Unconventional gas extraction **Policy**

Scope of the policy

1. This policy covers the Scottish Wildlife Trust's views on unconventional gas extraction - specifically with regard to the potential environmental impacts of on-shore hydraulic fracturing[1] and coal bed methane extraction. The policy will be kept under review and updated in light of future developments in unconventional gas exploration.

Policy headlines

i. The Scottish Wildlife Trust believes that the Scottish Government should focus resources on the development of renewable energy and ensure funding is prioritised to the implementation and development of low-carbon technologies rather than it being diverted to investing in extraction of a 'transition gas' such as methane.

ii. The Scottish Wildlife Trust believes that extraction of shale gas by hydraulic fracturing and coal bed methane extraction could pose environmental risks ranging from contamination of aquifers to accidental release of chemicals. There must be strict interpretation and enforcement of the regulatory regime to ensure that wildlife habitats and ecosystems are protected from the potentially damaging effects of hydraulic fracturing and coal bed methane extraction.

iii. The Scottish Wildlife Trust will consider its response to planning proposals for the extraction of shale gas and coal bed methane on a case by case basis. Where the Trust believes there would be a significant impact to wildlife, habitats or ecosystems or where the potential risk of environmental damage is high, regardless of mitigation, we will object. There should be no consents given to unconventional gas extraction in protected sites; the Scottish Wildlife Trust will object to such development proposals.

Context

Conventional gas vs unconventional gas

2. Conventional natural gas is usually extracted from discrete, well-defined reservoirs and can be extracted relatively easily using vertical wells. Unconventional natural gas (usually methane) is found in less permeable rock, distributed over a larger area, difficult to extract without well stimulation (such as hydraulic fracturing), often requires horizontal drilling and the recovery rate is low.

3. The two types of unconventional gas extraction covered by this policy are:
    a) Coal bed methane: natural gas (mainly methane) trapped in coal seams
    b) Shale gas: natural gas (mainly methane) trapped in fine-grained sedimentary rock called shale

Shale gas extraction by hydraulic fracturing

Process

4. A vertical well which is lined with a perforated steel and concrete casing is drilled down to shale rock, then horizontal drilling stretches the well along the gas bearing shale layer. Within the shale, explosive charges are used to create fractures in the rock casing. A mixture of water (c. 94%), sand (c. 5%) and chemicals (< 1%) is then pumped into the borehole at high pressure. This high pressure mixture goes through the perforations in the casing, causing the shale to fracture and release the gas. The sand grains lodge within the fractures and keeps them open, allowing the released gas to flow out of the rocks and along the well to the surface for collection. The well may be 1 – 4 km below the surface.

Fracturing fluid

5. Unlike in the USA, operators in the UK must disclose the composition of fracturing fluid. The chemical additives may include: scale inhibitor to prevent the build-up of scale on the wall of the well; acid to help initiate fractures; biocide to kill bacteria that produce hydrogen sulphide and lead to corrosion; friction reducer to reduce friction between the well and fluid injected into it; and surfactant to reduce the viscosity of the fracturing fluid. As an example, Cuadrilla[2] declared the following mix of hydraulic fracturing additives used for drilling four wells at Preese Hall (near Blackpool in England) in 2011: sand – open fractures; polyacrylamide emulsion in hydrocarbon oil - friction reducer; sodium salt – chemical tracer to detect flow back fluid.[3]

Coal bed methane extraction

6. Unlike shale gas extraction, much of the coal, and thus much of the methane, lies at shallow depths (about 1 km), making wells easier to drill - hydraulic fracturing is not normally required.

7. In coal bed methane reservoirs, the key parameters controlling the amount of gas in place include coal bed thickness, coal composition, gas content and gas composition. Coal bed methane may be spread over a very large geographic area. The challenge is not to find gas but to find areas that will produce gas commercially.[4]

8. Extraction of methane from coal beds involves drawing off water first by pumping. This lowers the pressure so methane can flow out of the coal and to the wellbore.

