CONCERN AND COUNTER-CONCERN:THE CHALLENGE OF FRAGMENTED FEARS FOR THE REGUATION OF HYDRAULIC FRACTURING

1. Introduction

Hydraulic fracturing for gas,[1] which is commonly known as 'fracking',[2] involves the extraction of natural gas through the process of injecting mixtures of water, sand as well as other chemicals into formations of shale, other rocks, and even coal, to allow gas trapped within the seams to flow out and be collected at the well head (Pearson, 2015) While the process is not new (Kutchin, 2001) it has recently become a prominent source of contention among scientists, politicians, and the wider public. In what are often polarised and vociferous debates, a developed industry is seen either as a means of achieving a degree of energy security and a source of employment, or a risk to public health and the environment.[3] Debates, which are often depicted as a battle of 'corporations versus communities,' are fuelled by some of the uncertainties surrounding the process and questions over whether it can properly contribute to the energy security of the nation.

This article considers how opposing stakeholder groups have directed their concerns at different issues relating to the hydraulic fracturing process. In particular, it outlines how the more high profile civic remonstrations have tended to target issues (e.g., noise, traffic, seismicity, water usage and contamination) where the regulatory regime is more established and arguably more robust, and which are endemic to other industries and processes that by comparison have received less attention. The less high-profile concerns, which have typically been the focus of the scientific community, relate to areas (e.g., flowback fluids) that are less well-established from a regulatory perspective; areas that may become more apparent with industrial scale hydraulic fracturing. A distinction can thus be seen over what civic and scientific groups predominantly highlight as concerns and which might be worthy of bespoke regulatory responses or indeed the halting of activities. Importantly, with the regard to the regulatory framework, civic concerns have tended to receive far greater attention and to resonate much farther, which may give the public a mistaken view of where potentially unmitigated risks lie. In looking at these issues, the authors highlight some of the challenges for the future regulation of this emerging industry.

Given the controversies around hydraulic fracturing, it is surprising, in debates over whether 'to frack or not', that the regulatory framework has not featured more prominently. Indeed, little has been said of the framework, and so it is worth providing an outline of how it works.[4] We only provide a brief overview, and so

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[1] Readers should note that the piece was written prior to the announcement of the proposed ban on the practice of hydraulic fracturing in the Labour Party Manifesto for the June 2017 General Election.

[2] 'The term fracking tends to have 'biased connotations' (Evensen, Jacquet, Clarke and Stedman. What's the 'fracking' problem? One word can't say it all. (2014) *The Extractive Industries and Society* 1, 130.

[3] Opposition tends to focus on the extent of the fractures created and the other environmental resources and features they might effect and on the visual and audible impacts.

[4] That not much has been said about the regulatory framework may have something to do with fact that the industry has not been properly commercialised, though it may also have something to do with the fact that the framework is not properly understood.

for a more comprehensive, though now slightly out-of-date, view, it is worth referring to the work of Bryden et al. (2014), from which the following section draws.

2. Regulatory Framework

The regulatory framework for hydraulic fracturing is complex and, to some extent, fragmented. It combines existing laws found in established frameworks for health and safety, the environment, and land law and property rights, as well as a range of additional measures. What is more, the framework comprises a mixture of command-and-control approaches (e.g., regulatory standards and permits), planning permissions, self-regulatory arrangements, and common law principles. It comprises overlapping procedures and a network of national and local bodies, each monitoring and managing different features of the process (Task Force on Shale Gas, March 2015). Table 1 provides an outline of the main requirements for securing permission for an *exploratory* well.

Table 1: Regulatory Framework

Procedural Requirement	Type	Comment
Permission from the Oil and Gas Authority in the form of a PEDL	PEDLs are granted under powers provided by the Petroleum Act 1998, section 3.	Mix of law and private governance It has to be shown that Operators will act accordance with a suitable environmental management system conforming to the principles in ISO 14001.
Environmental Risk Assessment	Not a statutory requirement, but is a suggested (in Department for Energy and Climate Change (DECC) regulation and best practice guidance now adopted by the Oil and Gas Authority (OGA)) to be mandatory part of the regulatory framework	Good practice suggests licensees should undertake an overview assessment of environmental risks, including risks to human health, covering the full cycle of the proposed operations, including well abandonment, with the participation of stakeholders, including local communities.
Planning Permission	Complex mix of law, planning policy and guidance.	Probably the most complex process and the part that leads to the most inconsistency in terms of decision-making.
Environmental Impact Assessment	The process by which the likely impacts on the environment of a proposed development or project are measured, and subjected to scrutiny under a complex mix of law planning policy and guidance.	This statutorily required (Town and Country Planning (Environmental Impact Assessment) Regulations 2011) assessment necessitates the inclusion of prevention, reduction and mitigation measures, as well as a broader range of aspects of the environments which might be impacted upon than the above risk assessment.
Landowner permissions	Legally required permission, disputes over which are resolved	Above land access remains important, but 'deep-level' permission made far easier due

	through private law and statute.	to the Infrastructure Act 2015
Complex mixture of regulatory permits from different agencies	Permits are found in a disparate and complex set of statutes and statutory instruments.	A numerous range of permits and permissions are potentially required dependent on geological and environmental characteristics of the site proposed for development.

A potential operator must first seek permission from the Oil and Gas Authority (or OGA) before well operations can commence.[5] It is worth noting at this point that the OGA is a government company sponsored by the Department for Business, Energy and Industrial Strategy (BEIS), with the latter being the department responsible for hydraulic fracturing following the disbandment in July 2016 of the DECC. This permission is known as a Petroleum Exploration and Development Licence, or PEDL, and is classed as landward production licence granted under Petroleum Act 1998 (s. 3). The PEDL is a form of deed that requires operators to adhere to its terms (Bryden et al. 2014). A PEDL can be held by one firm, or several working collectively. That said, where firms work collectively there is only one licensee, with the other firms sharing liability process (Task Force on Shale Gas, March 2015). PEDLs are granted through competitive licensing rounds. Applicants must show technical competence, environmental awareness, as well as financial capacity. Yet it is important to note that PEDLs only allocate oil and gas resources within a defined area, which means they do not include other important rights that will also be needed before hydraulic fracturing can commence (Bryden et al. 2014). While PEDLs would allow operators to undertake several exploration activities (such as, exploration of unconventional gas), this would further depend on those operators securing other drilling and consents and permissions (e.g., regulatory or landowner permissions). The PEDL contains terms that are called 'model clauses'. These are contained in regulations made under powers granted by the Petroleum Act 1998 (SI 2014 No. 1686, 2014). These model clauses include, for example, granting of rights for petroleum, payment of fees, parameters of the licensed field, and obligation to follow 'good oilfield practice' (Bryden et al. 2014). An important requirement is for the operator to practice in accordance with a suitable and robust environmental management system, one that conforms to the principles of ISO 14001. So, although management systems are voluntary instruments, it is interesting to note that the PEDL process makes them (de facto) mandatory. It is suggested that an effective, risk-based approach to hydraulic fracturing requires management systems to be applied to all operations, including pre-drilling and abandoned operations (DECC, 2015).

