Scottish Environment LINK

Unconventional Fossil Fuels Subgroup submissions to the

- **Economic Impact and Scenario Development,**
- **Understanding and Monitoring Induced Seismicity, and**
- **Decommissioning, Restoration and Aftercare**

studies under the Scottish Government moratorium on onshore oil and gas extraction

21 May 2016

1 General comments

Scottish Environment LINK welcomes the opportunity to feed into the Scottish Government commissioned research programme under the current moratorium on unconventional oil and gas (UOG) extraction. LINK members have called for a precautionary approach to shale oil and gas and coalbed methane development, and consequently welcomed the implementation of a moratorium on the industry in January 2015.

This submission follows our participation in a stakeholder workshop on 21 March with consultants taking forward studies into economic impacts (KPMG), seismic activity (BGS) and decommissioning and aftercare (AECOM). We are pleased to note the consultants' reassurance that the stakeholder workshop was the start of engagement, and look forward to ongoing participation in key stages of the research programme, as well as with the parallel transport impacts and climate impacts research.

However, we are concerned to learn of certain limitations of remit in the studies being taken forward, particularly the economic impacts research, and in the overall structure of the research programme.

Following the workshop it is apparent that the economic impact assessment will not take account of environmental impacts under the various scenarios. The analysis takes a very narrow approach towards assessing economic impacts and will not encompass significant areas of economic activity which might experience negative impacts e.g. local agriculture, food and drink industries, tourism, 'brand Scotland', climate change costs etc. Nor is the cost to the public purse of developing and enforcing a robust regulatory regime included in the assessment. Although KPMG assured us that they would report separately on environmental impacts, we do not consider this is at all adequate to ensure the assessment will be the robust, thorough study that Scottish Ministers need in order to make a properly informed decision about the industry. A full cost benefit analysis would seem to be essential to give a fuller picture. We have expressed these concerns to Scottish Ministers.

Further, as no overarching environmental study has been commissioned a number of key issues will fall through the gaps in this research programme, in particular, the impacts on biodiversity and wildlife. Finally, it is not clear how the Public Health Impact Assessment interacts with the rest of the research programme, which is problematic given the overlap on common issues, including economic impacts.

Three common issues are identified in the workshop packs across the five areas of research commissioned by the Scottish Government: costs of seismic activity remediation; costs of GHG impacts; and costs of decommissioning.

We would note further important common issues across the studies:

- Waste disposal

The chosen / permitted method of waste disposal of flowback fluid and produced water will potentially have significant bearing on the economic case for onshore oil and gas development, the decommissioning process, seismicity, transport and public health, depending on whether it involves the construction of treatment facilities and / or transportation to other sites for treatment disposal, or the re-injection of waste into the formation.

- Air pollution

Air pollution from onshore oil and gas drilling is linked to adverse public health impacts, which have an economic impact and potentially a climate impact. Transport is a key contributor to air pollution in the onshore oil and gas industry and the type and volume of transport air pollution is linked to the method of waste disposal employed.

- Calorific value

The calorific value of shale gas and coalbed methane from Scottish shales and coals will effect economic and transport scenarios, and potential public health impacts if the gas is to be fed into the grid and requires enhancement, as may have been necessary for the proposed Airth coalbed methane development.

2 Economic Impact and Scenario Development

2.1 Approach to economic research

We are concerned about the approach planned for the economic impact research. From the material distributed, it appears to be conflating two different methods, an economic impact assessment (EIA), which looks at the net change in jobs and GVA as a result of the introduction of unconventional oil and gas, and a Cost Benefit Analysis (CBA) which looks at the value to society of the introduction of UOG. This is especially evident on page 13 of the handout that shows the types of benefits you would factor into an EIA and the type of costs you would factor into a CBA. Our understanding is that this is methodologically flawed.

Standard economic impact assessments, which use input-output tables to identify the scope of related sectors are narrow in scope. Only sectors that are affected through sharing of direct inputs or outputs are included and therefore, sectors such as tourism and agriculture that may well be negatively impacted, albeit in a slightly more oblique way, are not included in the EIA. Additionally, we are aware that many EIAs ignore the jobs that would be lost in other sectors and so are not reliable in terms of predicting net jobs, and we hope that this assessment will endeavour to address this.

We welcome the recognition that there are potentially wide ranging social and environment costs associated with UOG, many of which are hard to quantify. However, we feel that these need to be built into a full CBA.

We would like clarification on the method(s) being used and reassurance that any EIA will address job losses in related sectors as far as possible. We recommend that a CBA is carried out to fully take account of the wider social, environmental and economic impacts.

2.2 The US 'shale gas revolution'

Much has been made of the US 'shale gas revolution' particularly by media and politicians in countries where unconventional gas resources are located. Barak Obama's pledge to 'take every possible action to safely develop… a supply of natural gas that can last America nearly 100 years'[1] has been echoed by

[1] http://www.bloomberg.com/news/articles/2012-01-25/obama-backs-fracking-to-create-600-000-jobs-vows-safe-drilling

David Cameron's desire to go 'all out for shale'.[2] Indeed, the growth of the shale gas industry in the US has reduced domestic gas prices and the US is predicted to become a net exporter of gas by next year.[3]

However, there are important differences between the US and European contexts that make a similar 'shale gas revolution' highly unlikely either on the continent or here in Scotland. Factors including more complex geology, greater density in population, differences in mineral rights and lack of access to drilling rigs and services, make UOG operations this side of the Atlantic more challenging and therefore more costly. These factors are all true for Scotland, with the shale and CBM resource located in the densely populated central belt, where highly faulted geological formations bear the legacy of extensive mining, and mineral rights belong to the crown rather than individual land owners.

While the US Government began funding Gas Technology Institute research and development into 'low permeability hydrocarbon bearing formations' in the early 1980's, and shared the findings with industry, no such equivalent programme has been undertaken in Europe; because of the differences in geology, US research is thought not to translate well to the European context.[4] Estimates of the cost of drilling a shale gas well in Europe compared to the US vary between $6.5 and $14 million compared to $4 million on the Marcellus, in part due to differences in the availability of rigs and drilling services.[5]

Furthermore, there is growing evidence that the industry in the US is not nearly as profitable as many of the headlines suggest, and heading for decline if not collapse, even prior to the drop in global oil prices. A number of experts and commentators are warning of lack of transparency in growth projection modelling[6], 'premature' peaking in major plays[7], and high levels of debt in an industry financed in large part by junk bonds that is spending more than it earns.[8]

The UK experience so far is not enormously promising. Cuadrilla has spent over £100 million to date on its plans to exploit the Bowland Shale in Lancashire and – while these outgoings reflect more than drilling costs – only fracked a single well.[9] After 20 years of exploration and development, the Airth coalbed methane proposal had still not advanced beyond the pilot project stage, and is currently bound up in both a Public Local Inquiry and the moratorium. Questions about its economic viability remain unanswered including whether the gas would require potentially costly enhancement with propane in order to be fed into the grid as planned.[10]

The economic study under the Scottish moratorium on unconventional oil and gas extraction should examine the factors that make conditions in Scotland different than in the US, and highlight where these mean a more challenging and costly context to operate in. It should also comment on the economic sustainability of the US unconventional oil and gas industry.

