This briefing considers unconventional gas exploration and extraction in Scotland and the UK; including the technique known as hydraulic fracturing (fracking), which has attracted a significant amount of scrutiny in recent months. It also considers some of the broader social, economic and environmental impacts that might arise from exploiting this resource.
# CONTENTS

**EXECUTIVE SUMMARY** ................................................................................................. 3

**BACKGROUND** ........................................................................................................... 4

WHAT IS UNCONVENTIONAL GAS AND HOW IS IT EXTRACTED? ........................................ 5
  Extraction Processes ........................................................................................................ 5

UNCONVENTIONAL GAS POTENTIAL IN THE UK ........................................................................ 9

UNCONVENTIONAL GAS IN THE US .................................................................................. 9

**GOVERNMENT POLICY** .............................................................................................. 10

  REGULATORY REGIME .................................................................................................... 11
  PEDL Licences .................................................................................................................. 11
  Planning Permission .......................................................................................................... 11
  Environmental Permissions ............................................................................................... 12
  Could the Scottish Government Ban Unconventional Gas Extraction? .......................... 12
  Other Permissions ............................................................................................................ 13

**CURRENT ACTIVITIES** ............................................................................................... 14

**THE IMPACT OF UNCONVENTIONAL GAS** ...................................................................... 17

  EUROPE ................................................................................................................................ 17
  UNITED KINGDOM ............................................................................................................ 18
    Security of supply and economic impacts ...................................................................... 20
    Environmental impacts .................................................................................................. 21

**SOURCES** ...................................................................................................................... 26

**ANNEXE A – CURRENT PEDL LICENCES** ........................................................................ 34

**ANNEXE B – CURRENT PEDL LICENCES BY SCOTTISH PARLIAMENTARY CONSTITUENCY** ................................................................. 35

**ANNEXE C – CURRENT UNDERGROUND COAL GASIFICATION LICENCES** ................................................................. 40
EXECUTIVE SUMMARY

There has been a rapid reduction in the availability of domestic natural gas, and the UK is a net importer. Because of this, accelerating global demand, rising prices, and the need to move away from high carbon electricity generation e.g. coal, the UK’s unconventional gas resources are considered to be increasingly attractive. Natural gas produces over a third less carbon dioxide than coal.

Unconventional gas is the collective term for different types of natural gas held in reservoirs not traditionally exploited for gas; e.g. coalbed methane, and shale gas.

Different techniques are used to unlock these resources, including hydraulic fracturing (fracking), which has attracted a significant amount of scrutiny. Fracking is often used synonymously to refer to shale gas and other sources, like coalbed methane; however, it is not always correct to associate fracking with unconventional gas.

In Scotland, the most developed project is for coalbed methane, which proposes to extract gas by draining water from a coal seam to reduce the pressure (known as dewatering).

Shale gas is extracted by fracking, which involves pumping water into seams at pressures high enough to fracture the surrounding rock, and release the gas. This water also contains tiny quantities of sand, and chemicals to improve the efficiency of the operation. Fracking can also be used for coalbed methane; however there are no current licences to carry out fracking in Scotland.

There are licences to explore the potential for underground coal gasification in Scotland; however these are at a very early stage. This technique gasifies the coal in-situ by injecting water/oxygen mixtures down one pipe, igniting and partially combusting the coal and extracting gas through another.

The shale gas industry in the US is well established, and energy prices have dropped as a result, however it is difficult to draw tangible conclusions from this, and apply them to the UK.

There is a lack of information about unconventional gas resources in the UK, and extensive exploration is needed before a realistic assessment of recoverable assets is possible. Nevertheless, the Bowland Shale in central England is thought to be a considerable resource.

Permission to exploit unconventional gas resources in Scotland requires a combination of licences, including DECC, the Coal Authority (in some cases), planning permission, and SEPA, who play a key role in controlling environmental impacts; public acceptability is also crucial, and some NGOs have called for a ban on the industry.

The main area of interest in Scotland is north of Falkirk where Dart Energy has planning and environmental permissions in place for coalbed methane exploration and pilot test wells. It is currently seeking planning permission for more wells and associated infrastructure. Dart also has a coalbed methane site near Canonbie in Dumfries and Galloway, with plans to develop.

Much of the debate around fracking has been framed by anecdotal instances of pollution in the US shale industry, and two earth tremors due to fracking in Lancashire. Some commentators note that there has been a “media frenzy” around these and broader resource estimates, with the basic facts being subject to misunderstanding and distortion; there is therefore a need to address issues of “actual, rather than assumed, public concern”.

Broader scrutiny of the potential social, environmental and economic impacts of shale gas and fracking has been carried out by House of Commons and House of Lords Committees, and a Royal Society and Royal Academy of Engineering report. These broadly support the development of the industry, subject to stringent controls.

Whilst domestic unconventional gas extraction is likely to improve energy security, and make a contribution to economic development, it is not likely that energy prices will drop in the UK. Debate about environmental impacts revolves around groundwater contamination, sourcing the volumes of water required for fracking, and greenhouse gas and other emissions. Of these, concerns about climate change, and whether natural gas can or should play a bridging role to low carbon generation that are the most contentious, with further research and monitoring required.
BACKGROUND

Natural gas has played a significant role in space heating and industrial processes since the UK’s North Sea resource was developed in the 1960s. More recently (1990s) gas has become a key fuel for electricity generation. Whilst natural gas is a fossil fuel, it produces over a third less carbon dioxide (per unit of energy) than coal. Electricity from gas therefore is expected to become increasingly important as many coal power stations are expected to shut in 2015 due to the EU Large Combustion Plants Directive.

UK Continental Shelf (UKCS) production of natural gas has been in decline since the turn of the century and, in 2012, it produced 36% less than in 2000. The UK has therefore been a net importer of gas since 2004, with pipelines delivering from Norway, Belgium and the Netherlands and Liquefied Natural Gas (LNG) coming in by ship. In 2012, imports accounted for 47% of supply (DECC 2013a & DEFRA 2012).

Due to this rapid reduction in domestic gas supplies, an acceleration in global gas demand, the rising price of gas from conventional sources, and the development of a transformational unconventional gas industry in the United States (considered in more detail on p9), together with the need to reduce carbon emissions from UK energy generation, it is becoming increasingly attractive to assess potential UK unconventional gas (UG) resources, both onshore and offshore (BBC 2013a, Oxford Institute for Energy Studies 2013, BP 2013a).

Whilst some advocate the large-scale exploitation of UG resources, citing positive impacts on energy security, prices and employment, as well as improved carbon emissions if gas displaces coal, others argue that the environmental risks outweigh any benefits that might accrue. Also, there does not appear to be broad public acceptance of the industry (BBC 2013b, Guardian 2013a, Friends of the Earth Scotland 2013a). The International Energy Agency (IEA) (2012) notes that natural gas may be poised to enter a “golden age”, however this is possible only if UG reserves can be “developed profitably and in an environmentally acceptable manner”. The IEA states:

> The boost that this would give to gas supply would bring a number of benefits in the form of greater energy diversity and more secure supply in those countries that rely on imports to meet their gas needs, as well as global benefits in the form of reduced energy costs.

Yet a bright future for unconventional gas is far from assured: numerous hurdles need to be overcome, not least the social and environmental concerns associated with its extraction. Producing unconventional gas is an intensive industrial process, generally imposing a larger environmental footprint than conventional gas development. […] The scale of development can have major implications for local communities, land use and water resources. Serious hazards, including the potential for air pollution and for contamination of surface and groundwater, must be successfully addressed. Greenhouse-gas emissions must be minimised both at the point of production and throughout the entire natural gas supply chain. Improperly addressed, these concerns threaten to curb, if not halt, the development of unconventional resources.

This briefing considers UG exploration and extraction in Scotland and the UK; including the technique known as hydraulic fracturing (fracking) which can be used to enhance natural gas extraction from underground shale rocks or coal seams, and which has attracted a significant amount of scrutiny in recent months. It also considers some of the broader social, economic and environmental impacts that might arise from exploiting this resource.
WHAT IS UNCONVENTIONAL GAS AND HOW IS IT EXTRACTED?

The terms 'conventional' and 'unconventional' describe the type of rock reservoirs where natural gas is found and the way in which the gas is extracted. There is no chemical difference between natural gas extracted from conventional and unconventional methods. Natural gas is a variable mixture of hydrocarbon gases but tends to be primarily composed of methane along with other light hydrocarbon compounds (e.g. ethane, propane).

**Natural gas** is a fossil fuel, formed from buried organic matter (such as the remains of plants, animals and microorganisms) over many thousands of years.

**Shale** is a sedimentary rock formed from mud, deposited at the bottom of ancient oceans that has been solidified into rock. This ocean mud is rich in un-decayed organic matter such as the remains of plants, animals and microorganisms. When the rock is buried (through natural Earth processes) it gets heated and pressurised, and the organic matter slowly transforms into hydrocarbons - gas forms at higher temperatures than oil. The mud grains that the shale is made up of are closely packed together in layers, making it difficult for fluids to move through the rock – and so natural gas gets trapped.

**Coal** is a rock formed from the burial, compaction and heating of ancient plant matter (peat) which has often been deposited in layers (which become coal beds or coal seams). Natural gas often forms from the organic matter as it transforms into coal, so many coal seams contain natural gas within the seam itself or in the surrounding rock. This coalbed methane is trapped underground until the coal is mined.

