the environment, which is aggravated by forecasts of the potential number of well sites and the distance of the frac-sand mines from the well sites. The well sites themselves occupy relatively small areas – estimated around the size of two football pitches – but the horizontal boreholes can extend for many thousands of metres from the well head itself.

In a recent study by the National Renewable Energy Authority in the USA (11), it was estimated that $CO_2$ emissions could be reduced by as much as 80% by 2050, with most electricity produced by a combination of wind and solar energy, with gas powered generation used to provide back-up in meeting peak demand. This argument is countered, to some extent, by environmental critics of shale gas extraction, who point to the fact that the lower costs of the gas would undercut renewable energy sources and render the future development of the former even more reliant on government subsidy.

In some countries in the EU opposition has been so fierce that fracking has been banned and agreements with international exploration companies cancelled. In others, such as Poland, the political imperative of having a low cost and independent energy source has generated the will to proceed with exploration despite the environmental concerns. One of the main problems appears to be the polarisation of opinion and the very great difficulty of having a rational and constructive public debate.

In the end the exploitation of shale gas in the EU may come down to economic necessity and political will. With costs of extraction so much higher than in the USA and environmental opposition so much stronger, it may be unlikely that we will witness in the EU the kind of growth seen there, but there is little doubt that some countries are intent on supporting the exploitation of this resource and competitive and geopolitical necessities may then force others to re-think.

## GLOSSARY

| | |
|---|---|
| Aquifer | "An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well". (en.wikipedia.org) |
| CNG | Compressed Natural Gas. |
| Fracking | Hydraulic Fracturing – the process of extracting gas or oil from shale by hydraulically 'fracturing' the shale to release the gas or oil deposits. |
| Frac-sand | 'Frac sand' is high-purity quartz sand with very durable and very round grains. It is a crush-resistant material produced for use by the petroleum industry. It is used in the hydraulic fracturing process (known as 'fracking') to produce petroleum fluids, such as oil, natural gas and natural gas liquids from rock units that lack adequate pore space for these fluids to flow to a well. Most frac sand is a natural material made from high purity sandstone. An alternative product is ceramic beads made from sintered bauxite or small metal beads made from aluminium. |
| Kaolin | China Clay. |
| MBTU | One Million British Thermal Units = 28.27 cubic metres of natural gas at defined temperature and pressure. |
| Methane | Natural Gas – $CH_4$. |
| Permeability | In geology this can mean the measure of the ability of a rock to transmit fluids. |
| Proppant | A solid material such as commercial grade silica and synthetic alternatives used during or following the hydraulic fracturing process of extracting oil and gas in order to keep the fractures in the rock 'propped' open so that the hydrocarbons can be extracted. |
| Shale | Shale is a fine-grained sedimentary rock that forms from the compaction of silt and clay-size mineral particles that we commonly call 'mud'. This composition means that the rock is made up of 'laminations' comprising many thin layers and that the rock readily splits into thin pieces along the laminations. |
| Silica | Silicon oxide – occurs naturally as sand or quartz. |
| Sintered Bauxite | Sintered bauxite is produced by crushing bauxite to a powder and then fusing it into spherical beads at very high temperature. These beads are very hard and very durable. |
| UKEA | UK Environment agency – a government department whose remit is to protect and improve the environment, and to promote sustainable development. UKEA plays a central role in delivering the environmental priorities of central government through our functions and roles. (www.environment-agency.gov.uk/aboutus/default.aspx) |
| Unconventional | Unconventional gas and oil; oil and gas resources which cannot be produced by the conventional processes of using the natural pressure of the wells and pumping or compression operations. |

## MEASUREMENTS

In Europe the metric system is widely implemented. In the UK this is also the case but there are certain anomalies – beer is served in pints and half pints rather than litres and half-litres. Road journeys and speed restrictions are still given in MPH (miles per hour) rather than KPH (kilometres per hour).

In the United States the imperial system is still in use and there may be some confusion when Tons (USA), Tonnes (metric) and Tons (UK) are mentioned in the case study.

In the UK a Ton (defined as a 'long' ton) is 20cwt (hundredweight) which is 2240lbs (pounds), i.e. there are 112lbs in a cwt.

In the USA a Ton (defined as a 'short' ton) is 20cwt which is 2000lbs because a hundredweight in the USA is defined as 100 pounds weight.

A metric Tonne = 1000kg = 1.1 short tons (USA).

A metric Tonne = 0.984 long tons (UK).