The environmental risk assessment process is another important feature of the extant regulatory framework. Although there has been some uncertainty on this issue, the (then) DECC confirmed that good practice would require licensees to undertake an overview assessment of the environmental risks involved. As well as covering the full cycle of projected operations, the assessment should include risks to human health. Moreover, this process requires the participation of stakeholders, including local community members (Bryden et al. 2014). An environmental risk assessment, the DECC has pointed out, should be done as early as practicable in the development of proposals (DECC, 2015). Any

[5] Part I of the Petroleum Act 1985 vests all rights to petroleum in the Crown, including the rights to search, bore and acquire it. The Secretary of State can grant licences to such persons as s/he sees fit. In some countries, such as the US, landowners own the hydrocarbons under their land and thus hold rights to exploit them.

assessment could inform other assessments, such as an environmental impact assessment (EIA) if required following screening by the planning authority (Bryden et al. 2014).

Possibly the most contentious, and almost certainly the most high profile, feature of the regulatory framework relates to planning and planning permission. While it is undoubtedly significant, due to the focus of this article, and given the development of later points, we need only to provide a brief outline here. Thus, proposals for shale gas exploration or extraction, as with *any* proposal for onshore oil and gas developments, are subject to the Town and Country Planning Act 1990. In order for them to conduct their operations, operators must gain site specific planning permissions. Shale gas operations involve minerals extraction, so applications must be submitted to the local Minerals Planning Authority (MPA). The MPA has a number of responsibilities, such as regulating developments to ensure conformity to legal constraints provided in planning permission. Decisions of the MPA should be taken in accordance with polices set out in the National Planning Policy Framework (NPPF) and the minerals section of the National Planning Practice Guidance (NPPG) (Department for Communities and Local Government, 2012). The procedures for determining planning applications are set out in the 1990 Act and the Town and Country Planning (Development Management Procedure) (England) Order 2010 (SI 2010 No. 2184). Amongst other things, applications must be publicised and it must be clear how interested parties can submit representations (Delebarre et al. 2015). When decisions are made only planning matters – or 'material considerations' – are to be considered (Delebarre et al. 2015). There is no complete list of what constitutes a material consideration, and such considerations may vary between local authorities, but the NPPG outlines principal issues including noise, visual impacts, archaeological and heritage features, traffic, and contamination.

An important feature of the planning process is the MPA screening exercise. This is carried out to ascertain whether developments and proposals require an EIA. The EIA process is a derivative of EU law (Directive 2011/92/EU, 2011).[6] All of those projects listed in Annex I to the EIA Directive need an environmental impact assessment to be undertaken. Such projects include those developments where more than 500 tonnes of oil or 500,000 cubic metres of gas will be extracted each day. Projects listed in Annex II require an environmental statement where, following investigation, and accounting for certain conditions (such as location), it is resolved that a project's impacts might be significant (Bryden et al. 2014). According to guidance from the DECC, even though applications are assessed individually, it is suggested that it is unlikely that an EIA will be required for exploratory drilling operations *not* involving hydraulic fracturing, unless the well pad is located in a site that is unusually sensitive to limited disturbance occurring over short periods (DECC, 2015). This suggests that exploratory hydraulic fracturing wells would be required to undergo an EIA. Importantly, applications for the production phase, where more than 500 tonnes of oil or 500,000 cubic metres of gas will be extracted daily would fall under Schedule 1, which would make the EIA mandatory. Extractor projections for proposed individual wellheads would however not currently place them in this category. Where an EIA is required, developers are encouraged to ask the MPA for an opinion on the level of detail to be covered before submitting applications

[6] Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment, as transposed in the UK (in part) by the Town and Country Planning (Environmental Impact Assessment) Regulations 2011/1824.

for planning permission (DECC, 2015). In such cases, to ensure relevant issues are identified and addressed, the MPA will consult other relevant bodies before giving an opinion.

It has already been stated that landowner permissions and access is an important feature of the regulatory process.[7] Recent legislative changes have also made this a more provocative feature. Neither the award of a PEDL, nor the grant of planning consent, entitles an operator to conduct exploratory operations. The reason for this is that permission is also required to actually drill *on* private land. When it comes to access , it has been pointed out by Brydon and colleagues that the standard practice is for licences or lease options to be taken which are conditional on the grant of a satisfactory planning consent *and* landowner permission (Bryden et al. 2014). It is arguable that the more contentious issue relates to access *under* neighbouring land. Conventional vertical drilling for gas and oil will inevitably have impacts on a relatively small area at the surface and the land directly beneath it. For the purposes of hydraulic fracturing however, wells extend horizontally from the vertical well and thus have the potential to – and are indeed likely to – affect adjoining land owned by third parties (Bryden et al. 2014). Until quite recently, the issue (of access under neighbouring land) was determined by the common law principles relating to trespass, with the Supreme Court even as recently as 2010 suggesting that the owner of the land's surface is the owner of the strata beneath it (*Star Energy v Bocardo*, 2010). Thus, operators would not only potentially need permission to work *on* someone's land, but they would also need permission to work *under* someone else's adjoining land. This, of course, was potentially a significant barrier to hydraulic fracturing operations. However, it has now been overridden by the Infrastructure Act 2015; a measure that to a large extent signals the government's intent with regard to the development of the hydraulic fracturing industry. Part 6 of the Act, particularly s.43 to 48, provides that when dealing with access to land at depths greater than 300m, new 'rights of use' are provided for exploiting petroleum or deep geothermal energy at deep level, without the need, at present, to notify the landowner (unless further regulations are made in this regard).

Lastly, in addition to PEDLs and planning permission, there is a bundle of requirements on the part of the operator to acquire the necessary permits and licences from relevant authorities. For instance, before any operation can commence an operator must seek environmental permits from the Environment Agency under the Environmental Permitting (England and Wales) Regulations 2016 and the Water Resources Act 1991. Depending on the scale of activities, permits may be needed for; groundwater activities, mining waste management, and water abstraction if the plan is to abstract more than 20m^3/day for use rather than purchasing water from a public water supply utility company (Bryden et al. 2014). Conditions are also placed on operations as part of the granting of a site based on Operational Risk Assessment (OPRA) methodology developed by the environmental regulators.[8] In addition, the Health and Safety Executive (HSE) will monitor oil and gas operations to ensure the necessary well integrity and site safety. The HSE is responsible for ensuring operators carry out safe working practices, required under the Health and Safety at Work Act 1974 and regulations made under the Act. Important here are the Borehole Site and Operations

[7] It tends to support the view that "the political and regulatory conditions remain broadly supportive [of hydraulic fracturing]. McGowan (2014)

[8] Once a site is awarded a permit, the environmental regulators continue to use the OPRA methodology and rating system to monitor a site's performance and compliance with permit conditions.