2.3 Climate change

'Costs of GHG impacts' is identified as a cross cutting issue between the Economic Impact Assessment and the Climate Impacts study. While it appears to be outwith the scope of this research to take account of climate change externalities (which could range from global losses e.g of small island states to the costs to taxpayers of having to find additional GHG emissions reductions from other sources, or the cost of adaptation requirements in Scotland e.g. flood management) some commentary on these and on the

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[2] http://www.theguardian.com/environment/2014/jan/13/shale-gas-fracking-cameron-all-out
[3] http://www.eia.gov/todayinenergy/detail.cfm?id=20992
[4] https://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/bp0812_stevens.pdf
[5] https://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/bp0812_stevens.pdf
[6] http://www.postcarbon.org/fracking-fracas/
[7] http://www.nature.com/news/natural-gas-the-fracking-fallacy-1.16430
[8] http://www.bloomberg.com/news/articles/2014-04-30/shale-drillers-feast-on-junk-debt-to-say-on-treadmill
[9] http://www.theguardian.com/environment/2016/may/19/fracking-investors-losing-patience-with-planning-delays-says-industry-boss
[10] http://www.heraldscotland.com/news/13099242.Burning_issue__poor_gas_quality_could_end_Scots_drilling_plan/

long-term economic impact of pursuing new frontiers of fossil fuels is necessary given the scale of the climate threat and the risk it represents to our whole way of life. The 2006 Stern Review estimated the true cost of carbon to society as $85/tC (about $310/tCO$_2$).[11] **As a minimum the economic study should provide some commentary on carbon costs based on the social or shadow price of carbon, even if it is outwith its remit to assess externalities in full**.

Climate change is one of the greatest threats humankind has ever faced. The Intergovernmental Panel on Climate Change has reported with greater certainty and scientific consensus than ever before that "*warming of the climate system is unequivocal*" and that "*human influence has been the dominant cause of the observed warming since the mid-20th century*".[12] Global warming of 2°C or more will result in catastrophic impacts, including an increase in extreme weather events, sea level rise, the destruction of livelihoods and even entire countries, species extinction and habitat loss. In turn these impacts will see increased political instability and violent conflict, a rise in migration and climate refugees.[13] Scotland is not immune from these impacts and their costs, both in incurring adaptation costs and likely detrimental impacts on key economic sectors including agriculture, fisheries and tourism.

The Paris Agreement, ratified in April 2016, commits nations to 'holding' global warming to 'well below 2°C' and pursuing efforts to limit warming to 1.5°C, in recognition of the fact that even 1.5°C warming will have devastating consequences for countries and peoples most vulnerable to the impacts of climate change. Scotland's Climate Act requires a reduction of at least 42% in GHG emissions by 2020 and 80% by 2050. The new SNP Government have a manifesto commitment to introduce a further Climate Change Act to strengthen the 2020 target to be 'more than 50%' in response to the Paris Agreement.

Analysis by the Carbon Tracker Initiative[14], an NGO which aims to improve the transparency of embedded carbon in equity markets, shows that in order to have a reasonable chance of staying below 2°C warming, 80% of the world's proven fossil fuel reserves must not be burned unabated.[15] The 'stranded assets' / 'carbon bubble' theory has gained widespread recognition with Bank of England Governor Mark Carney warning investors that meeting a carbon budget to avoid 2°C warming would "*render the vast majority of reserves 'stranded' — oil, gas and coal that will be literally unburnable without expensive carbon capture technology, which itself alters fossil fuel economics*". Scotland's, and indeed much of the world's, shale gas and coalbed methane resource is unproven and therefore additional to the 80% of known reserves that must stay in the ground. **The economic impact study should include some commentary on the risk that pursuing unconventional oil and gas resources in the context of the carbon bubble presents for Scotland, a country whose economy is already heavily dependent on hydrocarbons.**

In setting out the conditions for UK shale gas development to proceed, McGlade and Ekins state that Carbon Capture and Storage is *"key to the development of new gas resources, shale or otherwise…If CCS does not become available commercially soon, it is unlikely that there will be much scope within available carbon budgets for significant UK and European gas consumption beyond 2050. This calls into question the wisdom of developing a whole new UK shale gas industry for such a limited period of operation."* The authors go so far as to suggest that (without CCS), the construction of a new generation of gas power plants would be *"tantamount to an abandonment of the UK's contribution to limiting global warming to 2°C."*[16]

[11] http://webarchive.nationalarchives.gov.uk/20080910140413/http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2014/03/US-shale-gas-and-tight-oil-industry-performance-challenges-and-opportunities.pdf
[12] IPCC Fifth Assessment Report: Climate Change 2013 Working Group I Report "The Physical Science Basis" http://www.climatechange2013.org/images/uploads/WGI_AR5_SPM_brochure.pdf
[13] IPCC Fourth Assessment Report: Climate Change 2007 Working Group II Report "Impacts, Adaptation and Vulnerability" http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html
[14] http://www.carbontracker.org/team/about-us
[15] Carbon Tracker Initiative 'Unburnable Carbon – Are the world's financial markets carrying a carbon bubble?' 2011 http://www.carbontracker.org/wp-content/uploads/downloads/2011/07/Unburnable-Carbon-Full-rev2.pdf
[16] http://www.wbs.ac.uk/wbs2012/assets/PDF/downloads/press/ShaleGasUKERC1502Fin.pdf

The Scottish Government is already committed to no more than 50gCO_2/kWh from the power sector by 2030 - figure that requires either significant operation of CCS or almost no fossil fuel use. The SNP Government has been critical of the UK Government's decision last November to withdraw £1bn of ring-fenced funding for Carbon Capture and Storage (CCS) pilot projects and committed to examining what can be done to revive its future in Scotland, indicating that a new gas plant with CCS could be part of its new energy strategy. However, there are significant question marks over the feasibility of CCS technology on grounds of cost. The UK competition has been going on for almost a decade without success, and the two UK projects still in the running for the £1bn award both announced they could not proceed without it following the Chancellor's decision. **The role and cost of CCS in relation to developing new fossil fuel resources and infrastructure should be factored into the economic impact assessment.**

McGlade and Eskins also point to "*An important unknown at present [that is] the level of gas consumption that there could be in the UK energy system out to 2050 even under a deep decarbonisation pathway…. How much consumption and what role this gas plays is crucial to understanding the timeframes and scale that could be afforded to a potential shale gas industry consistent with overall energy system decarbonisation.*"[17]

It is difficult to see how commercial scale production of shale gas could begin in Scotland sooner than 10-15 years, given that no exploratory drilling has taken place at this stage, the various stages of appraisal and development to be undergone, regulatory and planning requirements to be met, and anticipated local opposition to individual projects.[18] The most advanced coalbed methane project in the UK, at the Airth field, has failed to reach commercial production after over 20 years of exploration and development, and at this stage is stalled not only by the moratorium but also a public inquiry. **The economic study should look at whether it makes economic sense to develop an onshore industry for such a short period of time, only to compete with North Sea production for Scotland's share of the remaining carbon budget**.