The main types of UG in the UK are as follows:

- **Shale gas** as the name suggests, is natural gas trapped within shale beds (as opposed to being within a conventional reservoir rock capped by shale beds). Shale gas reservoirs are often located at depths greater than 1000m. Shale gas has not yet been produced offshore.

- **Coalbed methane** (CBM) is natural gas found within coal seams that have not been worked because the coal is too deep or poor quality. CBM can be as shallow as 300m but is typically around 800-1000m depth, any deeper and the gas becomes more difficult and expensive to extract. CBM has been developed onshore and offshore.

- **Coal Mine Methane** (CMM) is natural gas extraction from worked coal seams; CMM is much shallower and currently onshore.

- **Tight gas** refers to gas deposits found in low permeability rock formations that cannot be commercially developed by conventional vertical drilling alone, because the gas is difficult to extract. Tight gas formations are typically located at depths greater than 1000m.

- **Underground coal gasification** (UCG) refers to the in-situ combustion of coal seams to produce syngas – a mixture of hydrogen and carbon compounds. UCG typically targets coal seams that cannot be accessed by traditional means and are typically at depths greater than 500m (some reports saying 1000 – 3000m). UCG can be done onshore or offshore.

Natural gas from unconventional sources is intrinsically more difficult to extract than from conventional reservoirs. However it is becoming increasingly commercially viable due to recent advances in drilling and well-site technology.

**Extraction Processes**

Conventional gas reservoirs are typically accessed by drilling a small number of near vertical wells which the gas flows into. Sometimes the gas extraction is enhanced by horizontal drilling, or by pressurising the reservoir.
Gas in **shale beds** and some **tight gas** is accessed by drilling a much greater number of wells from one site (termed ‘directional’ drilling) often with a significant horizontal component.

Once these wells are drilled, gas production can be stimulated by an established technique called hydraulic fracturing (fracking). The British Geological Survey (BGS) (2013a) explains the process as follows:

After initial exploration of the shale deposits, a borehole is drilled into the shale horizon at a carefully selected site. It may be drilled horizontally to increase the volume of rock that can be accessed by the borehole. A process called hydraulic fracturing (‘fracking’) is undertaken. This involves pumping water into isolated sections of the borehole at pressures high enough to fracture the surrounding rock. Sand entrained in the water helps to 'prop' open the fractures, create permeability in the rock and allow the gas to flow into the borehole. Chemicals are also added to improve the efficiency of the fracking operation.

The Royal Society and The Royal Academy of Engineering (2012) have recently carried out a review of the technique in the context of UK shale gas extraction, and describe a similar process. However, before fracking takes place, “explosive charges fired by an electric current perforate holes along selected intervals of the well within the shale formation from which shale gas is produced”. The use of this perforating gun depends on whether the borehole liner (casing) is cemented into place, or already perforated. The BBC (2013a) provides the following diagram:

According to Cuadrilla, the only company so far to carry out fracking for shale gas in the UK (at Preese Hall near Blackpool), the components of the drilling mixture are as follows (2013a):

- 99.75% water and sand; beyond that a very limited number of chemicals are used
- Polyacrylamide friction reducers (0.075%), commonly used in cosmetics and facial creams, suspended in a hydrocarbon carrier
- Hydrochloric acid (0.125%), frequently found in swimming pools and used in developing drinking water wells
- Biocide (0.005%), used on rare occasions when the water provided from the local supplier needs to be further purified

All of these chemicals have been approved for Caudrilla’s site specific use by the Environment Agency in England, but only one has been used by the company to date. Caudrilla (2013) states:

So far, as additives to fracturing fluid, Cuadrilla has only used polyacrylamide friction reducer along with a miniscule amount of salt, which acts as a tracer. We have not needed to use biocide as the water supplied by United Utilities to our Lancashire exploration well sites has already been treated to remove bacteria, nor have we used diluted hydrochloric acid in fracturing fluid. Additives proposed, in the quantities proposed, have resulted in the fracturing fluid being classified as non-hazardous by the Environment Agency.

Coal seams may be intact or naturally fractured. Depending on the geology of the coal seam, there are two options for coalbed methane extraction.

If the seams are thin, and already naturally contain fractures, or fracture very easily, there is no need to hydraulically fracture the seam. As a result, well designs are adapted to maximise gas extraction by established drilling and pumping techniques without stimulation – known as dewatering - which drains the water from the coal seam, reducing the pressure and thus allowing the methane to flow from the coal bed. These wells and the sites above ground are neither designed for, nor capable of using, the fracturing techniques described above. DART Energy (2012a) explains their dewatering process:

A vertical well is drilled through the coal seams. Up to four lateral wells are drilled along the individual coal-seams intersecting the vertical well. As pressure drops through pumping of water, gas is released from the coal along the lateral wells and produced up through the vertical well to gathering pipeline at the surface. Apart from a 6inch diameter hole, coal is left in-place.

The process is shown in the following diagram (DART Energy 2012b):
If the seams are thicker, or deeper, and fracture less easily, then hydraulic fracturing may be required to release the gas. However, as noted above, this is likely to require more horizontal wells to be drilled, as dewatering wells are not designed for fracking.

Fracking coal beds for methane generally requires less energy than fracturing shales. Smaller volumes of water are required to frac the seam, as water pressure does not need to be so high. The use of foam, rather than a water mixture significantly reduces water discharge and hence the volume of produced water that must be treated (SEPA 2012).

**Underground Coal Gasification** (UCG) gasifies the coal in-situ. Boreholes are drilled some distance apart on the seam, injecting water/oxygen mixtures down one pipe, igniting and partially combusting the coal and extracting the syngas through the other pipe (Environment Agency 2013).

The exploration and potential exploitation of a major new hydrocarbon resource, in particular the use of fracking, has attracted some considerable scrutiny in recent months. The use of the term fracking is also often used synonymously to reference shale gas, and by association other sources, like CBM. However, whilst this might be convenient, and popular, it is not always correct to associate hydraulic fracturing with UG extraction. Because of the significant shale gas industry in the US, much of the scrutiny to date focusses on shale – however, given that it is all natural gas, many of the social, economic, or environmental impacts will be the same. These are considered in more detail on p17.
UNCONVENTIONAL GAS POTENTIAL IN THE UK

There is a notable lack of information about UG resources in the UK, and an extensive exploration phase would be needed before a realistic assessment of potentially recoverable assets is possible.

Some speculative estimates of total shale reserves have been made (British Geological Survey (BGS) for DECC 2011, US Energy Information Administration (EIA) 2013a). However, most recently, a more detailed study by the BGS (2013a) estimated that the shale rock formation in central Britain (between Wrexham and Blackpool in the west, and Nottingham and Scarborough in the east – known as the Bowland Shale) could be equivalent to 37,000 billion cubic metres (bcm). Whilst there are significant uncertainties within this estimate, it is a considerable resource; however without further exploration to define how much of this gas can be extracted from these rocks, the magnitude of the UK shale gas resource remains uncertain.

National Grid’s Future Energy Scenarios (2013) anticipates that only a modest proportion of this may be recoverable (i.e. ‘extractable’). At a conservative recovery rate of 10% and annual UK gas consumption rates of about 80 bcm, the Bowland Shale could provide 46 years of gas supply.

To put this into context, DECC (2013b) currently estimates that remaining recoverable conventional UK gas reserves amount to 3,116 bcm.

CBM exploration in the UK is aided by historical information about coal seams and their gas contents. Substantial exploration is nevertheless required to determine commercial prospects.

UNCONVENTIONAL GAS IN THE US

Shale gas has become increasingly important in the US since the start of this century. In 2000 it provided only 1% of US natural gas; by 2010 it was over 20% and in 2012 the US became the world’s largest gas producer, overtaking Russia (EIA 2013b). BP (2013b) predicts that North American shale gas output, largely from the US, will grow by an average of 5.3% a year until 2030.

This supply has already affected global fuel markets. Some of the impacts of this rapid “glut” of American gas are set out below.

In Pennsylvania alone the industry supports over 100,000 jobs, and was worth $14 billion to the local economy, generating nearly $3 billion in taxes in 2012 – Arkansas, Louisiana, Oklahoma and Texas are experiencing similar “shale rushes” (Economist 2013a).

Gas prices dropped from $13 per unit in 2008 to around $2 in 2012 before rising again to approximately $4 this year (Economist 2013a, NY Times 2013a). This is significantly lower than other countries – approximately a third of the German gas price and a quarter of the South Korean one.

These prices are also affecting the electricity market, by displacing coal fired thermal generation, and slowing the expansion of both renewable energy and nuclear sectors (Bloomberg 2012).

There have been some reports of significant reductions in electricity prices, particularly for bulk industrial users, alongside an expansion in manufacturing output – particularly steel, chemical, plastic and fertiliser manufacturing (Bloomberg 2012, Economist 2013a). These however are difficult to map definitively for a market as large as the US, given that there are a number of separate trading areas. The EIA (2013c) projects a 2.2% rise in residential electricity prices in 2013, and shows that industrial sector prices across the country fluctuated slightly between 2011-13 (EIA 2013d).

The reduction in carbon intensive generation has had a knock on effect on carbon emissions; these have fallen by 9% since 2005, reversing a strong upwards trend, and the US Environmental Protection Agency (EPA 2013) has attributed almost half of the reduction to shale gas use.