Regulations 1995 (BSOR), which apply to onshore sites where borehole operations occur, and the Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 (DCR), which apply to wells drilled with a view to the extraction of petroleum regardless of whether they are onshore or offshore and are primarily concerned with well integrity and well control. They require *inter alia* such measures as pre-drilling assessment of below-ground conditions, preparation of a well examination scheme (to ensure that the well is designed and constructed to prevent unplanned escape of fluids) and certain reporting obligations (Bryden et al. 2014). In addition to the above, operators may need to consider obligations under the Control of Substances Hazardous to Health (COSHH) and Control of Major Accident Hazards (COMAH) regimes. Further to this, there are also measures to be considered relating to flaring and venting, British Geological Survey obligations, and Coal Authority authorisation which may be applicable to some projects.[9]

Having provided a brief overview of the extant regulatory framework, it is now pertinent to look at how this relates to recent debates over the hydraulic fracturing process.

3. Contrasting Concerns

There are different groups – or stakeholder constituents – that have raised various concerns over hydraulic fracturing. Yet it is the focus of these concerns that is of interest from a regulatory perspective. This is because some disparity seems to have emerged. Simply stated, there seems to be some contrast between the focus of public and media concerns, which involve areas where there appears to be a more established and robust regulatory framework, and those of the scientific community, which appear to involve greater regulatory 'unknowns', as it were. Such disparity is of itself not a concern and indeed occurs in a number of other regulatory regimes without the need to be addressed by a holistic reformative response.[10] But where these contrasts in perceived and actual concerns skew discourse around an emerging industry, and expose the potential for misdirection in the development of a regulatory framework, efforts need to be made to bridge this possible 'perception gap' and thus to imbue confidence in decision making regarding future regulation (Holder and Lee, 2007). Here, we provide an outline of this disparity before then considering its implications.

3.1 Public Perceptions and the Public Voice

As with the introduction and emergence of any new extractive process, which has the potential to raise environmental and human health concerns, there is likely to be at least some level of public and media attention and disquiet. This has been particularly evident in relation to hydraulic fracturing to access shale gas reserves. Since the earliest suggestions of the viability of adopting the process to support the energy needs of the country, there has been a polarised debate as to the necessity and safety of doing so (Williams et al. 2015). This piece focuses solely

[9] *Inter alia:* Operators may need a venting consent under the Energy Act 1976 and flaring consent under the Petroleum Act 1998.Under s. 23 of the Mining Industry Act 1926 (as amended), operators sinking boreholes greater than 100ft (30m) must give written notification to the Natural Environmental Research Council. Activity that disturbs or enters any of the Coal Authority's coal interests requires prior written authorisation. See for further examples Bryden et al. (2014)

[10] Quoting Douglas and Wildavsky (1982), Pedersen notes the increased 'receptiveness of law-makers (domestic, international and federal) to the increase in public concern for the state of the environment,' and that 'In some respects, disputes over environmental problems and risks are in essence 'the product of an ongoing debate about the ideal society'' Pedersen (2013)

on the environmental safety aspects of this debate, but it is important not to ignore the fact that this is closely linked to its viability as an energy source. The progress towards the exploitation of this method of extracting gas reserves has drawn the attention of established environmental groups (Friends of the Earth, n.d.), although it has also given rise to considerable local community opposition and support movements in regions where shale gas extraction is considered to be economically viable (Frack Free Lancashire, n.d. and Frack Off, n.d.). This phenomenon in particular has been seen on the Fylde Coast of Lancashire, as well as more recently in North Yorkshire. The ultimate influence of MPAs on the approval of any exploration and test (or in the future, commercial) extraction within the current licensing and permissions system has been one of the driving forces behind this proliferation of local voices on both sides of the debate. The recent decisions of Lancashire County Council MPA have been reconsidered and overturned on appeal (or a decision deferred) by the Communities Secretary Sajid Javid, owing to the decision to refuse applications being unfounded when weighed against evidence provided to support the applications. At the time of writing the appeal against the decision to overturn had been upheld following an appeal (*Preston New Road Action Group v Frackman*, 2017). However, the integral role of the local authorities in the permitting process remains, for the foreseeable future, intact.

This nature of public opposition relating to hydraulic fracturing, however, has often been focused on two concerns about the process, though not entirely unique to it; these concerns are induced seismicity and the contamination of groundwater via the seeping of fracturing fluid and natural gas from fractures extending from the central borehole during the production phase of operations. This is distinct from the issue of flowback fluids, discussed later, which are a waste product of the process. Groundwater contamination is suggested as occurring during extraction at the point when fractures are being created and fluids to create pressure to support gas flow are pumped at high pressure into the well. There are, of course, other very real concerns that are raised within the locality of hydraulic fracturing sites, specifically those pertaining to the noise and increased traffic issues, as well as broader national and international concerns regarding the continued use of hydrocarbons and their role in human-induced climate change. The localised issues fall within the remit of the local planning authority, as has been outlined above.[11]As noise and traffic are concerns regularly handled by such authorities in relation to a broader range of industrial processes and operations, their regulation ought not, in the interest of procedural fairness, be treated any differently to those if we accept that the harm suggested as being done by noise and traffic is identical to that caused by any other loud process which requires increased traffic movement. Indeed, this was one aspect of the disputed and recently overturned and upheld decisions in Lancashire (*Preston New Road Action Group v Frackman*, 2017). As such, noise and traffic concerns will not be discussed here, for this would raise issues relating to the efficacy of local planning authorities more broadly to address noise and traffic issues, which is not a criticism the piece seeks to raise (Task Force on Shale Gas, March 2015).

While not wholly unfounded, public concerns regarding induced seismicity and groundwater contamination (by natural gas or fracturing fluids) arising from the permeation of fractures into aquifers have tended to be incorrectly focused. This – perhaps bold - claim is based on the risks of hydraulic fracturing identified by

[11] The applications in question were refused and subsequently overturned or deferred by the Secretary of State for Communities and Local Government). See, DECC (2012) and DECDC (2013)

emerging and established research into the process. The issue of induced seismicity has given rise to arguably the greatest victory to date for those who have opposed the practice in the UK; namely, the moratorium on activity seen in Lancashire from April 2011 to December 2012 following verified reports from members of the public of tremors caused by exploratory drilling activities (de Pater and Baisch, 2011). The first point of note here should be that, much as the current positions in Wales and Scotland, this was a moratorium until the presentation of further data collected by enforced monitoring.[12]It was not, as was often and popularly portrayed, a ban on hydraulic fracturing activities. Further to this, the seismicity felt was of an order of magnitude so small as to fit well within established limits placed over other types of industrial projects, including quarry blasting to which a comparison is made by Westaway and Younger (2014).

