Review Comment 1

Dear Dr Mark Ireland (Reviewer 1),

Thank you for your detailed and constructive review. We are glad that you agree that the paper is of broad interest to Earth Scientists and beyond.

Your technical comments will tighten up how we describe shale gas activities in our revised manuscript thank you. In your general comments you suggest a glossary of terms; we address this suggestion alongside our responses to your specific comments in the attached document.

Best wishes,

Jen Roberts (Corresponding Author)

Response to Reviewer 1, Dr Mark Ireland

In the table below, our response (in blue text) can be found beneath each of your specific comments and technical corrections (in black text) which we have numbered for ease of any further discussion.

Specific Comments	
1	Lines 39/40 - in the introduction the authors introduce the stakeholders and include 'scientists'. With specific reference to controversial geosciences, it may be useful to pick apart the different roles which scientists have in shale gas – for example, within industry, within academia, within the regulators. We will amend the text as you suggest. New text is "Effective dialogue between stakeholders, including academics, regulators, industry, policy makers and the publics, is crucial to tackle this challenge"
2	The authors introduce that many geoscience concepts and technologies are unfamiliar to the public (line 49/50), but it may also be relevant to discuss here the contrast between established and 'new' activities. To this extent a discussion of changes in perceived acceptance – what may have been acceptable in the past, is no longer socially perceived as acceptable (e.g. Beck et al. 1993) In Lines 49/50 we are specifically referring to geological concepts. However, we agree that (evolving) technologies and applications are also relevant to include in the Introduction. Rather than refer to 'new' technologies, we prefer to refer 'unfamiliar' technologies (since hydraulic fracturing approaches have been used for decades, c.f. James Verdon's Short Comment on this paper). Further, in this paper we are focussed on perceived risk – and not acceptable risk. However, we agree with the general point and in the Discussion section for our revised manuscript we will include discussion of how perceived risk can evolve through time, and can be influenced through factors such as those raised by Reviewer 3 (politics, motivation).
3	Authors introduce disputes in geoscience, however, do not include here mention of the Lusi mud volcano (e.g. Tingay et al., 2018) – which is highly relevant given that it was a source of both geoscience, community and political contention.

	We agree, the Lusi mud volcano is a relevant case study and will add the suggested reference to the text into lines ~56.
4	The use of 'geological engineering' throughout may possibly lead to confusion, particularly given the broad appeal of the paper. It may make sense to use 'geologist' and 'engineer' separately, particularly in the case of hydraulic fracturing, where the two areas of expertise have different roles. We will go through the text and separate into these disciplines where appropriate. However, geological engineering is a commonly used term that includes all aspects of subsurface engineering including those outwith hydrocarbon and production.
5	Line 82/83 - references 'the language in communicating shale gas extraction' – although this paper focuses on the language surrounding induced seismicity, it seems likely that 'shale gas' more broadly is thwart with many examples of 'bad language'. For example, even the use of the word 'extraction' in the UK context and to hydraulic fracturing could result in confusion. The authors could expand on what they consider the term extraction to encompass. Does this include all elements of the E&P lifecycle? Given that we are writing for an audience that included non-geoscientists we were trying to avoid industry-specific terms or jargon. We had implicitly included all E&P into 'extraction'. However in the UK, the focus was on shale gas exploration rather than extraction. In lines 82/83 we will change this to "exploration and development", and we will double-check the specific language used throughout the manuscript.
6	The article should consider expanding the description of hydraulic fracturing, and consider describing the range of different techniques, e.g. King (2012). The article could also differentiate between hydraulic fracturing and other well stimulation techniques. The addition of a diagram to illustrate the practice of hydraulic fracturing could also make the article more widely accessible. In Section 1.2 we will include further detail on the hydraulic fracturing process and history of in the UK, as also suggested by Dr James Verdon in the Short Comment.
7	Since specific reference is made throughout to induced seismicty in the UK, perhaps an examination of the language used in the Hydraulic Fracture Plans prepared by operators and provided to the OGA and EA could be included in the compilation of publicly available expert reports. We considered this too, in our original research. However, we opted not to examine the language within the HFPs in our research because - although publicly available - HFPs are not public-facing expert-led reports intended to conclude or advise on the risk of seismicity - they are a permitting requirement that lays out the anticipated seismicity and how it will be managed.
8	Line 145 - the term 'tight gas' is introduced and seems to be used to refer to shale gas. In the O&G industry, commonly the terms tight gas and shale gas are used to define different resources. tight gas commonly refers to a resevoir where the hydrocarbons are within a conventional scale pore space (e.g microns) but are not connected. Whereas in shale gas resources the pores are often nanometres scale, and, for example may include pore space within organic components of the shale,