UK resource of shale gas and coal bed methane

9. Although the extraction of shale gas is still in its infancy in the UK, it has been estimated that the UK's recoverable shale gas resource is c. 150 billion cubic metres (bcm), equivalent to roughly two years of UK gas demand.[5] As a caveat with regard to this estimate, British Geological Survey (BGS) state that *ahead of more drilling, fracture stimulation and testing there are no reliable indicators of potential productivity*.[6] BGS estimate the coal bed methane resource at c. 2,900 bcm.

Resource in Scotland

10. In Scotland, potential coal bed containing methane and shale formations containing potentially extractable shale gas are present in the south, mainly across the central belt.[7] In Scotland, there are currently five live Petroleum Exploration and Development Licences (PEDLs) issued by the Department of Energy and Climate Change (DECC), which relate to shale gas or coal bed methane gas extraction.[8] See Appendix 1 for further details.

Regulation

11. Shale gas and coal bed methane extraction are a reserved matter. The operator must firstly obtain a Petroleum Exploration and Development licence (PEDL) from the UK's Department of Energy and Climate Change (DECC). This licence confers exclusivity in a defined area against other exploration companies, but does not confer any exemption from other legal/regulatory requirements. In particular, before works can start a licensee, requires the consent of the landowner(s), planning permission for any operations on land and must comply with appropriate health and safety and environmental regulations. In Scotland, Scottish Environment Protection Agency (SEPA) is the statutory consultee in the planning system and regulates the abstraction from and discharges to the environment (e.g. water, chemicals etc.). Scottish Natural Heritage (SNH) would be the statutory agency consulted where activities are likely to affect protected species and natural habitats. The Coal Authority must be consulted if any activity intersects, disturbs or enters coal seams (more applicable to coal bed methane).

12. Planning consent is determined by the local planning authority who will consult with the statutory agencies regarding environmental impacts.

Environmental Impact Assessment Directive (EIA)

13. The European Commission have stated that both the exploration and exploitation of unconventional hydrocarbons fall within the scope of the EIA Directive.[9] The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011 transposes the Directive into Scottish law.[10] Developments listed in Schedule 1 of the Regulations will always require EIA (in this case -extraction of natural gas where the amount of gas extracted exceeds 500.000 m^3 per day).

14. Some forms of shale gas and coal bed methane extraction operations will fall under Schedule 2 of the Regulations. As such they will be subject to case by case screening by the relevant planning authority to determine whether an EIA will be required.

15. The Scottish Wildlife Trust believes that an EIA covering the lifetime of the project should be carried out in full, for all shale and coal bed methane extraction activities, prior to submission of a planning application. The EIA should cover the period when operations cease and the site is decommissioned – leaving abandoned wells in place. The Environmental Statement should set out how the abandoned wells will be monitored to ensure well integrity is maintained in the long term (see also para. 30 below).

16. Because of the environmental risk posed by human error - which cannot be eliminated even through following best practice guidelines or other forms of mitigation - the Trust believes that planning consent

should be refused where operations would pose a significant threat and high risk to protected species, habitats or ecosystems, e.g. operational activities affecting Natura 2000 sites; nationally protected sites, Local Biodiversity Sites (i.e. Local Nature Conservation Sites); protected species such as freshwater pearl mussel and Atlantic salmon; ecosystems such as lowland raised bogs.

SEPA's role

17. SEPA's role[11] in relation to this industry is predominately controlling the impacts on the water environment from exploration and extraction processes, however it also includes the protection to air and land. The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR) applies and the operator would require a CAR authorisation to construct the well in addition to an authorisation for any abstraction and discharges activities. (For further details on SEPA's regulatory role please see Appendix 2.)