The monitoring of seismicity within the area surrounding a borehole has become a part of the process of receiving planning permission for even an exploratory drilling site.[13]Indeed, somewhat ironically, one of the most contentious planning applications relating to the process of hydraulic fracturing pertains to the establishment of a seismic monitoring station (LCC/2014/0097, 2014). The British Geological Survey (BGS), The Royal Society, The Royal Academy of Engineering as well as the recently disbanded Department for Energy and Climate Change have all concluded that induced seismicity as a result of hydraulic fracturing is able to be mitigated and that regulation and monitoring of sites is sufficient to avoid any harm to residents. Recommendations were however made by the BGS and DECC to apply existing monitoring regulations in a manner bespoke to the process of hydraulic fracturing rather than proposing more stringent new regulation (DECC, 2014 and Task Force on Shale Gas, July 2015). The aim of these suggestions is to enhance the monitoring of certain data indicative of risks suggested as arising from, or enhanced by, hydraulic fracturing. Monitoring of this type assesses both of the two potential sources of such induced seismicity, first from initial fracturing and second, where applicable, from the storage of by-products from the process in the wells once they have been exploited.[14] Both are regarded as satisfactorily mitigated by the existing regime (The Royal Society and The Royal Academy of Engineering, 2012), and yet the bespoke approach to monitoring proposed (by both the BGS and DECC) in the form of a so-called traffic light monitoring system has been adopted by the industry (UK OGA, n.d.). As such, despite the satisfactory nature of existing provisions and a 'negligible'(The Royal Society and The Royal Academy of Engineering, 2012, pp.4) risk in this regard, concerns have been raised and rather than quelled by the presentation of existing data and information (Cuadrilla Resources, n.d.), met with proposals for reform and demands for increased monitoring which has been implemented at the controversial sites in Lancashire discussed above ((The Royal Society and The Royal Academy of Engineering, 2012).

This is somewhat understandable as the very notion of 'fracturing,' even in an etymological sense, conjures images of an activity that is, for example, harmful and destructive. As such, it does draw the focus and ire of those seeking to halt the use of the process and might consequently demand regulatory responses

[12] The Scottish Parliament voted to ban the practice in a debate on broader environmental policy, but this does not bind the Scottish Government, whose policy is at present a moratorium until further information is available.

[13] Such monitoring both forms part of and must be approved by the MPAs within the local planning permission systems outlined above.

[14] This also presents risks with regards to groundwater contamination to be discussed later.

which address this perception (Evensen et al. 2014). Studies into the perception of risk in this area specifically suggest that the influence of imagery and wording which resonates with an individual can have a disproportionate impact on risk perception (Goidel and Climek, 2012). In particular, the mere use of the term 'hydraulic fracturing' elucidates different perceptions of risk to, say, 'natural gas extraction.' The authors do not seek to suggest that this is an unreasonable or indeed avoidable reality, but merely that its potential influence on regulation must be recognised. Humans have, it should be noted, been breaking open the earth and utilising natural resources for millennia, and have taken great strides in monitoring the impacts of such actions. Indeed, we can measure the relative impact of hydraulic fracturing to some degree as seismological data has been being collected in the regions where commercial sites might be set up for decades. Thus, we have some baselines against which to compare data collected before, during and after extraction to constantly assess the impacts thereof, and can form the basis of ongoing and increasingly thorough local and national monitoring of the processes (BGS, n.d.).

Firms are encouraged to establish pre-operation baselines, prior even to exploratory drilling, to reassure external stakeholders with regards to the safety of the process (Task Force on Shale Gas, July 2015). As has been noted above, and similarly to increased noise and traffic arising from hydraulic fracturing, seismic impacts of the extraction and exploration processes are not different to those caused by other types of industrial process, and for which there are existing means of regulation and monitoring.[15]As Holloway and Rudd (2013, pp.2)point out: 'a great deal of analysis indicates that the most significant environmental risks attributed to fracking are similar to risks long associated with all drilling operations.' As such, to treat them differently, owing to the practice inducing them alone may be similarly regarded as procedurally unfair should no unique risk in this regard justifying such differentiation be evidenced. Instead, any regulation of hydraulic fracturing ought to be imbued with the same limitations and standards for monitoring seismicity as other industries. In spite of this, limits set for seismic activity induced by hydraulic fracturing are far more stringent than those applied to other mineral and hydrocarbon extraction processes, such as quarries (Westaway and Younger, 2014). These more stringent baselines are what are proposed as the basis for a traffic light monitoring system of seismicity arising from a hydraulic fracturing industry in the UK. This suggests an, if anything, cautious approach to induced seismicity arising from drilling and fracture induction (de Pater and Baisch, 2011). This precautionary approach is arguably warranted by the perceived novel nature of the process, and the intensification of its use, but in essence the bespoke monitoring and regulation regime is emerging for an unlikely and sufficiently mitigated, yet high profile risk of hydraulic fracturing.

The risk of the contamination of groundwater sources from the extension of fractures created into underground aquifers (and aligned impacts) is arguably one of the most documented public concerns. Indeed, the concern is the subject of graphic video footage of tap water being ignited in the US in areas proximate to hydraulic fracturing sites. This has become emblematic in opposition movements of the dangers of the practice (Faucet Water Ignites!, 2010). And this, coupled with the emotive nature of the contamination of such a fundamental resource,

[15] Induced vibration is recognised as a statutory nuisance under Environmental Protection Act 1990 c.43 s.79(7) and the monitoring of seismicity in the UK has classified incidents as anthropogenic (i.e. induced) since 1970, a classification which includes that caused by industrial extraction activities.

makes the potential for such harm understandably the target of considerable vitriol. But again, the scientific research in this area suggests that although the potential for the seepage of contaminants exists, the likelihood of being the result of escapes from unexpectedly extended fractures created to access gas, is low. Indeed, mapping technology to assess the dimensions of fractures pre- and post-operations has been in existence for over two decades, and underpins both assessments of commercial viability and environmental safety (Speight, 2016, pp.129). This assessment of risk by science and industry is not based on the fact that such an eventuality is impossible, indeed it undeniably is and is accepted as being regardless of likelihood (Davies et al. 2012 cited in Task Force on Shale Gas, July 2015). It is instead based on the volume of research and monitoring that firms undertake both prior to and throughout the extraction process. A factor often omitted in the polarised discourse surrounding the controversial process is that licensed companies have a vested interest in avoiding harm to the environment beyond any inevitable impacts. Even if this is seen in a reductivist manner as only based on the motivation of avoiding litigation, to ignore it entirely would be remiss. Investment is being made into research to improve modelling techniques and to address the heterogeneity of wells and sub-surface strata, despite current methods being accepted as sufficient by regulators (Nejadi et al. 2017). Whilst this is also to assess viability of the wells and ensure they are operated as efficiently as possible for economic reasons, this has the direct consequence of providing considerable data on the extent of fractures created and the materials and features into which they extend, which regulators could assess to improve environmental monitoring.