	We will still give the example of 'tight gas' but include also specific reference to shale gas, so that the two are not confounded.
9	Line 154/155 – "not all seismic events have any detectable effect in terms of being felt, or recorded" – this statement could be expanded to include references, and to mention what the detection limits are for seismic events. We will add references to this sentence, but detection limits are not so simple, as the following paragraphs in the paper lay out.
10	Lines 156-167 – covers a discussion on quantifying seismicity. However, it would perhaps be appropriate here to discuss or make mention of other industries, such as quarrying, which have their limits set/defined by ground motion. We refer to other industries in the previous paragraph, see line 152 – 154, including citation of Westaway & Younger et al. (2014) which compare seismic limits for different industries.
11	Lines 173/174 – should the 'UK network' be defined? Are you referring to the BGS seismometer network? What is the detection limit of the dedicated surface arrays installed at the shale gas sites? We were referring to the detection limit laid out in Kendall et al. (2019) and also the BGS website, which indeed refers to the BGS seismograph stations. We will specify this in the text. For the detection limit of the dedicated surface arrays, this depends on factors outlined in lines 179/180, and so, similar to our response to Comment 9 in this table, it's not so simple as to give a number here.
12	Line 181/182 – Could you clarify if the induced seismicity is associated with HF or with the production, or both? This is an important distinction – we will clarify in the text.
13	Line 182/183 – "However, the largest recorded induced seismic events associated with shale gas extraction activities" – as previous, it might be worthwhile clarifying earlier in the paper where hydraulic fracturing sits within the context of shale gas extraction activities. See response to comment 6. We will refer to the recently published paper by Verdon and Bommer (2020), which documents other occurrences of hydraulic fracturing induced seismicity.
14	Line 213/214 – the technical expertise listed again includes 'disciplines' that might cause confusion. Geological Engineering – not a field or role common in O&G sector, Oil Field Services – would seem to be a catch all category, and could include petroleum engineer. See response to Comment 4 in this table. We are not sure how widespread knowledge of what 'oil field services' entails and so we will use this term but then specify geology, petroleum engineering, too.
15	Line 384/385 – "since hydraulic fracturing, by definition, will induce (albeit small) seismic events, it could be argued that assertions such as "shale gas development is associated with earthquakes" are factual" - are all seismic events earthquakes? what

	is the definition of the earthquakes? a section addressing individual scientific questions/ issues This sentence was also questioned by Dr James Verdon in his Short Comment. We will change the sentence to include caveat "depending on how 'earthquake' is defined".
16	Line 619 – 622 – perhaps it would be worthwhile providing definitions of these terms in a glossary of terms. Providing definitions of the terms you use. The problem here is that we cannot define the phrases that are used by the survey participants (who we are quoted in those lines). What is meant by the terms that they opt to use might differ from how we define them. It is therefore not appropriate to include these terms or our codes in a glossary. Clarifications to the text terminology that you (and the other reviewers) have suggested in your specific and technical comments, together with further detail on the HF process will tighten the language, thus removing the need for a glossary.
17	Line 656 – "much more decided on the topic than the UK general public" – referring back to the statement in the introduction that experts have a greater appreciation of uncertainty, this is an interesting finding, perhaps warrants discussion. We agree and will expand on this in the discussion, as you suggest.
18	Line 689 – It might be beneficial to introduce the concept of 'what constitutes an earthquake?' much earlier in the paper. In Section 1.2 we already introduce that a range of terms are used to describe seismicity, framed by the title of the Kendall et al (2019) paper 'how big is a small earthquake?'. We will raise the question 'what constitutes an earthquake?' more explicitly there.
Technical Corrections	
1	Line 52 – 'such uncertainty' – previous sentence does not specifically which uncertainty you are referring to. We will change this to make more specific ('uncertainty due to geological heterogeneity').
2	Line 70 - typo 'we explore the perception of and terminology' We will add oxford commas to make this sentence easier for the reader.
3	Lines 84/85 – examples of other causes of induced seismicity need references. We will add references (the same as those in Section 1.2).
4	Line 133/134 - Should include reference for moratorium/ suspension on fracking. We will add the BEIS reference which we use elsewhere in the article.
5	Lines 145 – examples of applications of hydraulic fracturing should include references. Are there examples of HF for water production? There are; we will add the references.

6	Line 148 – Davies & Cartwright, 2007 paper is not an appropriate reference here. We meant to cite a different Cartwright paper, but instead have replaced with Engelder & Lacazette (1990).
7	Line 168/169 – perhaps it should be clarified 'hydraulic fracturing' is one step in the extraction process. HF doesn't result in extraction, that still requires a pressure drawdown to create a differential. True. We will swap the wording to say "hydraulic fracturing for shale gas exploration and development". (see also response to General Comment #5).
8	Line 345 – missing close bracket - (micro-seismic events, seismicity, and earthquakes) Thank you. This will be rectified.
9	Line 698/699 – as Fig 1, TLS is OGA not UK Government. Thank you. We will change this.
10	Line 191 – should make it clear whether the '6 months following' is a 6 month moratorium, or 6 months after the induced seismicity. The sentence was missing the word 'for' which will clarify this.
11	Figure 1 caption– in the figure caption, it states that the traffic light system is from UK Government. The TLS is from the Oil and Gas Authority (OGA) and the OGA is a government owned company We will simply say 'the UK's TLS' rather than the UK governments.
12	Figure 2 caption – ": : :shale gas with earthquakes decreases, while the number of participants that: : :" should add in '2012-2014' to make it clear over what years. We will add this clarification to Figure 2 caption