In spite of the reduction in American carbon emissions, complicated global supply and demand markets for fossil fuels means that unused coal in one country tends to contribute to increased use (primarily for thermal generation) in others. In 2012, the US exported a record amount of coal, and whilst some commentators are predicting an increasingly weak market, exports are continuing to grow (EIA 2013e & 2013f, NY Times 2013b); the EIA (2013g) cites key factors affecting natural gas and coal market prices in Europe, and states that “favorably priced U.S. exports of coal have been an attractive alternative to natural gas for Europeans”.

As a result of unprecedented levels of domestic natural gas production, net imports fell 23% in 2012. As a percentage of total natural gas consumed, net imports decreased to around 6%, two points lower than in 2011 – this is the lowest they have been since 1998 (EIA 2013h).

This “glut” of gas and turnaround in import requirements means that many Liquefied Natural Gas (LNG) storage terminals are lying idle, leading to their proposed redevelopment as gas export hubs; at present, around 20 upgraded or new facilities are seeking approval to export LNG (NY Times 2013c). However there is increasing opposition to approving these export hubs, amongst fears that it will lead to an increase in domestic gas prices, and harm US manufacturing – in spite of free-trade agreements (Financial Times 2013).
There are no estimates of Scottish UG resources; however the BGS is expected to commence a more detailed study of shale in gas deposits in Central Scotland in 2014 (BBC 2013c).

There are numerous coalbed and shale deposits in Scotland, and in 2010 the BGS noted (DECC 2010) that a “proven petroleum system exists in the Midland Valley [of Scotland], utilising Dinantian oil shales as source rocks and interbedded sandstones as reservoirs. The Carboniferous rocks are only marginally mature at the surface, but lie in the gas window at depth”. Furthermore, the “Midland Valley may harbour more discoveries”. DECC (2011) also notes that the Orcadian Basin of Caithness, Orkney and Shetland islands has shale gas potential.

DART Energy (2013a) has published site specific estimates for CBM at Airth near Stirling of 0.26 – 0.4 bcm, which amounts to 0.018% of the UK’s estimated demand for gas over the next 20 years.

Although UCG was first trialled in the UK in the 1950’s, there are no realistic resource estimates available for UCG and tight gas in the UK or Scotland. There is currently some commercial interest for UCG offshore (see below); however no recoverable resource estimates have yet been made. The BGS (2004) estimates that there are around 17 billion tonnes of UK coal resource that is potentially suitable for UCG. The Parliamentary Office of Science and Technology (POST 2013) notes:

There are currently no official reserve estimates. The UK reserves could be anywhere from zero to substantial. To determine reliable estimates of shale gas reserves, flow rates must be analysed for a number of shale gas wells over a couple of years. Further, estimates will be determined by many non-geological factors including costs, engineering, supply chain and access restrictions due to environmental and planning issues. Without reserve estimates the commercial scale of shale gas extraction cannot be forecast.

As noted above, the US has experienced a boom in the exploitation of UG reserves and an associated reduction in energy costs, increase in manufacturing output and jobs; however many commentators warn that this experience is not likely to be replicated in the UK for a number of reasons (UKERC 2013, Oxford Institute for Energy Studies 2013, Economist 2013b), these are explored in more detail on p17.

GOVERNMENT POLICY

Although natural gas is a fossil fuel, it produces over a third less carbon dioxide (per unit of energy) than coal. Increasing the proportion of energy generated from gas and renewables is part of the UK Carbon Plan (HM Government 2011) for meeting carbon emissions targets.

Both the UK and Scottish Governments therefore support the extraction of UG, subject to appropriate regulation. The Department of Energy and Climate Change (DECC 2013c) states:

The Government believes that shale gas has the potential to provide the UK with greater energy security, growth and jobs. We are encouraging safe and environmentally sound exploration to determine this potential.

Indeed, DECC (2013d) has recently established an Office of Unconventional Oil and Gas to “promote the safe, responsible, and environmentally sound recovery of the UK’s unconventional reserves of gas and oil”, and the 2013 UK Budget proposes to introduce tax cuts on some of the income generated from producing shale gas from 62% to 30%. The UK Government also confirmed industry plans to give communities that host shale gas sites £100k per site, and up to 1% of all revenues from production – these are not statutory, and only apply when fracturing is occurring as part of an UG operation (HM Treasury 2013, BBC 2013d).
Similarly, the Scottish Government sets out their position in Scottish Planning Policy (2010), and in PQ S4W-11976 (Scottish Parliament 2013), as follows:

Scotland’s energy needs are set out in our Draft Energy Generation Policy Statement – which sets out the pathway to a low carbon generation mix in Scotland, supported by a diverse portfolio of energy sources to reflect the breadth of Scotland’s energy resources and ensure security of our energy supply. As part of that, the Scottish Government is open to onshore gas extraction, which, along with all other energy production in Scotland is subjected to a rigorous regulatory regime to ensure it is sourced and produced with due regard to the environment. Onshore gas is a valuable national resource which can play a part in Scotland’s energy mix. The Scottish Government therefore works closely with the UK Government on the licencing of onshore gas extraction in Scotland and with Scottish Environment Protection Agency on the regulation of unconventional gas in Scotland.

REGULATORY REGIME

The regulation of UG extraction in the UK draws on the experience of the onshore and offshore oil and gas industries over the last 60 years, and the risks posed by these activities are managed by various regimes within the UK’s regulatory system.

PEDL Licences

In the UK, all rights to the nation’s petroleum resources are held by the State1; however, the Government can grant licences that confer exclusive rights to “search and bore for and get” petroleum over a limited area and for a limited period (DECC 2012). Petroleum Exploration and Development Licensing (PEDL) rounds are therefore held whereby bids are assessed on their ability to “optimise exploitation of the UK’s petroleum resources”. To date, 13 onshore licensing rounds have taken place, and a 14th is expected to be launched next year with new blocks available across Central Scotland (DECC 2010 & 2013e).

The Royal Society and The Royal Academy of Engineering (2012) state:

Shale gas extraction was not considered when regulations for conventional gas extraction were formulated in the 1990s. There is no specific mention of shale gas in UK legislation. Licences specific to hydraulic fracturing or directional drilling are not awarded per se. Rather, PEDL licenses are issued along with consents for particular activities and controls can be imposed accordingly.

PEDL Licences also put in place conditions to control the venting and flaring of methane, and do not exempt applicants from other legal or regulatory requirements, as set out below.


Planning Permission

Following the acquisition of a PEDL Licence, the Local Planning Authority is responsible for granting planning permission (under the Town and Country Planning (Scotland) Act 1997) for surface works associated with borehole construction, extraction operations and wellhead development.

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1 In the UK, the Crown holds the right to gold and silver, and the State to oil, petroleum and natural gas - landowners hold only the remaining mineral rights.
Scottish Planning Policy (2010) provides guidance to planning authorities on onshore oil and gas extraction, including factors to be taken into account in decisions on planning applications. These include “disturbance and disruption from noise, potential pollution of land, air and water, impact on communities and the economy, cumulative impact, impact on the natural heritage and historic environment, landscape and visual impact and transport impacts”. Future planning policy is expected to be strengthened to “provide an adequate buffer zone between sites and settlements” (Scottish Government 2013a). This has been welcomed by Friends of the Earth Scotland (2013b).

In England, DECC (2013f) has published specific guidance for onshore oil and gas; however there are no current plans to do so in Scotland.

Operators may also need to submit an Environmental Impact Assessment (EIA) with their application. This is decided on a case by case basis by the planning authority, as set out in the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011, however it is widely considered to be best practice to carry one out.

The Management of Extractive Waste (Scotland) Regulations 2010 require an agreed waste management plan for the production of ‘flow-back’ fluid from hydraulic fracturing. In Scotland, this plan is controlled through planning permission for the site. Operators must have a waste management plan in place, and be able to demonstrate to planning authorities how they will store and dispose of wastes safely without causing pollution to the environment.

Environmental Permissions

SEPA plays a key role in controlling environmental impacts from the exploration and extraction of UG resources, and has set out detailed guidance (2012) relating to this. SEPA also has a duty to consider how Scotland can reduce greenhouse gas emissions from regulated industry and businesses under the Climate Change (Scotland) Act 2009, and is a statutory consultee in the planning process (as are Scottish Water, and Scottish Natural Heritage).

SEPA does not specifically regulate hydraulic fracturing. However, the Water Environment (Controlled Activities) Regulations 2011 (known as CAR) authorise activities associated with UG exploration and extraction, and CAR licences\(^2\) are required for the following:

- Deep borehole construction (>200m)
- Injection of fracturing fluid
- Abstraction of water for injection purposes
- Abstraction of flow-back water
- Discharge
- Management of abstracted fluids

The CAR licensing regime is the UK’s standard procedure for regulating large industrial water users and applies to any industry that might impact the water environment, e.g. farming, engineering and construction, distilling and brewing.

SEPA (2012) states:

Could the Scottish Government Ban Unconventional Gas Extraction?

Friends of the Earth Scotland (FoES) (2013a) recommends that the Scottish Government should “call a halt on the industry” and review the:

- Full lifecycle environmental and health impacts
- Impact that developing this industry will have on meeting climate targets
- Public acceptability of the industry
- Suitability of environmental regulations to deal with these new technologies

Energy licensing is reserved to Westminster, therefore FoES proposes that Ministers use the planning system to ban UG extraction.