Finally, we note that an argument frequently made by the industry that shale gas and CBM will reduce climate change emissions by substituting for coal in power generation is flawed, particularly in the Scottish context. Not only does the problem of methane (a greenhouse gas 86 times more potent that carbon dioxide over 20 years) leakage from unconventional gas infrastructure[19] seriously undermine this argument, but the recent closure of Longannet means there is no coal-fired power generation left in Scotland to displace, and the UK Government last year committed to the closure of all unabated coal-fired power station in the UK by 2025 – before a commercial-scale shale gas industry might reasonably be expected to exist.

The economic case for developing a Scottish unconventional oil and gas industry must therefore be examined in the context of national and global carbon budgets, existing national and global fossil fuel reserves, and the timescales and costs involved with bringing the industry from infancy to commercial production in relation to the managed decline of fossil fuel use to meet carbon budgets.

2.4 Renewables

The question of whether development of unconventional oil and gas in Scotland would move international prices and result in a substitution of gas for renewables is to be considered under the Economic Impact Assessment. In our view it is highly unlikely that the development of a Scottish shale or CBM industry would move international prices given the limitations of the resource, although the

[17] Ibid
[18] See http://www.pinsentmasons.com/PDF/ShaleGasFrackingPart1.pdf for an idea of phases of development and timescales. Pinset Masons suggest 20 years for full production.
[19] http://www.theguardian.com/environment/2015/jun/24/natural-gas-leaks-methane-environment, http://blogs.scientificamerican.com/plugged-in/methane-leakage-from-natural-gas-supply-chain-could-be-higher-than-previously-estimated/

supposed *prospect* of price reductions might have an impact. Therefore, we are concerned that even the initial development of this industry could suppress investment in renewables even if it doesn't affect gas prices.

The International Energy Agency has warned of the impacts of cheap gas on support for renewables: it's 2012 report 'Golden Rules for a Golden Age of Gas' found "*an abundance of natural gas might diminish the resolve of governments to support low and zero-carbon sources of energy: lower gas prices (and therefore lower electricity prices) can postpone the moment at which renewable sources of energy become competitive without subsidies and, all else being equal, therefore make renewables more costly in terms of the required levels of support*,"[20] while Fatih Birol has warned: "*Renewable energy may be the victim of cheap gas prices if governments do not stick to their renewable support schemes*."[21]

But crucially, even the anticipation of abundant, cheap gas could also have a major impact on investment in renewable energy, locking in dependence on fossil fuels well beyond what our climate targets demand. Professor Paul Stevens of Chatham House has written: "*There is a real fear among many analysts that shale gas may substitute not for coal but for renewables…the anticipation of cheap natural gas could inhibit investment in renewables. But again, if the revolution fails to deliver a lot of cheap gas, by the time this is realized it could well be too late to revert to a solution to climate change based upon renewables."* [22]

The Committee on Climate Change have also written of the dangers of a dash for gas in relation to renewables: "*The apparently ambivalent position of the [UK] Government about whether it is trying to build a low-carbon or a gas-based power system weakens the signal provided by carbon budgets to investors [is] damaging prospects for required low-carbon investments*".[23] Indeed, at a UK level Whitehall's enthusiasm for both shale gas and nuclear power have coincided with low renewables targets, lack of political support for renewables and no decarbonisation target for the electricity sector.

The economic impact study should look at the potential for onshore oil and gas to displace investment in renewable energy, and therefore both the climate and economic benefits (e.g. jobs) associated with renewables growth. Commentary should acknowledge the risks around locking in carbon intensive infrastructure in the context of global carbon budgets and the 1.5^{o}C target in the Paris Agreement.

2.5 Water use

Hydraulic fracturing requires the use of large volumes of water. Volumes used will vary between developments due to differences in geology, porosity of the shale or coal to be fracked, how often wells are fracked, lifetime of the well etc. A study by the US Geological Survey found that water usage in hydraulic fracturing had substantially increased in recent years (28 times more water than 15 years ago) and identified a strong correlation between the kind of fracturing used and water consumption, with horizontal wells generally consuming substantially higher volumes than vertical wells.[24] The highest yielding US shales – the Barnett, Marcellus and Fayetteville plays – tend to have a high percentage of horizontally fracked wells, and therefore higher than average water use.

According to this study, average (median) consumption is 15.3 million litres per oil well and 20 million litres per gas well fracked between January 2011 and August 2014, with upper end usage reaching 36

[20] http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf
[21] http://www.guardian.co.uk/environment/2012/may/29/gas-boom-renewables-agency-warns
[22] Chatham House August 2012 'The 'Shale Gas Revolution': Developments and Changes' http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/bp0812stevens.pdf
[23] Committee on Climate Change 13th September 2012 'The need for a carbon intensity target in the power sector' http://www.theccc.org.uk/wp-content/uploads/2013/02/EMR-letter-September-12.pdf
[24] Gallegos et al 2015 *Hydraulic fracturing water use variability in the United States and potential environmental implications* http://onlinelibrary.wiley.com/doi/10.1002/2015WR017278/full

million litres. While comparisons between scenarios in differing geological formations and regulatory frameworks must be made with caution, Cuadrilla's proposals at Roseacre Wood and Preston New Road in Lancashire are at the high end of average US water usage in hydraulic fracturing, 22.4 - 28 million litres of freshwater per well, for each of the 4 wells at both sites.[25]

While Scotland does not suffer from prolonged periods of water stress, according to SEPA we are vulnerable to "*localised and short-term dry periods which can cause environmental problems, and put stress on public water supplies and private abstractions… in addition, climate change is likely to bring uncertainty and, with a projected decrease in summer rainfall, may exert pressure in areas that have not yet experienced water scarcity*."[26]

Given that the onshore oil and gas resource is located in the most heavily populated and industrialised part of the country, consideration should be given by the economic assessment as to the impact of water usage in shale oil and gas extraction on other industries, agriculture and local usages, generally and in times of scarcity.