Whilst such modelling does not eliminate the risk entirely, it is certainly mitigated to a degree regarded as sufficient to meet requirements placed over the industry by the relevant regulatory authorities.[16] Arguably the most comprehensive collection of research using operational data in this area, represented by the US Environmental Protection Agency, outlines that whilst risks exist they could be 'prevented or reduced' without the necessity of halting all operations (US EPA, 2016). Specifically in the UK, even the most contested MPA decisions regarding the practice, those in Lancashire on the Fylde Coast, concluded that in regards the consequences of fracturing to induce gas flow, 'Whilst the concerns [over groundwater contamination] are understandable it is concluded that they cannot be supported' (LCC/2014/0097, 2014). Both UK and US regulators therefore stipulate that while efforts to continue reducing accepted risks should be maintained, the current level of risk does not support the ceasing of all activity of this type. Again, therefore, regulation and precaution in place is regarded as sufficient to address the risks presented by concerned groups. Despite this, continuing improvement of both monitoring and understanding of the processes involved and their impacts is suggested by regulators and is being enacted by industry.

The means of measurement and monitoring of fractures created is documented in a Hydraulic Fracturing Programme for each well which, industry guidelines suggest, should also contain a map of the fractures that are predicted to be made. Although far from an exact science (Bommer et al, 2015, pp.643),[17]coupled with

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[16] The Environment Agency in England, Natural Resources Wales, or the Scottish Environmental Protection Agency.

[17] 'Although uncertainties in such models will generally be high, an advantage is presented in the case of induced rather than natural seismicity, namely that new data should become available as operations proceed, thus allowing frequent updating of the risk model with better constraints.' (Bommer et al. 2015)

existing protections afforded by the Environment Agency, these 'programmes' provide a means by which to measure the accuracy of predicted impacts to the subsurface environment. They also provide the ability to assess whether existing measures are sufficient to mitigate the risk of the migration of fracturing fluid to groundwater sources.[18] Essentially, they provide a self-declared baseline for monitoring of the extent of fractures. While scepticism might abound as to the intentions of such self-declared programmes, rather than them being imposed by a regulatory body, two factors should be considered.

Firstly, extractors ultimately possess the greatest quantity of data relating to extraction processes based on hydraulic fracturing and the boreholes they necessarily create and exploit. This may have the advantage that the cost, both financial and otherwise, of establishing the baseline for monitoring is borne by them in the process.

Secondly, extractors are encouraged to submit the programmes in relation to each borehole drilled, and indeed have done so for the most part.[19]Given that this is arguably one of the most controversial modes of resource extraction in the world at present, the incentive for extractors to portray a positive image both in terms of human health and safety as well as the environment, is likely to be significant. However, the incentives to submit accurate projections of the extent and impact of fractures created go beyond their influence on public relations based on perceived honesty and transparency. They also provide a measure of technical ability and are fundamental in the securing of current and future planning permissions for extraction sites. Indeed, the initial licensing of a project, and retention thereof, as well as the securing of licences for other projects demand continued demonstration of this technical competency. Such competency may also form an aspect of acquiring planning permission for a specific site from local authorities. This is particularly crucial at present, for no commercial extraction sites exist in the UK. Thus, accurately forecasting, and remaining within, the projected impacts of exploration sites will be indicative of the likelihood of being able to do so in larger scale commercial projects. They are, put simply, a measure of competence. Similarly accurate mapping of geological conditions is inextricably linked to the productivity of wells and thus the viability of any project an extractor might undertake. For these reasons, amongst others, extractors are already adequately incentivised to monitor and limit their activities to such an extent that, as a direct consequence, they mitigate any harms arising from fractures created and control their extent and direction to the greatest degree possible. To suggest therefore that this area presents the greatest risk of the hydraulic fracturing process, as many public interest groups do, is ignoring the aligned interests of both themselves and extractors as well as significant monitoring already in place.

3.2 Expert and Scientific Concerns

Hydraulic fracturing on a scale to support the extraction of previously untapped oil and gas resources does bring with it concerns which research suggests need greater monitoring and regulation than has, as yet, been provided or outlined for

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[18] Note should be taken that the provision of protections under the Infrastructure Act 2015 discussed above for operations conducted below 300m depth, also ensure firms are highly unlikely to risk operating above this level, would need an even greater range of permissions and be unlikely to be awarded a licence to do so. As a consequence a further safeguard (although indirect) is present.

[19] Note that some licences taken up have not reached the point of attempting to obtain planning permission from local authorities and as such to suggest all extractors do so would be remiss.

the future in the UK. Note should be made here that scaling any project to commercial extraction levels has the potential to bring about previously unseen impacts; however, to refuse permissions and licences on this speculation would place restrictions on industry generally which would have considerable social and economic impacts.[20]Indeed, environmental law and regulation stemming from it has long accepted the reality that it impossible to fully predict outcomes of industrial processes, the precautionary principle is based upon that acceptance. Arguably the largest concern in relation to scaling up of projects raised by the various bodies which have conducted scientific research into the impacts of hydraulic fracturing on a commercial scale surrounds the management of its by-products. Also from within industry, '[a] range of stakeholder groups in shale gas development have identified…storage of flowback and produced water constituents and the potential for leakage into surface water and groundwater as priority risk pathways to be addressed by further government regulations or industry voluntary actions' (Kuwyama et al. 2017, pp.582). As such, the storage of so called 'flowback water' (Jiang et al. 2013) is one of the most serious concerns of scientific experts considering the broad environmental impact of hydraulic fracturing on a scale supportive of commercial gas extraction in the UK.

Flowback water has been suggested as having carcinogenic, toxic and developmental effects (Yao et al. 2015). However, the composition of fracturing fluid and thus the resultant flowback fluid can vary significantly. Indeed, 'the exact composition of fracturing fluids remains unknown' (Elliot et al. 2016, pp.1.) in many of the studies undertaken as they were conducted in the US where their contents are often classed as confidential commercial information. The UK regulatory system at present demands the submission of the contents of fracturing fluids to the relevant authorities,[21]and as such independent research could be conducted into such impacts without this barrier. However, even a US report suggesting the carcinogenic impacts of this by-product concludes only that research be used to, 'identify early warning indicators of exposure and effect, and to identify suitable remediation approaches,' (Yao et al. 2015, pp.129) rather than cession of the practice altogether. Even the locally rejected and recently governmentally overturned application in Lancashire by the Development Control Committee concluded that, 'these concerns [including hydrogeology, water resources and broad public health] are very low risk if regulated properly…such impacts would be low or could be mitigated and controlled by condition' (LCC/2014/0096, 2014, pp.56-57).

The safety of the fracturing fluid pumped into the well to open and maintain fractures itself therefore is agreed as a factor which can be controlled within current regulatory frameworks. A void which does exist however pertains to the storage and disposal of waste which cannot be reused.[22] The solution used in many US projects (Clark and Veil, 2009) is an area of concern for science and public opinion (Vaughan and Pursell, 2010) alike, and one in relation to which at present the regulatory framework is exposed as arguably being less prepared than it might. This is the process of deep injection of flowback fluids, which involves its disposal in abandoned wells. Deep injection differs considerably from the

[20] This would also arguably conflict with the approach taken in similar instances of other emergent industries where risk cannot be fully ascertained but a precautious permission is given.

[21] At present any hydraulic fracturing operation in the UK must submit the composition of its proposed fluid for use to the relevant environmental regulator, the Environment Agency in England, Natural Resources Wales, or the Scottish Environmental Protection Agency.