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\(^2\) Activities may be included in a multiple water use licence and may have different licensing requirements e.g. borehole construction a complex licence, abstraction a simple licence
Operators must submit a risk assessment and/or details of the borehole construction to us with their application for CAR authorisation to show that any adverse effects on the water environment or other water users will not be significant. The submission should include any mitigation measures that will be used to reduce adverse effects. Any authorisation granted will specify conditions to limit impacts and may also require a monitoring plan to be developed and agreed with SEPA and implemented by the operator.

Operators must provide details of all of the chemical additives contained in drilling and fracturing fluids. We can use this information in our examination of any application for injection, to ensure the substances involved are of a type and at a concentration that will not cause pollution of the water environment. [...] Operators have the right to claim that information contained within or attached to an application is commercially confidential.

Once extracted, gas does not necessarily need further treatment, however if e.g. refining or gasification is required, additional regulatory controls, such as Pollution Prevention Control (PPC) would apply to the treatment activities, and a permit from SEPA would have to be in place before activities could begin.

**Other Permissions**

All drilling operations should notify the Health and Safety Executive (2012), who monitor onshore gas operations from a well integrity and site safety perspective. They oversee that safe working practices are adopted by operators as required under the relevant regulations.

In relation to CBM, the Coal Authority (2013a) also needs to provide “prior written authorisation” for any “activity which intersects, disturbs or enters any of the Authority’s coal interests”.

For UCG, an operator will need to gain a Coal Authority rather than a PEDL licence. It is UK Government policy that carbon capture and storage will be required if the syngas is used for power generation over 300MW; other uses for the gas might however include refining for diesel, aviation fuel, or the petro-chemical industry – planning, and other environmental permissions would also be required.

Permission must also be sought, and a legal agreement reached with the landowner.

The sequence of authorisation is set out in the following diagram, which shows the way an application to explore for UG would be examined by all the agencies, e.g. an operator would always seek a PEDL before applying to the local authority for planning permission to construct a borehole. However, the environmental and planning process can be applied in parallel, but work cannot commence until all are in place (SEPA 2012):

![Diagram showing the sequence of authorisation](image-url)
CURRENT ACTIVITIES

As shown in Annexe A, there are currently six areas in Scotland where Petroleum Exploration and Development (PEDL) Licences have been issued. SEPA (2013) publishes regular updates on UG activities in relevant licence areas; the following table provides further information (Dart 2013b):

<table>
<thead>
<tr>
<th>Licence</th>
<th>Operator</th>
<th>Main Local Authority Area</th>
<th>Summary of Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEDL 133</td>
<td>Dart Energy Scotland</td>
<td>Falkirk &amp; Stirling</td>
<td>Dart Energy Scotland has planning and environmental permissions in place for 14 CBM exploration and pilot test wells in this area, and is seeking planning permission for a further 22 wells at 14 new and two existing sites, as well as a central gas and water treatment facility near Airth, north of Falkirk; 11 of these sites are in Falkirk Council's area, and three sites as well as the central treatment facility in Stirling Council’s. The application was submitted to both Councils. Pilot test wells are showing early signs of small volumes of gas production (currently generating electricity and feeding into the National Grid) which Dart hopes to accelerate. Current and proposed activities do not include hydraulic fracturing, although Coal Bed Methane Ltd, a previous operator used the technique in this area nearly 20 years ago. Dart proposes to use the dewatering technique, as explained above. SEPA has issued the operator with three CAR licences relating to current activities (abstraction, discharge of groundwater, and construction of a borehole) issued under the Water Environment (Controlled Activities) (Scotland) Regulations 2011. Following the granting of two extensions by Dart at the Council’s request, neither the Falkirk Application nor the Stirling Application was determined by the respective planning authorities prior to the expiry of the extended deadlines. Dart have therefore appealed to Scottish Ministers on the grounds of non-determination and are currently awaiting a Pre Examination Meeting to confirm the method of determination before a decision can be taken. The determination options available to the Reporter are written submissions; hearing sessions; or Public Inquiry.</td>
</tr>
<tr>
<td>PEDL 158</td>
<td>Caithness</td>
<td>Highlands &amp; Islands</td>
<td>No activity.</td>
</tr>
<tr>
<td>PEDL 159</td>
<td>Dart Energy Scotland</td>
<td>Dumfries &amp; Galloway&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Dart currently has planning and environmental permissions in place for eight CBM exploration and pilot test wells in the Canonbie area. These are demonstrating good production rates from the coal</td>
</tr>
</tbody>
</table>

<sup>3</sup> Also crosses border into England
The previous licence holders (Greenpark Energy – bought by Dart in April 2012) had two CAR licences issued in March 2011; one of these was for the introduction of fracturing fluids to groundwater for the purposes of gas extraction from coal measures. These were transferred to Dart, and they have subsequently surrendered the licence to discharge fracturing fluids.

Current and proposed activities do not include hydraulic fracturing, and none has taken place to date. Dart proposes to use the dewatering technique, as explained above.

There are currently plans to develop the area for CBM extraction.

<table>
<thead>
<tr>
<th>PEDL 161</th>
<th>Dart Energy Scotland</th>
<th>Fife</th>
<th>In 2008, a single borehole was drilled near Leven; however there are no further plans for development.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEDL 162</td>
<td>Reach Coal Seam Gas Ltd</td>
<td>North Lanarkshire</td>
<td>Reach CSG operates at Deerdykes near Cumbernauld, and has planning permission for the drilling of a single methane extraction borehole. SEPA have not issued any licences under Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR).</td>
</tr>
<tr>
<td>PEDL 163</td>
<td>Dart Energy Scotland</td>
<td>Perth and Kinross, &amp; Fife</td>
<td>In 2008, a single borehole was drilled near Thornton; however there are no further plans for development.</td>
</tr>
</tbody>
</table>

The Coal Authority has provided the following in relation to UCG (2013b):

<table>
<thead>
<tr>
<th>Licence</th>
<th>Operator</th>
<th>Main Local Authority Area</th>
<th>Summary of Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solway Firth</td>
<td>Five Quarter Energy Limited</td>
<td>Dumfries &amp; Galloway</td>
<td>Previously licensed to Clean Coal Energy Limited. Renewal application subject to competing application from Five Quarter Energy but renewal refused in July 2013. No exploration</td>
</tr>
</tbody>
</table>

---

4 Other LA areas covered by PEDL 162 include Falkirk, East Dunbartonshire and West Lothian
5 Thornton New Energy Ltd does not have a specific website, and appears to be owned by BCG Energy.
<table>
<thead>
<tr>
<th>Location</th>
<th>Company Name</th>
<th>Region</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Firth of Forth</td>
<td>Riverside Energy (Scotland) Limited&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Fife</td>
<td>Expired April 2013. Renewal subject to competing application from Five Quarter Energy and likely to be determined before end of 2013. No exploration drilling or planning application as of October 2013.</td>
</tr>
<tr>
<td>Kincardine Project</td>
<td>Cluff Natural Resources Plc</td>
<td>Clackmannanshire</td>
<td>Current – Expires July 2018. Recently granted for 5 year conditional period. Possible interaction with adjacent Dart CBM operations if they get a petroleum licence for Forth area.</td>
</tr>
<tr>
<td>Largo Bay</td>
<td>Cluff Natural Resources Plc</td>
<td>Fife</td>
<td>Recently granted for 5 year conditional period.</td>
</tr>
<tr>
<td>Musselburgh</td>
<td>Riverside Energy (Scotland) Limited</td>
<td>East Lothian</td>
<td>Renewal subject to competing application from Five Quarter Energy and likely to be determined before end of 2013. No exploration drilling or planning application as of October 2013.</td>
</tr>
<tr>
<td>Solway Firth</td>
<td>Five Quarter Energy Limited</td>
<td>Dumfries and Galloway</td>
<td>Application received in April 2013.</td>
</tr>
</tbody>
</table>

Current UCG licences are also set out in Annexe C.

There are therefore currently only three conditional licences (Thornton New Energy in Fife, and Cluff’s Kincardine and Largo Bay Projects). These are all conditional licences which would only be extended if the licensee can demonstrate progress with the project to the operational stage (including having finance in place). The Coal Authority further states (2013b):

<sup>6</sup> Riverside Energy is an Australian headquartered company who Thornton have “formed a multi million pound joint venture” with (BCG Energy 2010).
As the licences are conditional no underground coal gasification operations can take place until the Licensee has satisfied the pre-conditions set out in the licence which include the acquisition of all the other necessary rights and permissions to carry out the operations. These include planning consent for any onshore installations and the equivalent consent for offshore; environmental permission and the consent of the Health & Safety Executive. The licensee will also have to secure the consent of a landowner for any surface installation (or the equivalent for sea bed installations) and satisfy the Authority that the finance is in place to carry out the operations.

Exploration is permitted under the consent granted by the Authority but once again this is dependent on other rights being in place. Before any exploration operations take place the licensee has to secure a supplemental exploration agreement from the Authority when site specific issues are addressed and the licensee has to demonstrate that all the other rights to sink the borehole(s) are in place. These rights will include any environmental permits and Health and Safety permits.