Environmental impacts of unconventional gas activities – hydraulic fracturing

18. The key environmental impacts are summarised below:

    a) surface and ground water pollution by:
        i. spillage of chemicals in fracturing fluid
        ii. flowback
        iii. contamination of ground water
    b) climate change
    c) water use
    d) seismicity
    e) other impacts such as noise and transport

Surface and ground water pollution

Spillage of chemicals in fracturing fluid

19. Surface spills of drilling and fracturing fluid may pose a greater contamination risk than hydraulic fracturing itself.[12] The Royal Society (RS) report[13] recommends that the potential impact of any spills of fracturing fluid (or wastewaters) onsite should be mitigated using established best practices. The impact of fracturing fluid spills can be further mitigated by using non-hazardous chemicals where possible although there is no generic list of approved chemicals for use in fracturing fluid. All chemicals to be used in fracturing fluid must be disclosed. SEPA authorisation is required for the storage and use of fracturing fluid.

20. The Scottish Wildlife Trust believes that to minimise risks to the water environment, non- hazardous chemicals should be used in fracturing fluid. The Trust also believes that there should be monitoring of the water environment, funded by the operator, during production operations and findings should be regularly reported to SEPA. As a reference, baseline water quality data will be required.

Flowback

21. A large amount of the water mix flows back to the surface over the well's lifetime. Whilst 'flowback' fluids include the drilling and fracturing fluids pumped into the well, it also contains:

    a) chemical transformation products that may have formed due to reactions between fracturing additives
    b) substances mobilised from within the shale formation during the drilling and fracturing operation
    c) naturally occurring radioactive materials (NORMs)

22. The composition of flowback fluid is variable due to the nature and concentrations of substances found in different shale formations.[14]

23. In the USA, wastewaters are often stored onsite in open pits which are prone to leakage.[15] Open storage ponds are not permitted in the UK. Wastewaters are stored in closed metal tanks before being treated. Leaks or spills of wastewaters can be managed in the same way as spills of fracturing fluid. This storage hazard is not unique to shale gas extraction but common to many industrial processes. Waste waters can be recycled and reused although this is likely to concentrate hazardous substances and complicate the disposal process. Operators would be required to formulate waste management plans to comply with the Management of Extractive Waste (Scotland) Regulations 2010, enforced by the planning authority, in addition to obtaining the appropriate Waste Management Licence from SEPA.

24. The Scottish Wildlife Trust believes that options for treating and disposing of wastes must be planned from the outset and agreed with the planning authority and SEPA. The Trust also believes that there should be monitoring of the water environment during production operations (see also para. 23 above). The Trust believes that wastewater should not be re-used in the fracturing fluid if it contains chemical contaminants and radioactive materials that may pose a risk to the water quality of the aquifer in an event of well failure or of fractures extending out of the production zone (see also report for European Commission DG Environment[16]).

Contamination of groundwater

25. Groundwater is water that collects in rock formations known as aquifers. Groundwater is not stationary but flows through and along rock crevices from the area where water enters the aquifer (recharge zone) to an area where water leaves the aquifer (discharge zone). Where this is near the surface, springs occur and support the flow of rivers and grounded wetlands such as fens and marshlands.[17] The quality of groundwater is generally high. Fracturing, 'flowback' fluids and methane could contaminate groundwater and have potentially severe impacts on drinking water quality and/or surface waters/wetland habitats. Routes of exposure include:[18]

    a) catastrophic failure or full/partial loss of integrity of the wellbore
    b) migration of contaminants from the target fracture through subsurface pathways including:
        i. the outside of the wellbore itself
        ii. other wellbores (such as incomplete, poorly constructed
        iii. older/poorly plugged wellbores)
        iv. fractures created during the hydraulic fracturing process
        v. natural cracks, fissures and interconnected pore spaces

26. With regard to methane contamination of groundwater supplies, baseline data is essential to determine if methane originates from the shale itself rather than from the fracturing process.

27. The RS report[19] has the following recommendations to mitigate the risk of groundwater contamination:

    a) the UK's environmental regulators should work with the British Geological Survey (BGS) to carry out comprehensive national baseline surveys of methane and other contaminants in groundwater
    b) operators should carry out site-specific monitoring of methane and other contaminants in groundwater before, during and after shale gas operations
    c) arrangements for monitoring abandoned wells need to be developed

d) funding of this monitoring and any remediation work needs further consideration
e) the data collected by operators should be submitted to the appropriate regulator

28. The Scottish Wildlife Trust believes that the EIA must include baseline data of methane concentration of an aquifer which is at risk from operational activities. Planning consent should not be given where this data has not been made available.