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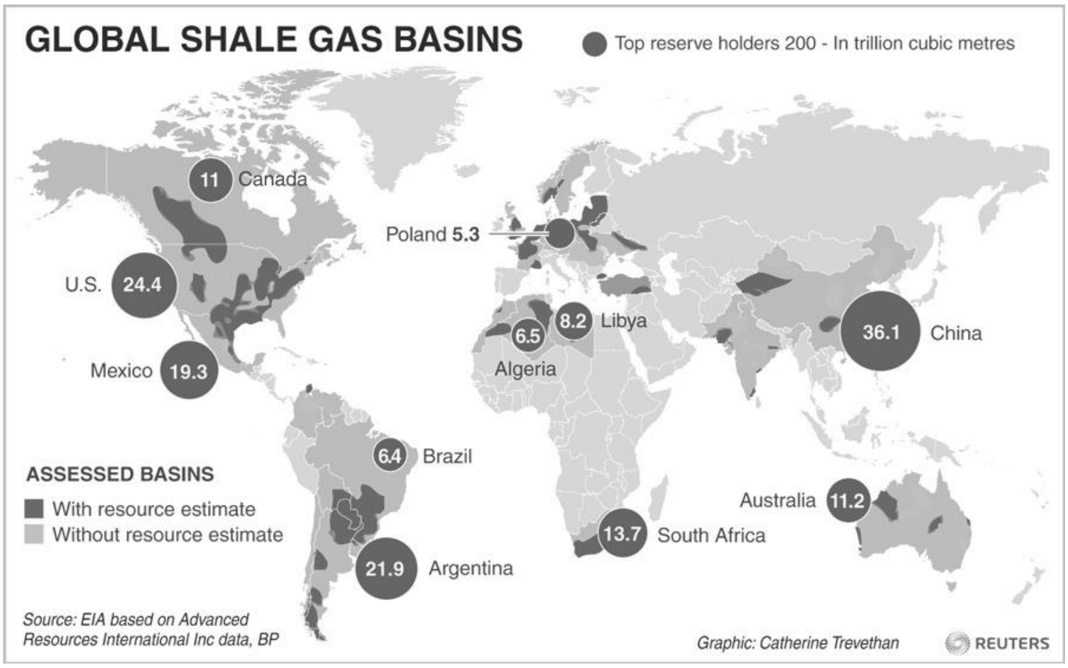
## EXHIBITS

### *EXHIBIT 1 GLOBAL SHALE GAS BASINS*

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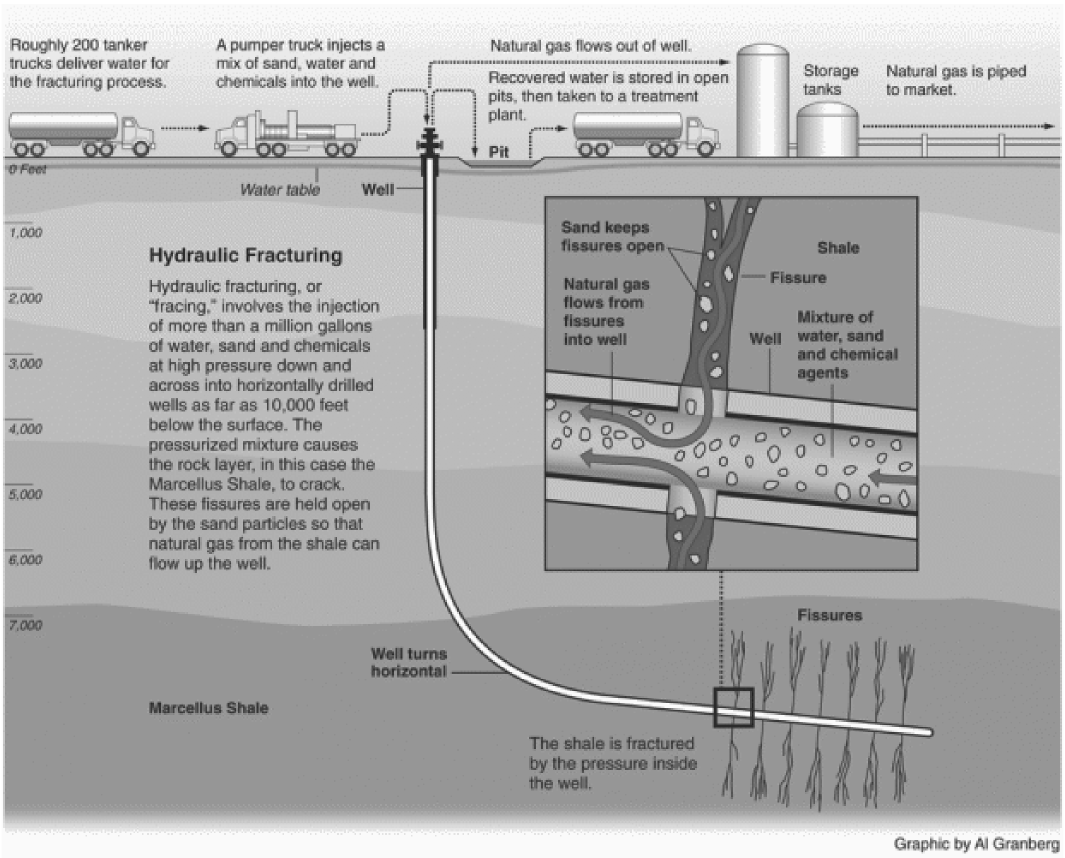
### *EXHIBIT 2 – Fracking Pro*

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