THE IMPACT OF UNCONVENTIONAL GAS

At a European, UK and Scottish level, there are three key underlying and interrelated themes that drive energy policy; namely improving security of supply and affordability, and minimising environmental impacts (EU 2013, DECC 2013g, Scottish Government 2013b). This section considers UG in the context of these themes.

EUROPE

The Economist (2013b) notes that there is a “mismatch between the hope and reality for European shale gas”; and that extracting it will be a “slow and difficult business”. It goes on to summarise the situation across Europe as follows:

- Only a handful of test wells have been sunk; it is therefore too early to tell “whether Europe’s shale beds will really prove as bountiful as America’s”
- Determining which countries might enjoy a bonanza of cheap gas is highly speculative: many things are in flux, including extraction technologies and production rates
- On top of this speculation, there have been a number of problems “above ground”, where a moratorium on fracking is in place in France; and the Netherlands and Luxembourg have suspended all drilling for UG. In Germany, North Rhine-Westphalia, the most promising region, has suspended fracking pending research on the risks involved. In Austria the cost of complying with environmental regulations makes UG uneconomic
- Further east, the Czech Republic recently introduced a moratorium, Bulgaria has one in place and Romania only recently lifted its ban

To conclude, the Economist (2013b) states:

Oil companies will send people and equipment where the ride is easiest and the deals are tastiest, which explains why drilling rigs are scarce in Europe. Nearly 1,200 of them scoot around America’s shale beds; in Poland they number only half a dozen. But even if the welcome mat is rolled out now, it will be a long time before Europe can catch up with America. It may take five years to assess whether shale gas exists in commercial quantities, another five before production starts and then a few more before shale could provide a significant addition to supplies: in short, a fracking long time.
The European Commission Joint Research Centre (2012) considered the Potential Energy Market Impacts of UG in the European Union by running a global energy system model which was able to draw some preliminary conclusions as to what can be expected. These are summarised below:

- Shale gas has the potential to impact global gas markets, but only under strongly optimistic assumptions about its production costs and reserves
- The model included the EU’s CO2 emissions targets, and did not preclude a significant absolute growth in gas use; this therefore supported the potential role of gas as a bridge fuel
- The USA and China are well placed to become the top producers of UG, although significant production also takes place in most of the other regions. The scenario analysis suggests that UG will tend to be used within the regions where it is produced
- No single region will produce enough UG so as to move from being a net importer to a net exporter
- Significant shale gas production has the potential to lower gas prices, although the extent of this reduction strongly depends on the way gas is priced in the future. In particular, continued oil indexation\(^7\) is likely to balance any positive impacts that the arrival of UG will have on markets; if oil indexation weakens, price impacts will strengthen.

In the US, where gas prices have dropped significantly, they are not indexed to oil. Regarding the continued setting of European gas prices in relation to oil by many producers, Oil and Gas UK (2013) note:

> Within mainland Europe, several buyers have successfully challenged the operation of the oil indexation of prices under long-term contracts and obtained discounts as a result. Nonetheless, it would appear as though the underlying pricing structures mostly remain in place […]

According to the European Commission, about half of the EU’s gas consumption in 2012 was supplied under oil indexed contracts, with north-west Europe being considerably more liberal (about 70 per cent open market pricing) than central Europe (less than 40 per cent). The story of oil indexation and its expected decline in the EU would appear to have further to run, therefore.

In a European context, it appears that future oil prices and their continuing indexation to gas will play a more significant role in costs to the end user than the availability of UG, regardless of origin.

**UNITED KINGDOM**

The impacts of UG extraction in the UK are also thought unlikely to be the same as in the US. This is primarily because UK shale and CBM is considered to be harder to exploit, for the following reasons (POST 2011):

- UK basins are smaller and more fragmented
- UK source rock tends to contain less gas at lower pressure
- Fracking may be more challenging due to higher clay contents in the rock

Additionally, the Royal Society and The Royal Academy of Engineering (RS/RAE) (2012) note that in the USA, landowners own the hydrocarbons under their land and thereby hold the rights to exploit them. In the UK, ownership is conferred on the state – hence the need for PEDL Licensing.

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\(^7\) Oil remains the world’s leading fuel, and continues to drive the pricing of most energy commodities (BP 2013)
Ownership, however is not the only differentiating factor; the Oxford Institute for Energy Studies (OIES) (2013) states:

Much is made of the mineral ownership rights in the US residing (in the main) with land ownership as a key factor. This is correct, however what is not commonly appreciated is the sheer pace with which the development of shale gas activity commenced, under a largely favourable, light touch regulatory framework. The speed with which leases (conferring drilling rights) were secured and wells drilled on numerous plays throughout the US can be likened to several ‘gold rushes’ occurring in parallel.

The OIES (2013) illustrates the speed of development in the US by noting that in Pennsylvania alone, 6,000 shale gas wells have been drilled since 2007, and goes on to state that:

These starkly illustrate the challenge for the UK. Even if the UK shale gas well flow-rates are sufficient to support commercial development, the sheer number of wells, their visibility during drilling and associated traffic is likely to be a test in terms of public acceptance.

The issue of public acceptance of unconventional gas, in particular the potential environmental impacts of fracking have recently attracted a significant amount of scrutiny. The OIES (2013) also considers that a “dose of reality” is needed in the “current media frenzy […] which has focussed on resource estimates with no attention paid to the practicalities of achieving material levels of […] production”. The University of Strathclyde (2013), and others (Frackland 2013) consider that much of the public debate around fracking has been characterised by misunderstanding and distortion of the basic facts in the media, and the RS/RAE (2012) highlight the need for “expert understanding about risks to be challenged and ‘blind spots’ to be explored” by the “public at large, civil society organisations, those who adopt more sceptical perspectives on technological developments, as well as protest groups” to “help ensure the government addresses issues of actual, rather than assumed, public concern”.

To date, some senior Westminster politicians have alluded to the US boom, and the potentially transformative effects of a domestic UG industry, for example:

- The Chancellor, George Osborne in his Autumn Statement commented (Hansard 2012a) that “We do not want British families and businesses to be left behind as gas prices tumble on the other side of the Atlantic”
- The Prime Minister, David Cameron wrote (Telegraph 2013a) that “the benefits are clear”, and that it “has real potential to drive energy bills down”, “create jobs in Britain”, and “bring money to local neighbourhoods”
- The Secretary of State for Energy and Climate Change, Ed Davey stated (Guardian 2013b) that “If we can have gas safely in this country that will mean jobs, tax revenue and greater energy security”. However, he has also warned that (Guardian 2013c) UG will not have “any effect” on energy bills given Britain is part of a global energy market, and cited previous experiences with North Sea gas, the discovery of which didn’t significantly move UK prices
- The Secretary of State for Justice, and Lord Chancellor, Chris Grayling (Guardian 2013c) stated that fracking is the “solution” to the problem of high energy bills
- The Energy Minister, Michael Fallon stated (BBC 2013b) that it would be “irresponsible” not to support firms trying to access UG, on the subject of whether it could lead to lower household energy bills, Mr Fallon said “We can't be absolutely sure, but the potential is obviously enormous.”
Security of supply and economic impacts

There is debate over whether the introduction of UG into the energy mix will improve energy security at a UK level. An editorial in the Guardian (2013a), states that UG companies are “not in business to do UK consumers a favour, or to rescue the UK government from its energy policy shambles”, furthermore:

If shale gas is extracted in commercial quantities it will be sold to the highest bidder. If that means pumping it across the Channel to Europe – the way our North Sea gas went – then that’s what will happen.

A letter to the Independent however notes (2013) that at a European level:

[…] UK gas prices are linked to those of continental Europe. However, the more gas produced in the UK, the more gas available in Europe, and the less dependent the region as a whole becomes on imports of pipeline gas from Russia and North Africa, and liquefied natural gas from the rest of the world. Reducing Europe’s gas import requirement would have a major impact on regional and global gas pricing.

Dart Energy has a gas sales agreement in place with SSE, to supply CBM produced gas over an 8 year period from 2013 (Energy Global 2013), and Centrica has recently taken a 25% stake in Caudrilla’s licensed area in the Bowland Shale (Telegraph 2013b).

There appears however to be a need for more evidence to support the theory that the exploitation of UG will lead to tangible price reductions. Following an inquiry into the Impact of Shale Gas on Energy Markets the House of Commons Energy and Climate Change Committee (ECCC) (2013a) concluded that:

[…] there remains substantial uncertainty about the impact shale gas will have on gas prices, both internationally and domestically, and it is by no means certain that prices will fall as a result of foreign or domestic shale gas development. It would be wrong for the Government to base policy decisions at this stage on the assumption that gas prices will fall (it is possible that they will rise) in the future. However, if large quantities are found they will either bring down prices in the UK, or generate substantial tax revenues, or both - and will certainly reduce imports with benefits to our balance of payments and energy security.

The Government, in response to this inquiry (HoC ECCC 2013b) broadly agreed with the findings, and stated:

[…] that there is no guarantee that gas prices will fall in the absence of oil indexation. However, moves to deliver liquid, transparent, more effectively linked gas markets […] can have a downward effect on gas prices and can enhance security of supply.

Furthermore:

The US boom in unconventional oil and gas production has been supported by favourable geology, low population density, a competitive supply industry which has developed significant advantages of scale, variable levels of environmental regulation, and strong development incentives for landowners.