2.6 Wastewater disposal

A further crucial aspect of water usage in hydraulic fracturing relates to waste disposal. Flowback is the contaminated water that returns to the surface after hydraulic fracturing takes place. It consists of both fracking fluid and water produced from the shale formation. Initial flowback consists largely of the components of the injected fracking fluid (which may contain substances harmful to human health and the environment), but as gas and oil production rates decline, flowback generally consists of produced water, which may be highly saline and contain heavy metals, BTEX compounds, Naturally Occuring Radioactive Material (NORM) and other potentially harmful substances naturally occurring in the shale, depending on the specific geology. High levels of flowback are consistent with (but not necessarily indicative of) high volumes of fracking fluid and high levels of oil and gas production. Flowback levels start high but drop off and level out over the lifetime of a well, as gas flow declines. With CBM, the initial de-watering process used to depressurise the coal seam and release gas, results in high volumes of produced water containing NORMs, BTEX and other contaminants, whether or not hydraulic fracturing is subsequently used.

A study by Duke University found that volumes of flowback from shale oil and gas wells in the USA between 2005 and 2014 were 84% of the volume used in the hydraulic fracturing process.[27] Again, while the US experience should be used with caution, the limited UK experience of shale gas fracking demonstrates high volumes levels of flowback requiring specialist treatment and disposal.

Cuadrilla's application acknowledged that "*the maximum cumulative volume of flowback fluid based on a 40% return rate which will be treated across Preston New Road and Roseacre Wood projects is 68% of the available capacity. Therefore the impact is considered to be very substantial and significant.*"[28] The available capacity referred to amounts to 2 of only 3 national waste facilities permitted to treat waste fluid of this sort.[29] The only real life data from hydraulic fracturing in the UK, at Cuadrilla's Preese Hall site, demonstrated approximately 70% flowback rates, much closer to the figures in the Duke study.[30] Therefore should flowback rates be closer to the levels demonstrated at Preese Hall, just 8 wells at 2 sites could be said to completely overwhelm total available capacity, and potentially, national capacity.

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[25] Cuadrilla Roseacre Wood Environmental Statement, Scheme Parameters B7.1
[26] SEPA Consultation on Scotland's National Water Scarcity Plan
[27] see https://www.sciencedaily.com/releases/2015/09/150915135827.htm, Kondask and Vengosh 2015 *Water Footprint of Hydraulic Fracturing* http://pubs.acs.org/doi/10.1021/acs.estlett.5b00211
[28] Caudrilla Arup ES pg 525
[29] See Alan Watson, Director Public Interest Consultants Proof of Evidence, 4.17 http://programmeofficers.co.uk/Cuadrilla/Proofs/NWFOE/FOE2.1.pdf
[30] Appendix 7 to Alan Watson Proof of Evidence, Email correspondence between Cuadrilla and the Environment Agency 23/2/2012 re Flowback rates at Preese Hall http://programmeofficers.co.uk/Cuadrilla/Proofs/NWFOE/FOE2.2.pdf

A further crucial issue raised at the Public Inquiry relates to the risk of induced seismicity associated with managing daily flowback from the two sites: the estimated maximum daily flowback from each site of 250m^3 would take up 65% of treatment capacity at the 2 facilities identified by Cuadrilla, compared with the calculated cumulative peak daily flowback of 262m^3, requiring 68% of capacity. According to expert evidence: "*Limiting the flowback volume from the second site to just 12 m^3/day would be enormously challenging bearing in mind that the estimated peak daily volume of flowback fluid generated during: the flow testing phase is 250m^3; and the extended flow testing phase is 40m^3 ...In any case staggering the operations of the two sites to reduce the combined impact to this level would therefore require an unprecedented level of integration and co-ordination between the two operations.* "[31] The key mechanism for controlling flowback is the use of a 'choke manifold' at the surface, however: "*allowing the flowback of fluids, particularly immediately post-fracking, is necessary in order to address seismicity. It is therefore not a straightforward decision to limit or prevent the flowback of fluid through the use of the choke valve in order to reduce demand for treatment capacity*."[32]

The UK 'Strategy for the management of Naturally Occurring Radioactive Material (NORM) waste' indicates potentially significant pressures on treatment and supply chain facilities:

"*There is some evidence that onshore treatment and disposal of produced water is becoming an issue for some industries (particularly oil and gas production) who generate NORM waste which cannot be classed as exempt radioactive waste. Information obtained by the data collection process is that, within the UK, there are only three facilities permitted to store NORM wastes and two facilities permitted to discharge liquid NORM radionuclides. Another issue is that NORM wastes produced during oil and gas production tend to contain organic hydrocarbons and inorganic heavy metals such as cadmium and, particularly, mercury. Thus, liquid NORM waste treatment often requires use of a combination of different processing techniques to remove the organic and inorganic elements.*"[33]

As noted above, an answer to a Parliamentary question indicates that there are only 3 facilities currently licensed to treat flowback fluid.[34] The UK NORM waste strategy indicates that there may be increased pressure on these facilities from both the anticipated growth of unconventional oil and gas, possible changes to the OSPAR Convention that would prevent the current practice of disposing of NORM waste from offshore oil and gas at sea, and from anticipated decommissioning of north sea oil and gas. An obvious response might be to build more treatment, storage and disposal facilities, however there are high costs associated with developing treatment methods. The consultation preceding the Strategy indicates that:

"Respondents to the data collection exercise indicated that they operate in a market which is subject to stringent regulatory controls and this manifests in them being subject to environmental and safety permissions which incur high costs; often associated with using consultants to carry out radiological assessments. As a result of these costs, market barriers to new treatment and disposal providers are high. However, decisions to enter the NORM waste treatment and decommissioning market are for supply chain providers to make on the basis of their own business case decisions."[35]

The examples of Preese Hall and Airth are important in that they did not factor in the costs of treating NORM liquid waste. Cuadrilla dumped NORM liquid waste from Preese Hall into the Manchester Ship Canal, however revised Environment Agency regulations mean this option is closed for the Roseacre Wood and Preston New Road proposals. Dart Energy proposed to dispose of NORM liquid waste, untreated, in a stream feeding into the Forth, while NORM sludges were to be transported to Aberdeen for disposal.