[22] Note should be made that a considerable amount of flowback water can be reused in the continued operation of a well, but that as well productivity falls, the opportunity to do so does also.

process of fracturing to stimulate gas flow in terms of its impacts upon the subsurface geology surrounding a well (Frohlich et al. 2011 and Ellsworth et al. 2013). The duration of pressure exerted on the fractures created initially and the permanent presence of flowback fluid within the abandoned well alter the risks this process presents from those which necessitate it. As such the monitoring of abandoned wells utilised in this manner and indeed their broader regulation must reflect the distinctive characteristics of this activity from those of the production and exploration phases and detail the assigning of liability for integrity failures which at present, they do not (Task Force on Shale Gas, July 2015). This is owing in part to the present interpretation of European Union legislation by the Environment Agency as meaning they could not at present issue a licence for this practice based on available data. However the Second Report of the Task Force on Shale Gas suggests extraction on a commercial scale might necessitate it, where geological conditions suit (Task Force on Shale Gas, July 2015, pp.11). Avoidance of the technique must be balanced with the considerable costs of the alternative approach to flowback fluid disposal involving transport, treatment and disposal at other sites. Such a process would inherently bear its own considerable risk and as such increases the likelihood that the viability of this option will be reconsidered should commercial extraction ensue in the UK.

The major challenges with regards to regulating waste fluid storage and disposal are the inevitable variance in quantity and composition of fluids between sites as well as the geologies into which they are injected and thus what monitoring of abandoned sites should be carried out[23] This is further complicated by the potential for 'green completion' of wells to be made mandatory, as it is within some US jurisdictions. This is the process of extracting gas and other hydrocarbons from the flowback fluid for storage before then sending the remnants to be processed. At present, the regulatory system in the UK allows for extractors to adopt individual measures for disposal and green completions are not mandatory. The use of deep injection to dispose of flowback fluids, whether subsequent to green completion or not, has been suggested as being allowed only where the geology of the abandoned well being utilised is deemed suitable (Task Force on Shale Gas, July 2015, pp.12). This adds a further layer of complexity to any regulation of hydraulic fracturing as a means of commercial extraction. The combination of both lacking data on the content (and potentially wide variance thereof) and prescribed procedure for disposal suggest that a bespoke measure for the process might be necessary in the future. Unlike noise and traffic impacts and induced seismicity discussed above, there is significant potential for effects idiosyncratic to hydraulic fracturing here, and for which existing regulation in the UK surrounding wastewater from industrial processes might need amendment to suit deep injection disposal if permitted. The suggestion is not that capacity to treat wastewater is lacking, but that the regulation of that treatment might require adaptation. This is owing to the inherent variability in fluids within the industry used to create the fractures and in the composition of subsurface strata both of which can vary from well to well, with firms even opting to vary the former dependent on the latter.

It should be noted at this stage that induced seismicity caused by deep injection is of greater concern to those studying the industry as a whole than that caused

[23] This is a particular concern given the structure of the emergent UK industry where many small companies often are involved with a single licence and no regulation at present exists assigning responsibility for wells abandoned by companies which later cease to operate.

during the creation of fractures to induce gas flow (Ellsworth et al. 2013). This is because the injection of flowback fluid into abandoned wells involves high and sustained pressure into an already fractured subsurface. Suggestions that the two sources of seismicity should be addressed in an identical way are, however, rebuffed. '[T]here has been a degree of 'cross-contamination', whereby concerns regarding one particular source of induced seismicity has led to increased public, regulatory and media attention on all anthropogenic causes of earthquakes, with the concomitant blurring of the specific technical issues in each case' (Bommer et al. 2015, pp.623). As such, there is arguably a danger that the conflation of the two could cause the regulation of one or both to be weakened as a result. Put simply, seismicity induced by initial fracturing to permit the flow of gas to a central well is mitigatable but not avoidable if an industry is to proceed. By contrast that induced by deep well injection is avoidable in its entirety by mandating that this means of disposal is not permitted. As such to suggest an even treatment of these sources based on their shared outcome would be a negligent assessment of them and the appropriate manner to address them.

Public concern is focused on the potential immediate impact to groundwater of the extraction process and the risk of induced seismicity caused by it. However, these fears are not substantiated once taken in light of regulatory responses to scientific evidence. This cannot however be said of the less prominent fears surrounding flowback fluid and its disposal. This is somewhat understandable as the treatment of quantities of flowback fluid is a consequence of commercial scale extraction, of which there is at present no example in the United Kingdom. As such, public concerns over impacts to water have focused on those suggested as arising from processes common to both test and commercial scale operations. Given that test operations are inextricably linked to production operations however, both concerns ought to be considered by all stakeholders and, where necessary, be subject to necessary regulation beyond that already in existence. The divide in concerns to which further regulation might be applied can in short be summarised as perceived and scientifically supported assessments of risk. This is not to say that the risks of groundwater contamination and induced seismicity at the instance of fracture creation are zero, but that measures to mitigate them are available and indeed prescribed within the current regulatory framework. The measures put in place are of course benefited by the availability of data and methods supporting their monitoring and mitigation either as a response to existing concerns or as a result of other industrial and regulatory processes. Risk assessments might suggest preferred or prospective solutions to the issue of flowback fluid management and well abandonment. However they do not prescribe regulated methods or standards to be achieved, or assign a monitoring body for them.[24] As such one of the major scientific concerns in relation to hydraulic fracturing is yet to be addressed and is not a focus of public concern when it perhaps ought to be. The risk may not materialise into an impact, but much as the precautionary principle dictates that regulation need not adapt to some concerns raised in relation to the process where that risk is so unlikely or the potential harm negligible, it equally dictates that for recognised and unmitigated risks, it ought to. Two key challenges exist therefore for regulators and firms in this emerging industry. The first is how to justifiably distinguish between commonly held but erroneous concerns and those supported by scientific evidence but which lack public awareness. The second is how to appropriately

[24] The question here is whether a well utilised for deep injection of flowback fluid, if permitted, would be subject to the same monitoring as an abandoned well which was not.

address both concurrently within a regulatory framework in order to garner the support and confidence of industry and external stakeholders for it.

4. Final Comments

We have considered in this article some recent debates and issues around hydraulic fracturing. The discourse to an extent can be regarded as symbolic of the power struggles that exist over the development of new industrial areas and of the struggles between political protest and what is often seen as the interests of big business and big government (Bennie, 1998). Yet, we can also see how discourse can become selective and skewed. We have considered how different stakeholder groupings, and particularly civic and scientific groupings, have tended to target their concerns at different issues. We have seen that the more prominent civic remonstrations have been targeted at those processes and issues where the regulatory regime is more established, and possibly more robust. On the other hand the far less high-profile concerns, which have tended to be the focus of concern the focus for the scientific community, relating to areas such as flowback appear to be less well established from a regulatory point of view, and may become problematic if hydraulic fracturing is developed on an industrial scale. There appears a strong distinction between what civic groups and scientific groups highlight as the concern with the process. But what has never really been shown in these debates is that where the regulatory framework is concerned, the civic concerns have not taken into account the extant legal regime.