While the position in the UK is different, the Government is taking steps to ensure that we make the best use of our unconventional gas resources.

The House of Lords Economic Affairs Select Committee is also currently carrying out an inquiry into the Economic Impact on UK Energy Policy of Shale Gas and Oil (2013a). The majority of written evidence (2013b) is broadly in accordance with Bloomberg New Energy Finance who state
in theirs that “even under the most favourable case for shale gas production, […] [coupled with] low demand […], the UK will not be self-sufficient in gas. The reliance on continued imports will ensure that UK gas prices remain tied to European and world markets and so the direct impact of shale on the cost of electricity in the UK will be limited.”

**Environmental impacts**

As previously noted, the potential environmental impacts of UG have received a significant amount of scrutiny, and the RS/RAE published Shale Gas Extraction in the UK: A Review of Hydraulic Fracturing in June 2012. This made ten top level recommendations relating to:

- detecting groundwater contamination
- ensuring well integrity
- mitigating induced seismicity
- detecting potential leakages of gas
- the integrated management of water
- managing environmental risks
- best practice for risk management
- future training for regulators
- regulatory coordination
- further research

Some of the issues relevant to these recommendations are explored in more detail below.

**Pollution incidents in the US**

Anecdotal instances of pollution (mostly water contamination) in America received prominence through a film called Gasland (2011), and some states (e.g. New York) have put in place moratoriums on fracking (Reuters 2013). The RS/RAE (2012) noted differences in practice between the UK and North America, in particular:

- The number of well casings, and the extent to which these are cemented in place – some were uncased except in the section from the surface casing down to just below the aquifer, others had not been cemented at all, or the cementation had not reached the required height
- In some states, such as Pennsylvania and Texas, there is a requirement to cement casing to approximately 75 ft below any aquifers. Failure to do this can lead to groundwater contamination as occurred in Pavillion, Wyoming.
- In the UK, standard practice is to have three strings of casing with at least two (intermediate and production casing) passing through and thereby isolating any freshwater zones. Best practice is to cement casings all the way back to the surface, depending on local geology and hydrogeology conditions.

On this subject, the Secretary of State for Energy, Ed Davey stated (Hansard 2012b)

> The reports from US regulators and review bodies do confirm that gas developments there have, on occasion, led to water contamination. There are relatively few confirmed instances of this—most complaints on investigation have proved to be attributable to causes other than gas production. And no case has yet come to light in which it has been confirmed that fracking has contaminated an aquifer. But the instances of contamination which have occurred confirm the need for the industry to consistently apply good practice, and the need for proper scrutiny and oversight of the industry to ensure that this is in fact done.

As a result, it appears that both US state and federal level policies in relation to fracking are becoming more stringent, with many new regulations e.g. in relation to drilling, casing, cementing, testing, monitoring and plugging of oil and gas wells, as well as protection of water supplies (Baker & McKenzie 2012).
Seismic Events

In April and May 2011 two earth tremors were detected following Cuadrilla’s hydraulic fracturing operations at Preese Hall, Lancashire. The company subsequently postponed fracking operations to allow for investigations to take place (Caudrilla 2013b).

As a result of these tremors, DECC suspended all fracking operations, and carried out an investigation of their causes and the scope for mitigation of seismic risks in any future operations of this type (Hansard 2012b). It was subsequently concluded that fracking had induced these tremors; however BGS (2013b) states that “It is well-established that fluid injection can induce small earthquakes. Typically, these are too small to be felt”. Furthermore “We would not expect earthquakes of these relatively small magnitudes to cause any damage”.

The BGS subsequently commented (New Scientist 2012) that the risks to groundwater and of earthquakes had been exaggerated, with the minor earthquakes caused by fracking “Comparable in size to the frequent minor quakes caused by coal mining. What's more, they originate much deeper in the crust so have all but dissipated by the time they reach the surface”. The larger of these two tremors has been compared in similarity to the effect of a passing truck (RS/RAE 2012).

It was therefore announced (Hansard 2012b) by the Secretary of State that the Government accepted all of the RS/RAE (2012) recommendations addressed to it (outlined above), and that exploratory hydraulic fracturing for shale gas could resume in the UK. However operators seeking consent for fracking would now be required to:

- Conduct a prior review of information on seismic risks and the existence of faults
- Submit to DECC a frac plan showing how any seismic risks are to be addressed
- Carry out seismic monitoring before, during and after the frac
- Implement a “traffic light” system which will be used to identify unusual seismic activity requiring reassessment, or halting, of operations – the red light which halts operations is undetectable by human senses.

Water

Concerns have been raised about potential contamination of groundwater. Additionally, the sourcing of the volumes of water required for fracking has been questioned.

An assessment of the environmental and climate change impacts of shale gas (Tyndall Centre 2011) sets out concerns about ground and surface water contamination, possibly even affecting quality of drinking water and wetland habitats, depending on factors such as the connection between ground and surface waters. It states:

The depth of shale gas extraction gives rise to major challenges in identifying categorically pathways of contamination of groundwater by chemicals used in the extraction process.

However, an inquiry by the House of Commons Energy and Climate Change Committee into Shale Gas (ECCC 2011a) found no evidence that fracking posed a direct risk to underground water aquifers provided drilling wells are constructed properly. In response, the Government (ECCC 2011b) noted:

The technologies used in shale gas operations are not generically novel or unfamiliar. Hydraulic fracturing, water injection and lateral drilling, individually or in combination, are all familiar techniques that DECC and the other regulators have had to deal with robustly for a long time.
The RS/RAE (2012) considered that because fracking takes place many hundreds of metres or even several kilometres below aquifers, it is very unlikely that fracking will affect them. However, more likely causes of possible contamination include faulty wells, and the report called for the same stringent controls for offshore wells to be applied onshore:

Ensuring well integrity must remain the highest priority to prevent contamination. The probability of well failure is low for a single well if it is designed, constructed and abandoned according to best practice. The UK’s well examination scheme was set up so that the design of offshore wells could be reviewed by independent, specialist experts. This scheme must be made fit for purpose for onshore activities.

Regarding resource use, the excessive use of water for fracking is highlighted by the IEA (2012) as generating “particular public concern”, and the Tyndall Centre (2011) notes that “water resources in many parts of the UK are already under pressure”. This is echoed by a senior adviser to DECC, who states (Guardian 2013d):

Drilling for shale gas requires a significant amount of water – about 15,000 tonnes per well. At each site, typically, about 10 wells are drilled. [...] Despite the common view of our weather, parts of the UK do not have a plentiful supply of water, especially the south-east. According to the Environment Agency there is less water available per person in the south-east than in many Mediterranean countries – and with increasing population, shortages are increasing. We need to carefully manage how the water is delivered to and from potential sites. If trucks were to be used, you would need about 10,000 of the largest to transport water to and from a single site. Piping water in and out would be better, saving both emissions from transport and disruption to local communities.

As previously noted, if fracking was to occur for CBM it generally requires less water than fracking for shale, and proposed operations (which do not require fracking) in Scotland require water to be pumped out\(^8\), rather than into wells. Nevertheless, water produced from CBM still requires sophisticated clean up and disposal.

The IEA (2012) further notes that the amount of water required for shale gas extraction, calculated per unit of energy produced, is comparable to the amount required for the production of conventional oil. The RS/RAE (2012) puts this into context by citing research that estimates that the amount needed to operate a hydraulically fractured shale gas well for a decade may be equivalent to the amount needed to water a golf course for a month; the amount needed to run a 1,000 MW coal-fired power plant for 12 hours; and the amount lost to leaks in United Utilities’ region in north west England every hour.

Efficient use of water, and continued research into improving this is therefore essential. This is not always straightforward, as for example, some techniques which decrease the amount of water used need thicker fracturing fluids, and “a complex cocktail of chemicals to be added”. Water can also be eliminated altogether by using hydrocarbon-based fracturing fluids, such as propane or gelled hydrocarbons, but their flammability makes them more difficult to handle safely at the well site. More attractive is the use of foaming fluids, in which water is foamed with nitrogen or carbon dioxide, with the help of surfactants (as used in dish washing liquids), and can be up to 90% gas (IEA 2012).

The RS/RAE (2012) consider that because large quantities of industrial wastewater are regularly produced, regulated and monitored in the UK, then this can be managed sustainably; providing that recycling and re-use of wastewaters and that water disposal options are planned from the outset.

\(^8\) Up to 880m\(^3\) a day, which is proposed to be piped directly to an outflow at the River Forth
Greenhouse Gas and Other Emissions

The Scottish and UK Governments have agreed to meet a number of domestic and European targets to decarbonise the UK’s economy, and to shift to renewable energy. Both Scottish and UK Governments have agreed to reduce greenhouse gas emissions by 80% by 2050, with interim targets in 2020 equating to 42% in Scotland, and 34% across the UK. The EU has a target to reduce EU-wide greenhouse gas emissions by 20% by 2020 (Scottish Government 2013c).

The Scottish Government has a target for the equivalent of 100% of Scotland’s own electricity demand, and 11% of heat demand to be produced by renewable sources by 2020, with an interim electricity target of 50% from renewable sources by 2015. Scottish electricity generation should also be “largely decarbonised by 2030”. It has also been agreed that 20% of total energy production across the EU should be generated by renewable sources, with the UK committed to sourcing 15% of its energy from renewables (Scottish Government 2013b & 2013c).