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[31] Alan Watson Proof of Evidence, 4.41 & 4.43 http://programmeofficers.co.uk/Cuadrilla/Proofs/NWFOE/FOE2.1.pdf
[32] Alan Watson rebuttal of evidence 2.6 http://programmeofficers.co.uk/Cuadrilla/Proofs/NWFOE/FOE2.4.pdf
[33] UK NORM Waste Strategy Annex B, B37
[34] Appendix 5 to Alan Watson Proof of Evidence, Email correspondence between Cuadrilla and the Environment Agency 23/2/2012 re Flowback rates at Preese Hall http://programmeofficers.co.uk/Cuadrilla/Proofs/NWFOE/FOE2.2.pdf
[35] Consultation on a UK NORM Waste Strategy 3.52

Following treatment, wastewater may still contain low levels of NORM. Scottish Water has raised the issue of increased costs of monitoring should the volumes of NORM wastewater being dealt with increase.[36]

The Economic Impact Assessment should examine the impact of limited existing NORM waste liquid treatment, storage and disposal facilities on the case for developing unconventional oil and gas in Scotland, including the impact on other economically important industries. It should provide commentary on the interlinkages between flowback management and seismic risk in relation to the economics of developing the industry. The high costs of developing new methods of waste treatment, costs of transportation to specialist treatment facilities and additional costs of monitoring, should also be taken into account.

2.7 Biodiversity

Direct risks to biodiversity from shale gas and coal bed methane development include: habitat loss and fragmentation; wildlife disturbance; and water pollution. [37]

Each well pad in a typical development requires up to 2 hectares of land, in addition to land for transport access, drainage and storage systems, pipelines and other associated infrastructure. This could lead to significant habitat loss and fragmentation at landscape level, depending on the sensitivity of the sites in question.

The overlap of potential licensing areas for onshore oil and gas extraction with important places for wildlife, such as Natura sites, should be considered. However it should be noted in relation to habitat loss, that protection of existing designated areas (such as SPAs and SACs) is not in itself sufficient to prevent habitat loss and fragmentation, or ensure compliance with EC wildlife law. Significant proportions of some Annex 1 habitats (see the Habitats Directive) are outwith designated sites e.g. blanket bog, which are present within areas proposed for licensing for onshore oil and gas extraction. Therefore, whilst a spatial assessment of potential licensing areas and their overlap with designated sites would be useful, sensitive ecosystems such as wetlands, saltmarsh habitat, peatlands and natural woodland would not be fully covered.

Wildlife disturbance could result from increased noise and light levels from extraction infrastructure and associated transport. Environmental impacts from high water usage could include impacts on fish and other wildlife if water stress pressure is increased on rivers with low flows.

Risks to biodiversity from water pollution could include groundwater contamination from well leakage, migration of contaminants from fractured shale seams or coal seams, as well as accidental surface spillages of waste fluids. Impact assessments will need to pay particular attention to species sensitive to degradation in water quality, such as fish and invertebrates. Consideration of water 'pollution' must include species that may be vulnerable to elevated salinity of sediments. Even if the risk of pollution events is low, the potential for long-terms impacts and costs associated with single incidents is important. **Groundwater contamination should be considered from the perspective of both public health risk and risk to habitats and biodiversity, with consequent economic risks.**

It is worth emphasising that some of the above impacts and interactions between biodiversity and significant levels of onshore gas extraction are not well understood, meaning that the precautionary principle must be applied in assessing impacts. This has implications for requirements of a regulatory, compliance and monitoring regime.

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[36] Response to consultation on UK NORM Waste Strategy http://www.gov.scot/Resource/0045/00454920.pdf
[37] More discussion and references in relation to the above can be found in Moore et al (2014) *Hydraulic fracturing for shale gas in the UK Examining the evidence for potential environmental impacts* http://www.rspb.org.uk/Images/shale_gas_report_evidence_tcm9-365779.pdf

Economic considerations in relation to the above would include potential additional costs to developers of enhancement, mitigation and compensation measures where required due to impacts on habitats and species, and associated costs for environmental regulators (SNH and SEPA) in relation to planning, monitoring and enforcement. Additionally the value that society places on biodiversity should be a component of the wider social and environmental impacts in a CBA.

2.8 Landscape Impacts

The UK Government's Strategic Environmental Impact Assessment for the 14th onshore oil and gas licensing round plans notes that: "*there is potential for a significant negative effect on landscape associated with onshore oil and gas activities. This principally reflects the potential landscape and visual impact of construction activities and associated machinery such as drilling rigs.*"[38] Added to this is the impact of networks of access roads, pipelines, gas and water treatment facilities, vents and flares.

A New York State Government study indicates that according to industry estimates the average size of a multi-well pad for the drilling and fracturing phase of operations is 3.5 acres (=0.014 km^2), with an average area of 1.5 acres (=0.006 km^2) after partial reclamation.[39] The study notes that while multi-well pads can decrease the number of pads required, the size of these pads tends to be larger as the drilling and storage equipment needed for this type of production is larger.

According to Ineos: *"Typically, those living in a Shale gas community (approximately 100 square kilometers) would benefit from the output of 200 wells".*[40] The SEA assumes a minimum distance of 5km between pads meaning that depending on how many wells INEOS intend to drill per pad (again, the SEA assumes an average of 2) the landscape impact could be very intense in areas targeted for shale gas in a high production scenario.

Greenpark Energy received planning permission for 19 CBM sites in and around the village of Canonbie in Dumfries and Galloway. The 19 sites were distributed over an area of approximately 23 square km, with wells to be drilled less than 1km from the heart of the village.[41]

We note that the impact on the quality of life of communities living in areas under license for onshore gas extraction could be severely impacted by the landscape impacts of a production scenario. Furthermore there is potential for detrimental economic impact on tourism and local businesses as a result of reputational and actual damage to environment and landscape. Projects like the Falkirk Wheel and the Central Scotland Green Network show the efforts that have been made to rehabilitate areas of the Central Belt that have been damaged by industrial development in the past.

The economic impact assessment should include potential impacts on tourism and local businesses. The value of landscape to society in contributing to wellbeing and quality of life should be included in wider social and environmental impacts as part of a CBA.

2.9 Regulatory costs

The economic impact study should take into account the costs of developing and applying a regulatory and enforcement regime for shale and CBM in Scotland, including the costs of ongoing

[38] DECC Strategic Environmental Assessment for Further Onshore Oil and Gas Licensing Environmental Report, 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/273997/DECC_SEA_Environmental_Report.pdf

[39] New York State Department for Environmental Conservation http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch50911.pdf

[40] http://www.ineos.com/businesses/ineos-upstream/news/ineos-plans-25-billion-shale-gas-giveaway

[41] See map of the proposed developments https://eaccess.dumgal.gov.uk/online-applications/files/7627D57EFFAEC49C7865A654F593A766/pdf/09_P_4_0487-CBM_Developments-89704.pdf

monitoring. The capacity of regulators and local authorities should be considered, including the need for use of independent consultants for monitoring. A useful case study could be the example of open cast coal in East Ayrshire, where there is monthly compliance monitoring of sites by independent engineers.