What we need to be mindful of is what this means from a regulation and policy perspective, and of the dangers of allowing important issues to be sidelined. What, if any, are the implications for future and further policy developments in this area? We also need to be mindful of the wider ramifications and the relationships between campaign groups, the scientific community, and the policy and regulatory community. Perhaps one implication is that, due to how arguments have been presented, and due to some claims appearing to be more prominent than others, the wider public may have a mistaken view of the hydraulic fracturing process as well as of the security around different aspects of the procedures used. In particular, those concerns that may be more acute to hydraulic fracturing tend to be overlooked in protests, and yet this is where there might be a need for open and transparent discourse and debate. It could be posited that this says something about the nature of protest: that those who organise protest will design and manage their campaigns around those issues that resonate with their intended and target audiences. There is a certain cognizance and proximity over issues around seismicity, noise and traffic that is not necessarily true of other concerns around the process. As such, their focus on concerns that appeal to a non-expert audience is perhaps understandable when these concerns are the ones that are likely to mobilise the support of large numbers of people. It may of course be that noise and smell are, so to speak, more publicly emotive issues than the more difficult to understand and absorb issue of, say, flowback. Narrowly construed concerns surrounding water contamination from seepage during the extraction process are also often more apparent in campaigns opposing the process. By contrast, it may be that the lack of commercial scale extraction results in a lacking evidence base for concerns on the flowback the process would produce. But the outcome of these issues is the potential that the wider public is receiving a skewed view of where the risks of hydraulic fracking may lie. As a result, important aspects of the debate may be hidden.

What we appear to be seeing, however, which we have seen before with events surrounding Brent Spar, (Bennie, 1998) is that campaigns are capable of having a narrowing, and possibly even misleading, impact on discourse and responses thereto. And as has been pointed out by Bennie in her analysis of the Brent Spar saga, while the industries have acknowledged the importance of democratic legitimacy of gaining the public's trust, it may still be the case the people trust environmental and community groups more than politicians or industry (Bennie, 1998). If this remains so, then there is danger that we may be creating unnecessary fear in one area while simultaneously underplaying problems in another. What may be needed, of course, is a more balanced public debate and more participatory activity where the potential regulatory weaknesses reside. But there are further issues stemming from discourse surrounding the hydraulic fracturing debates. To create proper legitimacy around the process, there may be a far greater responsibility on the part of industry, who hold greater knowledge of the process themselves, to allay those concerns without losing focus on the concerns omitted or less common in civic campaigns. The argument is therefore not opposed to the wide ranging regulatory literature on the 'framing' of hydraulic fracturing in policy discourse (Hilson, 2015), indeed it embraces the challenges it poses and suggests that these alternative perspectives should be recognised, but should not distort the regulatory framework to reflect that which science does not support to the detriment of that which it does. The evolution of regulation must strike a balance between concerns of these often conflicted and diverse groups. It seems the case that this conflict cannot be resolved solely through the presentation of facts and expertise, owing to a plethora of factors influencing perceptions into which research has been conducted (Boudet et al. 2014). However, it is essential to incorporate both into any regulatory process which aims to be commonly regarded as both *scientifically effective and publicly legitimate*.

5. References

Andersson-Hudson, J. Knight, W. Humphrey, M. and O'Hara, S (2016) Exploring support for shale gas extraction in the United Kingdom. *Energy Policy* 98. pp. 582–589.

Bennie, L.G. (1998) Brent Spar, Atlantic Oil and Greenpeace. *Parliamentary Affairs* 51(3) pp.397-410.

Bommer, J. Crowley, H. and Pinho, R. (2015) A risk-mitigation approach to the management of induced seismicity. *Journal of Seismology* 19(2) pp 623–646

Boudet, H. Clarke, C. Bugden, D. Maibach, E. Roser-Renouf, C. and Leiserowitz, A. (2014) Fracking controversy and communication: using national survey data to understand public perceptions of hydraulic fracturing. *Energy Policy* 65. pp.57–67

British Geological Survey. *Earthquakes in the UK.* Available at: <http://www.bgs.ac.uk/discoveringGeology/hazards/earthquakes/UK.html> [Accessed. 10th March 2017]

Bryden D. Nierinck, J. and Parish, R (2014) UK Shale Gas: Mapping the Current Regulation and Legal Landscape. *Environmental Liability* 1 pp.28-40.

Council Directive 2011/92/EU of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment

Clark, C.E. and Veil, J.A. (2009) *Produced water volumes and management practices in the United States.* Environmental Protection Agency (US). Available at: <https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/2080370> [Accessed. 10th March 2017]

Climek, M., Brou, L., Means, M., Goidel, K. (2013) *Fracking and Polarization of Public Opinion* Available at: <https://sites01.lsu.edu/wp/pprl/files/2012/07/National-Fracking-Report-7-24-13-Public-Policy-Research-Lab-at-LSU.pdf> [Accessed. 10th March 2017]

Cuadrilla Resources. (2017) *E-Portal for our Preston New Road exploration site.* Available at: <http://www.cuadrillaresourceseportal.com/> [Accessed. 10th March 2017]

Davies, R. J. Mathias, S. A. Noss, J. Hustof, S. and Newport, L. (2012) Hydraulic fractures: How far can they go? *Marine and Petrol. Geol.* 37 pp.1-6.

Delebarre, J. Ares, E. and Smith, L. *Shale Gas and Fracking* House of Commons Library Briefing Paper SN06073, 25 June 2015.

Department for Communities and Local Government, (2012) *National Policy Framework* London. Department for Communities and Local Government.

Department for Communities and Local Government. (2014) *Planning Practice Guidance: Minerals* London. Department for Communities and Local Government.

Department for Communities and Local Government (2013) *Planning Practice Guidance for Onshore Oil and Gas.* London. Department for Communities and Local Government.

Department for Energy and Climate Change (DECC), (2015). *Onshore oil and gas exploration in the UK: regulation and best practice* London. Department for Energy and Climate Change.

Department for Energy and Climate Change (DECC), (2014) *The Unconventional Hydrocarbon Resources Of Britain's Onshore Basins- Shale Gas*. Department for Energy and Climate Change

Douglas, M. and Wildavsky, A. (1982) Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers. Berkeley. UNIVERSITY OF CALIFORNIA PRESS.

Elliott et al. (2016) A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity. *Journal of Exposure Science and Environmental Epidemiology* 27(1) pp.90-99

Ellsworth, W. L. et. al. (2013) Injection-Induced Earthquakes. *Science* 341(6142).

Energy Act 1976 c.76 London. HMSO.

Environmental Protection Act 1990 c.43. London. HMSO.

Evensen D, Jacquet J, Clarke C, Stedman R. 2014. What's the 'fracking' problem? One word can't say it all. *The Extractive Industries and Society*, 1, pp.130-136.