29. The Scottish Wildlife Trust believes that all of the RS's other recommendations listed above (paragraph 30: (b) – (e)) should be fully implemented prior to consent being granted.
30. Even with best practice measures and mitigation, human error cannot be ruled out and this is highlighted in the Tyndall Centre report [20] which states: *There is a clear risk of contamination of groundwater from shale gas extraction. It is important to recognise that most problems arise due to errors in construction or operation and these cannot be eliminated.*

31. A report commissioned by the European Commission [21] found that the likelihood of properly injected fracturing liquid reaching underground sources of drinking water through fractures is remote where there is more than 600 metres separation between the drinking water sources and the producing zone.

32. In light of the above, the Trust believes that fracturing should not be permitted where the separation zone between an aquifer and the gas extraction zone is less than 600 m.

Climate change

33. Some consider that the use of shale gas (e.g. methane) is a 'transition fuel' - helping to displace higher emitting fuels such as coal.[22,23] Others believe that reliance on shale gas could further lock countries into fossil fuel economies and delay the incentive to invest and develop low-carbon technologies and renewable energy.[24] Leakages of methane gas during extraction could offset the lower CO_2 emissions.[25]

34. The Scottish Wildlife Trust believes that the Scottish Government should focus resources on the development of renewable energy and ensure funding is prioritised to the implementation and development of renewable energy technologies rather than it being diverted to investing in extraction of a 'transition gas' such as methane.

35. The Scottish Wildlife Trust believe that on site methane leakages/emissions should be monitored by the operator as part of monitoring and reporting on local air quality. In line with SEPA's recommendations, operators should use technologies that capture the gas prior to escape in order to reduce methane emission to air.[26]

Water use

36. Various estimates abound of how much water is necessary for fracturing. The RS report quotes work carried out by Moore (2012) which states that the amount needed to operate a well for a decade is the same as that needed to run a golf course for a month.[27]

37. Local conditions will dictate the source of water and operators may decide to abstract water under license (from SEPA) or have water delivered by tankers. Extra demand for water through abstraction may cause problems in drought prone areas, but it is probably more applicable to south of the Border than to Scotland.

38. The Scottish Wildlife Trust believe that effects on the local hydrological regime and water supplies should be fully assessed as part of the EIA and CAR abstraction licence and a license refused where there is likely to be a significant impact.

Seismicity

39. In 2011 Blackpool experienced a seismic event shortly after Cuadrilla Resources fracked a well at the Preese Hall site. Drilling was suspended and an independent study[28] concluded that the observed seismicity was induced by the injection of fluid into an adjacent fault which resulted in a number of small earthquakes.

40. 'Induced seismicity' can occur in previously aseismic areas following oil and gas activities. Thousands of induced earthquakes are registered annually, and operators can take steps to reduce or control seismicity.[4] Natural or mining-induced earthquakes in the UK are not uncommon with around 150 earthquakes recorded on average each year; 15% are felt by people.[29]

41. Seismicity risk is discussed in detail in the RS report [30] which suggests that operators should carry out a seismic risk assessment as part of the EIA. Further suggested mitigation is summarised below:

    a) Operators should carry out site-specific surveys to characterise and identify local stresses and faults
    b) Seismicity should be monitored before, during and after hydraulic fracturing
    c) Traffic light monitoring systems should be implemented and data fed back to well injection operations so that action can be taken to mitigate any induced seismicity
    d) Operators should share data with DECC and BGS to establish a national database of shale stress and fault properties so that suitable well locations can be identified

42. The Scottish Wildlife Trust believes that operators should reduce the risk of a seismic event by following the mitigation recommended in the RS's report.