This should take into account:

- Requirements for ongoing monitoring of well pads for methane leakage, potentially for a number of years post-decommissioning, including the costs of establishing a baseline;
- The cost of establishing a compliance regime in the context of the likely maximum lifetime of any unconventional oil or gas extraction. Given it is recognised that unconventional gas is, at best, a bridging or transitional fuel as part of a low carbon transition, this implies the need for short-term industry with a consequent winding-up and managed winding-down of infrastructure, business models and regulatory and legal frameworks. The cost-effectiveness of setting up a regulatory regime should be considered therefore in the context of a time-limited industry.

2.10 Community and social impacts

Key purported community or social benefits of an onshore unconventional gas industry cited by operators, politicians and commentators include: reduced energy bills, community benefit payments and jobs.

Section 2.2 above describes the factors that mean a USA-style shale gas revolution is highly unlikely to be replicated in Europe. The claim of reduced householder energy bills as a result of abundant cheap domestic gas, described by leading economist Lord Stern as 'baseless economics', has largely been discredited. Former chair of Cuadrilla, Lord Brown has stated that domestic shale gas production won't have a "material impact" on household bills. Unlike the USA, the UK is part of a well-connected regional gas market that means any gas produced here will be sold to the highest bidder. Dart Energy's deal to provide SSE with gas from its Airth coalbed methane proposal was fixed to market rates.

A voluntary UK wide industry scheme backed by the UK Government to share the proceeds of unconventional gas extraction with communities has come under criticism from communities in targeted areas in England. The scheme, which all UKOOG's members have signed up to, proposes:

- At exploration stage, £100,000 in community benefits per well-site where fracking takes place
- 1% of revenues at production will be paid out to communities. [42]

The removal of rights for property owners to refuse drilling or fracking underneath their land in England and Wales also lead to the introduction of a further voluntary commitment of £20,000 per lateral well drilled.[43]

However a recent investigation by an independent journalist, Ruth Hayhurst, revealed that conditions restricting which operations trigger payments mean that some communities may not receive anything, and that communities aren't getting the information they need about the scheme from operators.[44] The Infrastructure Act 2015 defines hydraulic fracturing as that which "*involves or is expected to involve the injection of more than 1,000 cubic metres of fluid at each stage, or expected stage, of the hydraulic fracturing, or more than 10,000 cubic metres of fluid in total*",[45] meaning that any proposals that involve less than this volume of fluid will fall outwith the community payment scheme.

[42] https://www.gov.uk/government/publications/about-shale-gas-and-hydraulic-fracturing-fracking/developing-shale-oil-and-gas-in-the-uk#community-and-public-engagement
[43] https://www.gov.uk/government/news/government-proposals-to-simplify-deep-underground-access-for-shale-gas-and-geothermal-industries
[44] https://drillordrop.com/2016/04/13/research-raises-questions-over-industry-payments-to-shale-gas-communities/
[45] 4BSection 4A (1)(b)(i)(ii) supplementary provision http://www.legislation.gov.uk/ukpga/2015/7/part/6/crossheading/other-provision-about-onshore-petroleum/enacted

Questions remain over the definition of a community, whether communities with coalbed methane wells would be eligible and details of the scheme for horizontal wells. The voluntary nature of the schemes has also raised community concerns.

INEOS, the leading industry player in unconventional gas extraction in Scotland has proposed its own community benefit scheme, which involves:

- "plans to give 6% of its Shale gas revenues to homeowners, landowners & communities close to its wells
- "estimates it will give away over £2.5 billion from its new Shale gas business
- "those living in an INEOS Shale gas community (100km square) would typically share £375 million over the life of the project
- "home owners and land owners directly above the wells would share 4% of the revenue – typically £250 million
- "shale gas communities living close to the wells would share 2% of the revenue, typically £125 million"[46]

We are concerned that these numbers may be misleading. In its announcement of the scheme, INEOS noted that: *"The single Marcellus shale gas field in the USA produces over twice as much gas as the UK consumes and UK reserves are estimated to be significantly greater than this."* INEOS refer to 'reserves', when according to the UK Department for Energy and Climate Change there is not "*sufficient understanding of the geology, or experience of the engineering or costs of production to make a reliable estimate of…[UK] shale reserves at this stage*".[47] Moreover, it is inappropriate to extrapolate UK production figures and any community payments based on these from Marcellus Shale production, given the costs of production in the UK context are likely to be much higher, as noted above in section 2.2.

We would also raise concerns about any conflation of payments or compensation agreed with landowners in order to access their land with the distinct concept of 'community benefit'. In Scotland property owners retain the right to refuse permission to operators wishing to drill or frack for shale oil or gas underneath their homes. INEOS would be expected – and potentially required by law – to pay some form of compensation to owners who agree to fracking underneath their property, therefore two-thirds of the 6% community benefit might be better described as payments for access to land. It is important to note that operators with a Coal Authority license to exploit coalbed methane extraction do not have to negotiate with property owners to access seams underneath their homes.

As with the UKOOG scheme, INEOS's offer is voluntary, and if exploration proves unsuccessful, communities could be left with a legacy of numerous test wells and no community payments. Director Tom Crotty has warned: *"We want to share the benefits but there is also sharing of the risk. So if you drill and there is nothing there, there is no gas and there is no money."*[48]

The economic assessment should scrutinise the nature of community payments and set out clearly what the existing voluntary schemes mean for communities in areas under license.

Predicted jobs figures must be treated with caution given that they are dependent on a whole range of factors, including ultimately whether there is, at the end of any initial exploratory activity, a resource that is economically viable to extract. We note that jobs per site are relatively few, and potentially itinerant, with specialist (and therefore more highly paid) roles moving between sites and around the country. INEOS have indicated that around 30 people would be employed on site,[49] however Cuadrilla's proposals for Roseacre Wood and Preston New Road would result in 19 *"estimated gross local jobs*

[46] http://www.ineos.com/businesses/ineos-upstream/news/ineos-plans-25-billion-shale-gas-giveaway
[47] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/324555/Resources_vs_Reserves_-_note_-_27-6-13-2.pdf
[48] http://www.telegraph.co.uk/news/earth/energy/fracking/11462840/Fracking-communities-may-miss-out-on-cash-payments.html
[49] http://www.heraldscotland.com/news/13206238.Ineos_director__I_will_pitch_plan_to_people_on_personal_level_if_possible/

created".[50] We note that following INEOS's deal with IGas to buy out certain of its Scottish licenses, IGas closed the Stirling HQ which had been the base of its, and Dart Energy's, predecessor companies since the 1990s.[51] Further, we note that a recent initial recruitment round for various jobs in INEOS Shale, including commercial direct, geologist and land managers, were advertised as located in London, clearly not local to the operators' target areas of the central belt and northern England.[52]

It is apparent from the limitations of the scope of the economic study that it may omit to account for potential loss of jobs in some local industries. We note that agriculture, tourism and fishing may suffer, and some commentary on this, and the concept of socially useful employment in an era of climate change, would be very valuable.