Faucet Water Ignites! Natural Gas in Well Water! (2011) Available at: <https://www.youtube.com/watch?v=PRZ4LQSonXA> [Accessed. 10th March 2017]

Frack Free Lancashire. *Frack Free Lancashire.* Available at:< http://frackfreelancashire.org.uk/cms/> [Accessed. 10th March 2017]

Frack Off: Yorkshire. *Frack Off: Yorkshire.* Available at:< frack-off.org.uk/region/Yorkshire/> [Accessed. 10th March 2017]

Friends of the Earth UK. *Fracking in the UK* Available at: <www.foe.co.uk/ fracking> [Accessed 10th March 2017]

Frohlich, C. Hayward, C. Stump,B. and Potter, E. (2011) The Dallas-Fort Worth Earthquake Sequence: October 2008 through May 2009. *Bulletin of the Seismological Society of America* 101 pp. 327–340

Goidel, K. and Climek, M. (2012) *Louisiana Survey: Full Report.* Available at: <https://sites01.lsu.edu/wp/pprl/files/2014/07/LA-Survey-2012.pdf> [Accessed. 10th March 2017]

Greenpeace UK. *Fracking in the UK. No thanks!* Available at: <www.greenpeace.org.uk/climate/fracking> [Accessed. 10th March 2017]

Hilson, C. (2015) 'Framing Fracking: Which Frames Are Heard in English Planning and Environmental Policy and Practice? *Journal of Environmental Law* 27 (2) pp.177

Holder, J. and Lee, M. (2007) *Environmental Protection, Law and Policy: Texts and Materials.* 2nd ed. Cambridge. CAMBRIDGE UNIVERSITY PRESS

Holloway, M and Rudd, O. (2013) *Fracking the operations and environmental consequences of hydraulic fracturing.* Beverley, MA. SCRIVENER PUBLISHING (WILEY).

Infrastructure Act 2015. c. 7. London. HMSO.

Jiang, Q. et al. (2013) Application of ceramic membrane and ion-exchange for the treatment of the flowback water from Marcellus shale gas production. *Journal of Membrane Science* 431. pp. 55–61

Kutchin, J. (2001) *How Mitchell Energy & Development Corp. Got Its Start and How It Grew: An Oral History and Narrative Overview* Updated ed. Boca Raton FL. UNIVERSAL PUBLISHERS.

Kuwayama, Y. Roeshot, S. Krupnik, A. Richardson, N and Mares, J. (2017) Risks and mitigation options for on-site storage of wastewater from shale gas and tight oil development. *Energy Policy* 101 pp. 582–593

Lancashire County Council (2014) *Planning Application LCC/2014/0096.* Available at: < http://planningregister.lancashire.gov.uk/PlanAppDisp.aspx?recno=6586> [Accessed. 10th March 2017]

Lancashire County Council (2014) *Planning Application LCC/2014/0097.* Available at: < http://planningregister.lancashire.gov.uk/PlanAppDisp.aspx?recno=6587> [Accessed. 10th March 2017]

McGowan, F. (2014) Regulating innovation: European responses to shale gas development. *Environmental Politics* 23(1) pp. 41-58.

Mining Industry Act 1926 c.28 London. HMSO.

Nejadi, S. Trivedi , J.J. and Leung, J. (2017) History matching and uncertainty quantification of discrete fracture network models in fractured reservoirs. *Journal of Petroleum Science and Engineering* 152. pp.21-32.

de Pater C.J. and Baisch, S. (2011) *Geomechanical Study of Bowland Shale Seismicity: Synthesis report.* Available at : <http://www.cuadrillaresources.com/wp-content/uploads/2012/02/Geomechanical-Study-of-Bowland-Shale-Seismicity_02-11-11.pdf > [Accessed. 10th March 2017]

Pearson, J. (2015) Hydrocarbon Hysteria: Differentiating Approaches to Consumption and Contamination in Regulatory Frameworks Governing Unconventional Hydrocarbon Extraction J.P.L 1(3).

Pedersen, O. (2013) Modest Pragmatic Lessons for a Diverse and Incoherent Environmental Law. *Oxford Journal of Legal Studies* 33(1) pp. 103–131

Petroleum Act 1998 c.17 London. HMSO.

Petroleum Licensing (Exploration and Production) (Landward Areas) Regulations. 2014 SI 2014/1686 London HMSO

Preston New Road Action Group v Frackman & Others [2017] EWHC 808 (Admin)

Speight, J. G. (2016) *Handbook of Hydraulic Fracturing.* New Jersey. WILEY 2016

Star Energy Weald Basin Limited v Bocardo SA[2010] UKSC 35

Task Force on Shale Gas. July 2015. *Assessing the Impact of Shale Gas on the Local Environment and Health (Second Interim Report)* Task Force on Shale Gas

Task Force on Shale Gas. March 2015. *Planning, Regulation and Local Engagement (First Interim Report).* Task Force on Shale Gas.

The Royal Society and The Royal Academy of Engineering (2012) *Shale Gas Extraction in the UK: A Review of Hydraulic Fracturing*. Available at:

<https://royalsociety.org/~/media/policy/projects/shale-gas-extraction/2012-06-28-shale-gas.pdf) pp.4 (Last accessed. 10th March 2017> [Accessed. 10th March 2017]

Town and Country Planning (Development Management Procedure) (England). (2010). SI 2010/2184. London HMSO

Town and Country Planning (Environmental Impact Assessment) Regulations (2011) SI 2011/1824. London HMSO

United Kingdom Onshore Operators Group (UKOOG). 2016. *UK Onshore Shale Gas Well Guidelines: Exploration and Appraisal Phase. Issue 4*. London. UKOOG.

UK Oil and Gas Authority. *Traffic Light Monitoring Infographic.* Available at: <https://www.ogauthority.co.uk/media/3153/infographic_traffic-light-system.pdf> [Accessed. 10th March 2017]

US Environmental Protection Agency (2016) *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States: Executive Summary.* Available at: <https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf> [Accessed. 10th March 2017]

Vaughan, A.D., Pursell, D. (2010) *Frac Attack: Risks, Hype, and Financial Reality of Hydraulic Fracturing in the Shale Plays.* Available at: <http://www.chemungcounty.com/usr/ACNE/Frac%20Attack%20Review.pdf> [Accessed. 10th March 2017]

Westaway, R. and Younger, P. (2014) Quantification of potential macroseismic effects of the induced seismicity that might result from hydraulic fracturing for shale gas exploitation in the UK. *Quarterly Journal of Engineering Geology and Hydrogeology.* 47 pp. 333-350

Williams, W. Macnaghten, P. Davies, R. and Curtis, S. (2015) Framing ‘fracking: Exploring
public perceptions of hydraulic fracturing in the United Kingdom. *Public Understanding of Science* 26(1) pp. 1–17.

Yao, Y. et al. (2015) Malignant human cell transformation of Marcellus Shale gas drilling flow
back water. *Toxicology and Applied Pharmacology* 288. pp.121–130.