Other impacts

43. During operation, well drilling will cause continuous noise as drilling is conducted 24 hours per day prior to the extraction or fracturing process. Transporting water, sand, fluids, wastes and hard standing equipment would substantially increase the volume of traffic in the local area. Each well head requires a well 'pad' where the pipes are brought to the surface and an extraction area might have many of these, spaced about 1 km apart. Creating these pads will require an extensive use of hardcore and concrete. The possibility of land not being suitable for return to its former use after well abandonment is another factor potentially affecting local habitats and ecosystems.

44. The Scottish Wildlife Trust believes that developers should state current and future operation proposals as part of the EIA to ensure that the total ecological footprint of the development and phased future wells are included as part of the EIA. The Trust believes that planning consent should be refused where the ecological footprint of present activities and or/combined with future proposals would have a significant impact on protected species, protected habitats and ecosystems.

Coal bed methane extraction

45. Many of the potential environmental impacts associated with shale gas extraction apply to coal bed methane extraction. Unlike hydraulic fracturing, coal bed methane pumps water out rather than injecting in a fracking fluid. Surplus water which has been drawn off by pumping must be disposed of in an environmentally acceptable manner and is subject to licensing by SEPA (see Appendix 2).

46. Surface disposal of large volumes of water can affect streams and other habitats, and if subsurface reinjection is proposed this makes production more costly.

47. Other environmental concerns include potential methane contamination of groundwater along new coal bed methane beds. As with shale gas extraction methane can escape during operation. Similar to shale gas operation there will be an ecological footprint of production, increased noise and volume of traffic.

SWT priorities for action

1. The Scottish Wildlife Trust will advocate the principles outlined in this policy to Government, the business sector, and other key stakeholders to ensure that coal bed methane extraction and hydraulic fracturing activities are subject to strict regulatory control.

2. The Scottish Wildlife Trust will consider its response to planning proposals for the extraction of shale gas and coal bed methane on a case by case basis.

3. The Scottish Wildlife Trust will object to planning proposals for unconventional gas extraction which are sited in protected areas.