Finally, we note that a Defra report and an investigation by journalists at the Ferret, have suggested that fracking could have an adverse impact on house prices, estimating house prices may be affected by up to 10%. [53] **The report could usefully explore what this means for communities living in proximity to proposed development areas, in the context of environmental justice and considering social mobility factors** (i.e. that households in lower income groups may be less likely to be able to move in response to new development, and therefore be potentially at greater risk of exposure to adverse health impacts).

2.11 Public health

The Public Health Impact Assessment should be a key input to the other studies carried out under the moratorium. We are not clear as to how the PHIA interacts with the Economic Impact Assessment in terms of the scenarios defined by the economic study. **The public health costs to society should be included in the wider social and environmental costs considered under a CBA**.

The PHIA should include comprehensive research into the following[54]:

- **The potential acute and cumulative health impacts of exposure to water, soil** and **air pollution** from drilling chemicals, and hydraulic fracturing fluids, as well as naturally occurring chemicals mobilised by these processes (e.g. heavy metals, BTEX, VOCs, PAHs and NORM etc) entering the environment by way of: faulty well construction; damage or deterioration of wells during and after their productive life; naturally occurring and / or created faults, fractures and cleats; accidents and spills; wastewater treatment and disposal. Further, the impact of particulate matter and diesel exhaust from onsite equipment, and the interaction of these pollutants with fugitive emissions of methane and other substances from well-heads etc.

- **Community impacts** associated with socio-economic changes such as increased vehicle traffic, road damage, industrialisation of local areas, noise, odour complaints, increased demand for housing and medical care and other challenges presented by 'boom town' industries, impacts on pre-existing local businesses and industries, house prices and insurance.

- **Particular occupational health impacts** for workers in the unconventional fossil fuel industries over the long term, and specific short-term health risks.

We are particularly concerned about five specific health risks that are documented in health research:

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[50] Cuadrilla Bowland Ltd Planning Statement Exploration Works Planning Application, Preston New Road Lancashire
[51] http://www.bbc.co.uk/news/uk-scotland-scotland-business-32672278
[52] http://www.heraldscotland.com/news/14478229.Despite_moratorium_____energy_giant_hires_crews_to_frack_central_Scotland/?commentSort=score
[53] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/440791/draft-shale-gas-rural-economy-impact-report.pdf and https://theferret.scot/fracking-property-prices-scotland/
[54] LINK was not invited to participate in the PHIA stakeholder process, but Friends of the Earth Scotland who were approached directly took part in a stakeholder workshop in November 2015. The information outlined in this submission regarding public health was fed in to that process by FoES.

- Low birth weights and congenital disorders linked to unconventional gas developments
- Cancer risks from exposure to both naturally occurring radioactive materials and specific naturally occurring chemicals (such as benzene) released into the environment during unconventional gas operations, as well as carcinogenic chemicals introduced during drilling and hydraulic fracturing , diesel exhaust fumes from onsite equipment, and the interactions between groups of pollutants
- Long-term exposure to endocrine disrupting chemicals, and e.g. the adverse reproductive health effects linked to this, immuno and neuro toxicity over the whole life cycle of fracking operations
- Mental health and wellbeing impacts from on-going stress as a result of exposure to noise pollution, light pollution, truck movements, visual impacts, risk of earthquakes, air and water pollution, climate change
- Respiratory disease, caused or exacerbated by air pollutants including benzene, toluene as well as particulate and nitrogen dioxide pollution and ground-level ozone

2.12 Other comments

Shale gas exploration, and to a lesser extent coalbed methane development, in the UK is at an early stage. Should the Scottish Government permit the industry to proceed, operators would need to undertake a certain amount of exploration and development to establish whether there is an economically and technically viable resource. **The economic impact study should include a scenario where operators discontinue operations after an initial exploratory phase**. For example, Cuadrilla has estimated that it would need to drill and frack 40 wells over 5 years to establish whether there is an economically viable industry.[55]

[55] http://www.theguardian.com/environment/2014/jan/31/uk-shale-gas-fracking-cuadrilla

3 Understanding and Monitoring Induced Seismic Activity

The occurrence of induced seismic activity from unconventional oil and gas operations in the USA and Canada is well documented, and indeed the only UK experience of hydraulic fracturing for shale gas at Preese Hall in Lancashire in 2011 resulted in a number of minor earthquakes. While minor earthquakes such as experienced at Preese Hall may not be felt, nor result in damage to buildings, any damage to well integrity could exacerbate risks of pollution incidents including methane leakage and groundwater contamination.

It is important that the review addresses both the risk of earthquakes induced by the process of hydraulic fracturing itself, and also by the disposal of waste fluids by reinjection into fracked wells. This method of waste disposal (in part produced water from conventional oil and gas extraction) has been linked to "*almost a millenium's worth*" of quakes in 2 years in the previously geologically stable Oklahoma.[56]

Concerns have been raised that the Environment Agency in England and Wales has softened its position on this method of disposal,[57] with its latest guidance stating that: "*re-injection of flowback fluid for disposal is not necessarily prohibited and may be permissible where, for example, it is injected back into formations from which hydrocarbons have been extracted and will have no impact on the status of water bodies or pose any risk to groundwater.*"[58]

Given the pressures on existing NORM water treatment and disposal facilities, and the high costs associated with developing such facilities (see section 2.6 on wastewater disposal), there appears to be a risk that this method of disposal could be permitted in England and Wales.

Academics from the Universities of Edinburgh and Strathclyde have highlighted both the risks of induced seismicity and the need for better understanding of the implications of chemical interactions between fracking fluid and produced water in order to determine options for safe liquid waste disposal.

This study should address these questions and highlight where further work is needed to understand the consequences of hydraulic fracturing induced seismicity.