The path to decarbonisation is however not set in stone, and there are many complex options and different views about whether low carbon fuels like gas can or should play a bridging role. The following PQ (Scottish Parliament 2011) explores this in a Scottish context:

**Question S4W-04184: Alison Johnstone, Lothian, Scottish Green Party, Date Lodged: 23/11/2011** To ask the Scottish Executive whether it considers that the burning and extraction of shale gas and coal bed methane gas reserves will release significant quantities of climate change emissions into the atmosphere.

**Answered by Fergus Ewing (08/12/2011):** The Scottish Government does not expect significant emissions from the burning and extraction of shale gas and coal bed methane gas reserves in Scotland. Increased unconventional gas production, if properly controlled, could result in lower overall emissions, if it displaces fuels such as coal which are associated with higher emissions.

SEPA (2012) recognises that UG “could lead to delays in the programme to convert to renewable energy sources causing a delay in the reduction of greenhouse gas releases and the decarbonisation of the energy sector. However, it could also reduce CO2 emissions if natural gas displaces coal”.

As previously noted, US carbon emissions have fallen by 9% since 2005, reversing a strong upward trend, however complex global supply and demand markets for fossil fuels means that much of the coal that has been displaced from American markets has been burnt in Europe.

The Tyndall Centre (2011) concluded that:

Carbon dioxide from burning this new source of fossil fuel could take up over a quarter of a global emissions budget that offers a reasonable chance of avoiding 2 degrees Celcius warming. In the UK, if just 20% of the reserves identified under Lancashire were to be extracted and burnt, this would result in emissions of over 2,000 million tonnes of carbon dioxide, representing around 15% of the Government’s greenhouse gas emissions budget through to 2050.

Similarly, the IEA states (2013):

[…] an increased share of natural gas in the global energy mix is not sufficient on its own to put the world on a carbon emissions path consistent with an average global temperature rise of no more than 2°C. To achieve this target requires a greater shift to low-carbon energy sources, increased efficiency in energy usage, and new technologies, including carbon capture and storage.
This is confirmed by research from the New Economics Foundation (2012) which warns against further investment in fossil fuels, and estimates that “if we are to remain within safe global carbon emissions, 80 per cent of declared proven fossil fuel reserves are unburnable. Far from being assets, these are potentially toxic financial liabilities”.

Besides the potential for increased carbon emissions when burnt, concern has also been raised about methane leakage at the point of production (known as fugitive emissions).

The ECC Committee (2013) recommended that policies on flaring and venting of methane should be reviewed to keep fugitive emissions as close to zero as possible, and that these emissions should be monitored by DECC.

The RS/RAE (2012) considers that more work is needed to monitor this, and to explore the carbon footprint and climate risks associated with extraction and use. Similarly, SEPA (2012) states:

Methane is a more potent greenhouse gas than carbon dioxide. There is a lack of real field data in this area and more research is required, however it has been reported that fugitive releases of methane during shale gas operations is higher than those of conventional gas but less that from coal. However, others have questioned the validity of the data used to justify this position until this dispute is resolved by collection and analysis of actual data we will remain neutral but will require operators to make full use of technologies that capture the gas prior to escape in order to reduce methane emission to air. We are also considering the need for monitoring.

A recent report by DECC (2013h) on the Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use concludes that local emissions should not be significant if properly regulated, compared to the overall emissions from burning shale gas. It found that shale gas’s overall carbon footprint was comparable to gas extracted from conventional sources, lower than that of LNG, and, when used for generating electricity, significantly lower than that of coal.

Responding to the report, the Secretary of State, Ed Davey (DECC 2013i) said that gas was “part of the answer to climate change”, as a bridge in our transition to a green future. Indigenous on-shore production would allow the UK to control the emissions better rather than off-shoring them, contribute to energy security, and maintain tax revenues as the North Sea wound down.
SOURCES


Management of Extractive Waste (Scotland) Regulations 2010 No. 60


Reach Coal Seam Gas Limited. Available at: [http://www.reachcsg.co.uk/index.html](http://www.reachcsg.co.uk/index.html) [Accessed 22 October 2013].

Reuters. (2013) *New York State Assembly votes to block fracking until 2015*. Available at: [http://www.reuters.com/article/2013/03/06/energy-fracking-newyork-idUSL1N0BYFK320130306](http://www.reuters.com/article/2013/03/06/energy-fracking-newyork-idUSL1N0BYFK320130306) [Accessed 22 October 2013].


Town and Country Planning (Scotland) Act 1997 c. 8

Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011 No. 139


Water Environment (Controlled Activities) Regulations 2011 No. 176
ANNEXE A – CURRENT PEDL LICENCES
## ANNEXE B – CURRENT PEDL LICENCES BY SCOTTISH PARLIAMENTARY CONSTITUENCY

### Licences by Constituency

<table>
<thead>
<tr>
<th>Name</th>
<th>Licence</th>
<th>Operator</th>
<th>SP Region</th>
<th>Licenced Area km²</th>
<th>Constituency Area km²</th>
<th>% of constituency in block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airdrie and Shotts</td>
<td>PEDL162</td>
<td>REACH</td>
<td>CENTRAL SCOTLAND</td>
<td>109.02</td>
<td>213.904</td>
<td>51%</td>
</tr>
<tr>
<td>Caithness, Sutherland and Ross</td>
<td>PEDL158</td>
<td>CAITHNESS</td>
<td>HIGHLANDS AND ISLANDS</td>
<td>158.83</td>
<td>12791.434</td>
<td>1%</td>
</tr>
<tr>
<td>Clackmannanshire and Dunblane</td>
<td>PEDL133</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>91.33</td>
<td>255.144</td>
<td>36%</td>
</tr>
<tr>
<td>Clackmannanshire and Dunblane</td>
<td>PEDL163</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>1.38</td>
<td>255.144</td>
<td>1%</td>
</tr>
<tr>
<td>Coatbridge and Chryston</td>
<td>PEDL162</td>
<td>REACH</td>
<td>CENTRAL SCOTLAND</td>
<td>19.55</td>
<td>63.3</td>
<td>31%</td>
</tr>
<tr>
<td>Cowdenbeath</td>
<td>PEDL163</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>71.11</td>
<td>135.154</td>
<td>53%</td>
</tr>
<tr>
<td>Cumbernauld and Kilsyth</td>
<td>PEDL162</td>
<td>REACH</td>
<td>CENTRAL SCOTLAND</td>
<td>79.06</td>
<td>104.995</td>
<td>75%</td>
</tr>
<tr>
<td>Dumfriesshire</td>
<td>PEDL159</td>
<td>DART</td>
<td>SOUTH SCOTLAND</td>
<td>106.02</td>
<td>2881.723</td>
<td>4%</td>
</tr>
<tr>
<td>Dunfermline</td>
<td>PEDL133</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>49.79</td>
<td>213.243</td>
<td>23%</td>
</tr>
<tr>
<td>Dunfermline</td>
<td>PEDL163</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>79.41</td>
<td>213.243</td>
<td>37%</td>
</tr>
<tr>
<td>Ettrick, Roxburgh and Berwickshire</td>
<td>PEDL159</td>
<td>DART</td>
<td>SOUTH SCOTLAND</td>
<td>0.15</td>
<td>3193.473</td>
<td>0.005%</td>
</tr>
<tr>
<td>Falkirk East</td>
<td>PEDL133</td>
<td>DART</td>
<td>CENTRAL SCOTLAND</td>
<td>74.49</td>
<td>205.702</td>
<td>36%</td>
</tr>
<tr>
<td>Area</td>
<td>Pedl Code</td>
<td>Scheme</td>
<td>Region</td>
<td>Value</td>
<td>Total</td>
<td>%</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-----------</td>
<td>--------</td>
<td>-------------------------------</td>
<td>-------</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>Falkirk East</td>
<td>PEDL162</td>
<td>REACH</td>
<td>CENTRAL SCOTLAND</td>
<td>63.23</td>
<td>205.702</td>
<td>31%</td>
</tr>
<tr>
<td>Falkirk West</td>
<td>PEDL133</td>
<td>DART</td>
<td>CENTRAL SCOTLAND</td>
<td>51.06</td>
<td>109.229</td>
<td>47%</td>
</tr>
<tr>
<td>Falkirk West</td>
<td>PEDL162</td>
<td>REACH</td>
<td>CENTRAL SCOTLAND</td>
<td>30.55</td>
<td>109.229</td>
<td>28%</td>
</tr>
<tr>
<td>Glasgow Maryhill and Springburn</td>
<td>PEDL162</td>
<td>REACH</td>
<td>GLASGOW</td>
<td>0.05</td>
<td>27.046</td>
<td>0.2%</td>
</tr>
<tr>
<td>Kirkcaldy</td>
<td>PEDL163</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>44.04</td>
<td>99.654</td>
<td>44%</td>
</tr>
<tr>
<td>Linlithgow</td>
<td>PEDL133</td>
<td>DART</td>
<td>LOTHIAN</td>
<td>0.63</td>
<td>208.59</td>
<td>0.3%</td>
</tr>
<tr>
<td>Linlithgow</td>
<td>PEDL162</td>
<td>REACH</td>
<td>LOTHIAN</td>
<td>10.62</td>
<td>208.59</td>
<td>5%</td>
</tr>
<tr>
<td>Mid Fife and Glenrothes</td>
<td>PEDL163</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>32.09</td>
<td>150.084</td>
<td>21%</td>
</tr>
<tr>
<td>Mid Fife and Glenrothes</td>
<td>PEDL161</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>24.29</td>
<td>150.084</td>
<td>16%</td>
</tr>
<tr>
<td>North East Fife</td>
<td>PEDL161</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>76.60</td>
<td>775.786</td>
<td>10%</td>
</tr>
<tr>
<td>Perthshire South and Kinross-shire</td>
<td>PEDL133</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>6.40</td>
<td>1449.837</td>
<td>0.44%</td>
</tr>
<tr>
<td>Perthshire South and Kinross-shire</td>
<td>PEDL163</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>68.23</td>
<td>1449.837</td>
<td>5%</td>
</tr>
<tr>
<td>Stirling</td>
<td>PEDL133</td>
<td>DART</td>
<td>MID SCOTLAND AND FIFE</td>
<td>56.25</td>
<td>2163.589</td>
<td>3%</td>
</tr>
<tr>
<td>Strathkelvin and Bearsden</td>
<td>PEDL162</td>
<td>REACH</td>
<td>WEST SCOTLAND</td>
<td>87.84</td>
<td>143.945</td>
<td>61%</td>
</tr>
<tr>
<td>Uddingston and Bellshill</td>
<td>PEDL162</td>
<td>REACH</td>
<td>CENTRAL SCOTLAND</td>
<td>0.09</td>
<td>52.858</td>
<td>0.2%</td>
</tr>
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</table>
## Licences by Region