Cross-reference to other related SWT policies

1. The Planning System
2. Energy and nature conservation
3. Local Biodiversity Sites

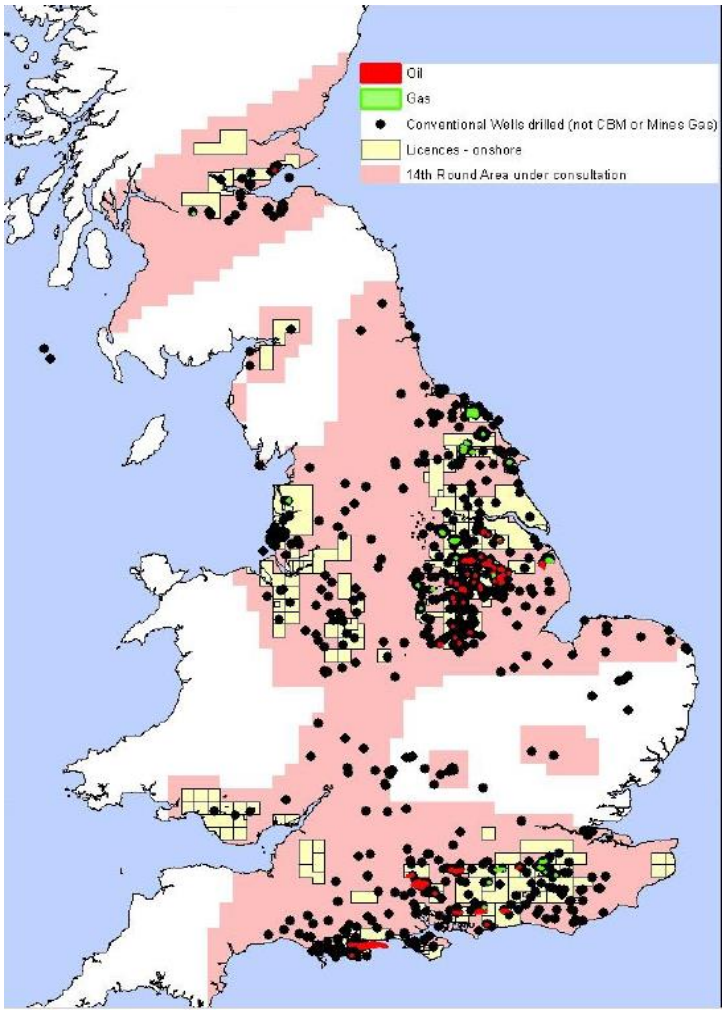
Appendix 1

Petroleum Exploration and Development licence (PEDL) in Scotland

1. Licences in Scotland for shale gas or coal bed methane extraction (see also Figure 1):

   a) PEDL 133 – covers large area at mouth of the Firth of Forth, falls within several Local Authority areas (Stirling, Clackmannanshire, Perth and Kinross, Fife, Falkirk and West Lothian). Issued to Dart Energy Ltd
   b) PEDL 159 – covers area along Scottish-English border, falls within Dumfries & Galloway Council. Issued to Greenpark Energy Ltd. Licenses recently taken on by Dart Energy
   c) PEDL 161 – towards the East Neuk of Fife, within Fife Council area. Issued to Dart Energy Ltd.
   d) PEDL 162 – covers a large area in central belt, falling largely into North Lanarkshire Council, but also extending into East Dunbartonshire, Falkirk and West Lothian. Issued to Reach Coal Seam Gas Ltd
   e) PEDL 163 – in west Fife, within Fife Council area, stretching into Perth & Kinross and Clackmannanshire. Issued to Dart Energy Ltd

Figure 1: Current UK Petroleum Exploration and Development Licences, conventional Oil and Gas Fields, locations of conventional well drilled, and the areas under consultation currently which may be offered in the 14th onshore Oil and Gas Licensing Round. [31]



Appendix 2

SEPA's regulatory role:[32]

The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR)

1. SEPA's role in relation to controlling the impacts on the water environment from shale gas and coal bed methane exploration and extraction processes are subject to controls under The Water Environment (Controlled Activities) (Scotland) Regulations 2011(CAR).

2. The following activities which are associated with shale gas and coal bed methane exploration and extraction fall within the CAR regulatory regime:

    a) borehole construction
    b) injection of fracturing fluid
    c) abstraction of water for injection purposes
    d) abstraction of flow-back water:
    e) management of abstracted fluids

Environmental Liability (Scotland) Regulations 2009 (ELR)

3. ELR requires operators to take preventive measures where there is an imminent threat of environmental damage and to take remedial measures where their activities have caused environmental damage. Unconventional gas extraction is likely to come within the scope of ELR. SEPA must be notified if operators have caused land or water damage or if there is an imminent threat of such damage. Scottish Natural Heritage (or Marine Scotland for the marine environment) would be notified in cases where the damage is likely to affect protected species and natural habitats.

The Management of Extractive Waste (Scotland) Regulations 2010

4. The production of flow-back fluid from hydraulic fracturing is a mining waste activity and would require an agreed waste management plan. Operators will need to 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. This may include a requirement to have a CAR authorisation for any discharge of any pollutants to the water environment.

Naturally occurring radioactive materials (NORM) radioactive substances

5. Although SEPA believe it is very likely that the fluids that flow-back to the surface after hydraulic fracturing will contain NORM below threshold values, they are adopting a conservative approach and are making it a requirement that all developments will require an authorisation issued under Radioactive Substances Act (1993) for the accumulation and disposal of the fluids that flow back as radioactive wastes.

Pollution Prevention and Control (PPC)

6. SEPA has regulatory powers under PPC for certain activities, such as those involving refining of gas, gasification or other heat treatments, combustion, or disposal of solid and liquid wastes.