Further, we reiterate concerns outlined in section 2.6 regarding the links between the challenges of flowback fluid and wastewater disposal management and the risk of induced seismicity. The ongoing Public Inquiry into Cuadrilla's proposals for hydraulic fracturing at Roseacre Wood and Preston New Road heard evidence regarding the risk of induced seismicity associated with managing daily flowback from the two sites: the estimated maximum daily flowback from each site of 250m^3 would take up 65% of treatment capacity at the 2 facilities identified by Cuadrilla, compared with the calculated cumulative peak daily flowback of 262m^3, requiring 68% of capacity. According to the expert evidence of Alan Watson: "*Limiting the flowback volume from the second site to just 12 m^3/day would be enormously challenging bearing in mind that the estimated peak daily volume of flowback fluid generated during: the flow testing phase is 250m^3; and the extended flow testing phase is 40m^3 ...In any case staggering the operations of the two sites to reduce the combined impact to this level would therefore require an unprecedented level of integration and co-ordination between the two operations.* "[59] The key mechanism for controlling flowback is the use of a 'choke manifold' at the surface, however: "*allowing the flowback of fluids, particularly immediately post-fracking, is necessary in order to address seismicity. It is therefore not a straightforward decision to limit or prevent the flowback of fluid through the use of the choke valve in order to reduce demand for treatment capacity*."[60]

This study should look into the interlinkages between waste fluid management and seismic risk.

[56] http://www.theguardian.com/environment/2016/jan/10/fracking-earthquakes-oklahoma-colorado-gas-companies
[57] http://energyandcarbon.com/uk-failing-lessons-fracking-waste-water/
[58] https://consult.environment-agency.gov.uk/portal/ho/ep/oog/guidance?pointId=1444679889218#section-1444679889218
[59] Alan Watson Proof of Evidence, 4.41 & 4.43 http://programmeofficers.co.uk/Cuadrilla/Proofs/NWFOE/FOE2.1.pdf
[60] Alan Watson rebuttal of evidence 2.6 http://programmeofficers.co.uk/Cuadrilla/Proofs/NWFOE/FOE2.4.pdf

4 Decommissioning, Site Restoration and Aftercare – Obligations and Treatment of Financial Liabilities

Decommissioning, restoration and aftercare of unconventional gas infrastructure should follow robust standards with costs fully absorbed by the industry, to ensure sites are returned to the same or higher quality environment, and to ensure there are no ongoing methane emissions or other pollution issues.

Minimum requirements should include:

- A written Decommissioning Plan, approved by the planning authority, SEPA, and an independent well examiner prior to planning consent, secured through an appropriate legal agreement;
- Clarity on how any ownership of land or infrastructure is considered to be relinquished by the operator. We recommend that consultants consider risks of land or infrastructure being abandoned by operators, looking at the example of open cast sites owned by ATH Resources (see Grievehill and Skares sites) which were abandoned by the liquidator as the company was registered in England (where insolvency law allows liquidators to abandon 'onerous property'). Another useful case study may be Cockenzie power station, where lack of clarity around long-term ownership of the sea wall at the time of consenting may result in significant liabilities being passed to the Local Authority;
- Robust measures to ensure restoration costs do not fall to the public purse;
- Restoration agreed to a minimum standard, which should identify opportunities to enhance the local environment;

A key long-term issue in relation to decommissioning, according to current understanding of risks, is likely to be ongoing fugitive methane emissions, which could significantly increase greenhouse gas emissions, as well as related groundwater pollution resulting in risks to people and wildlife.

Research led by Durham University, which tested soil methane levels at 102 decommissioned wells in the UK, found 31 sites with methane emissions significantly higher than control samples, albeit at relatively low levels. A single site was found which had methane emissions levels over ten times higher than the average decommissioned well. This site had not been decommissioned to contemporary standards, demonstrating the critical importance of robust standards and monitoring, but also demonstrating the potential long-term nature of leakage issues.[61]

Further research into the implications of chemical interactions between fracking fluid and formation water must be undertaken in order to understand the implications of re-injection of flowback or produced water as a means of waste disposal on decommissioning and monitoring.

An appropriate monitoring period post-decommissioning must be agreed with regulators and based on evidence, with a strict requirement for action to address ongoing methane leakage or water contamination. Cessation of monitoring should be contingent on evidence of a sustained period with no ongoing gas leakage and no pollution of water or soils.

There should be an agreed approach to how site data, including post-decommissioning monitoring of methane emissions, will be stored and made accessible to stakeholders.

Appropriate financial guarantees must be secured by the planning authority which would be capable of covering the entire cost of decommissioning in case of insolvency or non-compliance.

The sum required should be assessed independently and secured through either an ESCROW lump-sum payment or pay as you go ESCROW, combined with a bank guarantee or bond to cover any initial shortfall. Lessons should be learned from the open cast coal industry which shows that bonds are a

[61] See Boothroyd et al (2015) Fugitive emissions of methane from abandoned, decommissioned oil and gas wells. At: http://www.sciencedirect.com/science/article/pii/S0048969715312535

high-risk approach, as they place a heavy burden on planning authorities to monitor them and ensure they remain sufficient. Parent Company Guarantees should not be accepted, as the financial standing of the parent company may change over time. Guidance should draw on risk assessment work undertaken by East Ayrshire Council in 2014.[62]

In addition to financial guarantees on a project basis, a decommissioning levy should be considered to provide a pooled buffer fund, to cover shortfalls for unexpected environmental damage. This was considered by the Scottish Government in the case of open cast coal, but by this time the industry had largely collapsed leaving a £200 million liability, with coal prices too low for sites to be viable with a levy. A levy should be in addition to and not a replacement for site guarantees, in order to ensure that rogue players are not incentivised to abandon liabilities, and to ensure operators benefit from good practice e.g. minimising restoration costs through good ongoing site management. For the same reasons, funding decommissioning through general taxation would not be acceptable.

We recommend that consultants review the Environmental Liability Directive (transposed into Scottish law via the Environmental Liability Regulations) which states that "Member States should take measures to encourage the use by operators of any appropriate insurance or other forms of financial security and the development of financial security instruments and markets in order to provide effective cover for financial obligations under this Directive".

Secure and cost-effective decommissioning is dependent on ongoing site maintenance, monitoring and enforcement action during site operations, as it will be more difficult and costly to safely decommission wells in disrepair.

Experiences with open cast coal in Scotland showed there were capacity issues in planning authorities, in terms of having the technical, resource and staff capacity to conduct site monitoring and take appropriate enforcement action. A culture of 'light-touch regulation' led to widespread environmental damage and a failure of industry to absorb environmental externalities. In order to avoid repeating these mistakes, a strategy would be needed in advance of any unconventional gas development to ensure that either planning authorities and regulators have sufficient technical and staff resource to carry out required monitoring and enforcement, or planning authorities have access to that resource, either via independent contractors (e.g. East Ayrshire Council's current approach to open cast coal), or via a centralised unit established to provide advice or undertake compliance functions.

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[62] Available here: http://docs.east-ayrshire.gov.uk/crpadmmin/2012%20agendas/cabinet/21%20may%202014/Decommissioning,%20restoration,%20aftercare%20and%20mitigation%20financial%20guarantees.pdf