<table>
<thead>
<tr>
<th>Name</th>
<th>Licence</th>
<th>Operator</th>
<th>Area km²</th>
<th>Area of region</th>
<th>% of region in block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Scotland</td>
<td>PEDL133</td>
<td>DART</td>
<td>125.54</td>
<td>954.76</td>
<td>13%</td>
</tr>
<tr>
<td>Central Scotland</td>
<td>PEDL162</td>
<td>REACH</td>
<td>301.50</td>
<td>954.76</td>
<td>32%</td>
</tr>
<tr>
<td>Glasgow</td>
<td>PEDL162</td>
<td>REACH</td>
<td>0.05</td>
<td>209.43</td>
<td>0.02%</td>
</tr>
<tr>
<td>Highlands and Islands</td>
<td>PEDL158</td>
<td>CAITHNESS</td>
<td>158.83</td>
<td>41261.17</td>
<td>0.4%</td>
</tr>
<tr>
<td>Lothian</td>
<td>PEDL133</td>
<td>DART</td>
<td>0.63</td>
<td>872.97</td>
<td>0.07%</td>
</tr>
<tr>
<td>Lothian</td>
<td>PEDL162</td>
<td>REACH</td>
<td>10.62</td>
<td>872.97</td>
<td>1%</td>
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<tr>
<td>Mid Scotland and Fife</td>
<td>PEDL133</td>
<td>DART</td>
<td>203.77</td>
<td>9211.56</td>
<td>2%</td>
</tr>
<tr>
<td>Mid Scotland and Fife</td>
<td>PEDL163</td>
<td>DART</td>
<td>296.24</td>
<td>9211.56</td>
<td>3%</td>
</tr>
<tr>
<td>Mid Scotland and Fife</td>
<td>PEDL161</td>
<td>DART</td>
<td>100.89</td>
<td>9211.56</td>
<td>1%</td>
</tr>
<tr>
<td>South Scotland</td>
<td>PEDL159</td>
<td>DART</td>
<td>106.17</td>
<td>16384.95</td>
<td>1%</td>
</tr>
<tr>
<td>West Scotland</td>
<td>PEDL162</td>
<td>REACH</td>
<td>87.84</td>
<td>2332.5</td>
<td>4%</td>
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</tbody>
</table>
### Summary by Constituency

<table>
<thead>
<tr>
<th>Constituency</th>
<th>Total Licensed Area km²</th>
<th>Constituency Area km²</th>
<th>% of constituency in block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airdrie and Shotts</td>
<td>109</td>
<td>214</td>
<td>51%</td>
</tr>
<tr>
<td>Caithness, Sutherland and Ross</td>
<td>159</td>
<td>12791</td>
<td>1%</td>
</tr>
<tr>
<td>Clackmannanshire and Dunblane</td>
<td>93</td>
<td>255</td>
<td>36%</td>
</tr>
<tr>
<td>Coatbridge and Chryston</td>
<td>20</td>
<td>63</td>
<td>31%</td>
</tr>
<tr>
<td>Cowdenbeath</td>
<td>71</td>
<td>135</td>
<td>53%</td>
</tr>
<tr>
<td>Cumbernauld and Kilsyth</td>
<td>79</td>
<td>105</td>
<td>75%</td>
</tr>
<tr>
<td>Dumfriesshire</td>
<td>106</td>
<td>2882</td>
<td>4%</td>
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<tr>
<td>Dunfermline</td>
<td>129</td>
<td>213</td>
<td>61%</td>
</tr>
<tr>
<td>Ettrick, Roxburgh and Berwickshire</td>
<td>0</td>
<td>3193</td>
<td>0%</td>
</tr>
<tr>
<td>Falkirk East</td>
<td>138</td>
<td>206</td>
<td>67%</td>
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<tr>
<td>Falkirk West</td>
<td>82</td>
<td>109</td>
<td>75%</td>
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<tr>
<td>Glasgow Maryhill and Springburn</td>
<td>0</td>
<td>27</td>
<td>0%</td>
</tr>
<tr>
<td>Kirkcaldy</td>
<td>44</td>
<td>100</td>
<td>44%</td>
</tr>
<tr>
<td>Linlithgow</td>
<td>11</td>
<td>209</td>
<td>5%</td>
</tr>
<tr>
<td>Mid Fife and Glenrothes</td>
<td>56</td>
<td>150</td>
<td>38%</td>
</tr>
<tr>
<td>North East Fife</td>
<td>77</td>
<td>776</td>
<td>10%</td>
</tr>
<tr>
<td>SP Region</td>
<td>Total Licensed Area km²</td>
<td>Region Area km²</td>
<td>% of Region Licensed</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------------------</td>
<td>-----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Perthshire South and Kinross-shire</td>
<td>75</td>
<td>1450</td>
<td>5%</td>
</tr>
<tr>
<td>Stirling</td>
<td>56</td>
<td>2164</td>
<td>3%</td>
</tr>
<tr>
<td>Strathkelvin and Bearsden</td>
<td>88</td>
<td>144</td>
<td>61%</td>
</tr>
<tr>
<td>Uddingston and Bellshill</td>
<td>0</td>
<td>53</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Summary by Region**

<table>
<thead>
<tr>
<th>SP Region</th>
<th>Total Licensed Area km²</th>
<th>Region Area km²</th>
<th>% of Region Licensed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Scotland</td>
<td>427</td>
<td>955</td>
<td>45%</td>
</tr>
<tr>
<td>Glasgow</td>
<td>0.05</td>
<td>209</td>
<td>0.02%</td>
</tr>
<tr>
<td>Highlands and Islands</td>
<td>159</td>
<td>41261</td>
<td>0.4%</td>
</tr>
<tr>
<td>Lothian</td>
<td>11</td>
<td>873</td>
<td>1%</td>
</tr>
<tr>
<td>Mid Scotland and Fife</td>
<td>601</td>
<td>9212</td>
<td>7%</td>
</tr>
<tr>
<td>South Scotland</td>
<td>106</td>
<td>16385</td>
<td>1%</td>
</tr>
<tr>
<td>West Scotland</td>
<td>88</td>
<td>2333</td>
<td>4%</td>
</tr>
</tbody>
</table>
### ANNEXE C – CURRENT UNDERGROUND COAL GASIFICATION LICENCES

Coal Authority (2013b):

**Underground Coal Gasification Scotland**

<table>
<thead>
<tr>
<th>Licence</th>
<th>Licensee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1 – NT39</td>
<td>Thornton New Energy</td>
</tr>
<tr>
<td></td>
<td>Term extended once - due to expire in January 2015 unless progress made</td>
</tr>
<tr>
<td>Central Forth</td>
<td>Riverside Energy</td>
</tr>
<tr>
<td></td>
<td>Licence now expired but renewal application being processed in competition with Five Quarter Energy</td>
</tr>
<tr>
<td>Kincardine</td>
<td>Cluff Natural Resources</td>
</tr>
<tr>
<td></td>
<td>Granted for a 5 year conditional period in July 2013</td>
</tr>
<tr>
<td>Largo Bay</td>
<td>Cluff Natural Resources</td>
</tr>
<tr>
<td></td>
<td>Granted for a 5 year conditional period in August 2013</td>
</tr>
<tr>
<td>Musselburgh</td>
<td>Riverside Energy</td>
</tr>
<tr>
<td></td>
<td>Licence now expired but renewal application being processed in competition with Five Quarter Energy</td>
</tr>
<tr>
<td>Solway Firth</td>
<td>Five Quarter Energy</td>
</tr>
<tr>
<td></td>
<td>Originally licensed to Clean Coal Energy but expired and new application received from Five Quarter Energy</td>
</tr>
</tbody>
</table>
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