7. The PPC regulations are designed to control emissions to the environment from certain specified activities. If any of the following processing steps are necessary to satisfy statutory and contractual specifications, an application for a PPC permit will possibly need to be submitted and early engagement with ourselves is encouraged:

i. Removal of the treatment chemicals or well contaminants from the extracted gas:
   a) gases, e.g. hydrogen sulphide, sour/acid gas, CO2, mercaptens etc.
   b) water
   c) solids (sands, clay, potentially scale-like carbonates and sulphates, mercury etc.)
   d) treatment chemicals added at well head
   e) removal of longer chain hydrocarbons
   f) storage
   g) compression
   h) flaring/venting

8. It should be stressed that the initial exploration for gas, drilling etc. does not fall into one of these activity descriptions and would not require a PPC permit. However, to allow the processing of any gas on the site, a PPC permit must be in place (applied for, determined and where appropriate issued) prior to gas being accepted into the process, i.e. the treatment process must not begin unless a valid permit is in force.

[1] Often referred to as 'fracking' in the media
2 Cuadrilla is an independent UK energy company led by a team of experts in unconventional sources of exploration. see: http://www.cuadrillaresources.com/
[3] See: http://www.cuadrillaresources.com/wp-content/uploads/2012/02/Chemical-Disclosure-PH-1.jpg
4 See: EU Commission's report on unconventional gas 2012. http://iet.jrc.ec.europa.eu/energy-security
[5] Shale gas and fracking -- House of Commons Library Report. Standard Note: SN/SC/6073 December 17 2012. Author: Dr Patsy Richards
[6]See: The Unconventional hydrocarbon resources of Britain's onshore basins- shale gas. (DECC 2012) https://www.og.decc.gov.uk/UKpromote/onshore_paper/UK_onshore_shalegas.pdf
[7] British Geological Survey has identified the Midland Valley Basin as containing potential areas with reserves of shale gas.
[8] See: https://www.gov.uk/oil-and-gas-petroleum-licensing-guidance
[9] See: http://ec.europa.eu/environment/eia/pdf/Annexe%202.pdf.pdf (Dec. 2011)
[10] See: http://www.legislation.gov.uk/ssi/2011/139/schedule/1/made
[11] See SEPA's Regulatory guidance: Coal bed methane and shale gas (2012) - for more details http://www.sepa.org.uk/customer_information/energy_industry.aspx
[12] Groat and Grimshaw (2012) Fact-based regulation for environmental protection in shale gas development, Energy Institute, University of Texas: Austin. http://energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf
[13] See: Shale gas extraction in the UK: a review of hydraulic fracturing. The Royal Society June 2012.
[14] Broderick et al (2011) *Shale gas: an updated assessment of environmental and climate change impacts.* A report commissioned by The Co-operative and undertaken by researchers at the Tyndall Centre, University of Manchester: http://www.co-operative.coop/Corporate/Fracking/Shale%20gas%20update%20-%20full%20report.pdf
[15] *Op cit.* 12
[16] Available at: http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf
[17] *Ibid*
[18] *Op cit.*13
[19] *Op cit.* 13
[20] *Op cit.* 14
[21] *Op cit*. 4
[22] See: the case for tight gas speech at: http://www.shell.com/home/content/media/speeches_and_webcasts/archive/2011/brinded_london_09112011.html?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+shell_speeches+(Royal+Dutch+Shell+plc+speeches)
[23] See: Dieter Helm discussion on the merits of shale gas vs coal in: The Carbon Crunch. 2012. Yale University Press
[24] Broderick et al (2011): http://www.co-operative.coop/Corporate/Fracking/Shale%20gas%20update%20-%20full%20report.pdf
[25] Methane has a global warming potential 25 times great than CO_2 over a century timescale.
[26] *Op cit.* 11
[27] Moore (2012) Gas works? Shale gas and its policy implications
[28] See: http://www.businessgreen.com/digital_assets/5216/DECC_shale_gas_report.pdf
[29] See BGS report on earthquakes http://www.earthquakes.bgs.ac.uk/publications/annual_reports/2011_22nd_annual_report.pdf
[30] *Op cit.* 13
[31] See: https://www.og.decc.gov.uk/UKpromote/onshore_paper/UK_onshore_shalegas.pdf
[32] *Op cit.* 11