Scottish Environment LINK

Unconventional Fossil Fuels Subgroup submission to the 'Understanding and Mitigating Community Level Impacts from Transportation' study under the Scottish Government moratorium on onshore oil and gas extraction

17 August 2016

1. General Comments

Scottish Environment LINK welcomes the opportunity to feed into the Scottish Government commissioned research programme under the current moratorium on onshore unconventional oil and gas (UOG) extraction. LINK members have called for a precautionary approach to shale gas, shale oil and coalbed methane development, and consequently welcomed the implementation of a moratorium on the industry in January 2015. This submission follows our participation in studies into economic impacts (KPMG), seismic activity (BGS) and decommissioning and aftercare (AECOM).

Transportation associated with UOG extraction has the potential to increase CO_2 emissions, air and noise pollution, disturb wildlife and result in loss of amenity to local communities. Many of these impacts overlap with issues identified in our written submission to the studies noted above and to the Public Health Impact Assessment.[1] It is unclear exactly how the various studies and PHIA overlap, but we would note the inter-relationships between these is critical to gaining a comprehensive understanding of the impacts of UOG extraction.

2. Vehicle movements associated with UOG

Vehicle movements can vary considerably in number and intensity during the lifetime of onshore unconventional oil and gas extraction. The stages of shale gas / oil and coalbed methane development typically include:

1. Construction of well pad and associated infrastructure
2. Well drilling and construction
3. Hydraulic fracturing / dewatering
4. Well completion / gas production
5. Well rehabilitation / secondary recovery
6. Well closure / site abandonment

The number and intensity of Heavy Duty Vehicle (HDV) movements will depend on certain variable factors including:

- whether shale gas, shale oil or coalbed methane is to be extracted
- the number of wells at each pad, and density of well pads
- the duration and timing of activities and the lifetime of a given well / pad
- the volume of water, chemicals and proppants required during hydraulic fracturing
- the volume of flowback fluid and produced water from a given well / pad
- whether wells are re-fractured

[1] http://www.scotlink.org/wp/files/documents/SE-LINK-UFF-Subgroup-submission-to-KPMG-BGS-AECOM-on-onshore-oil-and-gas-extraction.pdf

The US experience suggests a wide range of variability in these factors, related to the geology of the area in which hydraulic fracturing takes place. The Tyndall Centre's estimation of truck movements associated with key stages of shale gas extraction at a six-pad well, based on the US experience in the table below, provides a useful starting point for assessing traffic related impacts of UOG.[2] It is important to note that these figures do not include re-fracturing. Other assumptions are highlighted in the sections below.

Purpose	**Per well**		**Per pad**	
	Low	**High**	**Low**	**High**
Drill pad and road construction equipment			10	45
Drilling rig			30	30
Drilling fluid and materials	25	50	150	300
Drilling equipment (casing, drill pipe, etc.)	25	50	150	300
Completion rig			15	15
Completion fluid and materials	10	20	60	120
Completion equipment (pipe, wellhead)	5	5	30	30
Hydraulic fracture equipment (pump trucks, tanks)			150	200
Hydraulic fracture water	400	600	2,400	3,600
Hydraulic fracture sand	20	25	120	150
Flow back water removal	200	300	1,200	1,800
Total			**4,315**	**6,590**
...of which associated with fracturing process:			***3,870***	***5,750***
			90%	***87%***

Table 1: Truck visits over the lifetime of a six-pad shale gas well, from Broderick et al 2011[3]

2.1 Shale gas, oil or CBM

The traffic movements associated with shale gas, shale oil and coalbed methane will differ to a greater or lesser degree, most notably because coalbed methane extraction does not always require hydraulic fracturing, and therefore will not necessarily involve the high levels of HDV movements associated with transporting water requirements for that process. However, the industry in Australia anticipates that up to 40% of coalbed methane wells will require hydraulic fracturing to maintain productivity.[4] Further, the de-watering process that is used to de-pressurise coal seams and stimulate gas flow results in large quantities of produced water that will require transportation to specialist treatment and disposal facilities.

2.2 Number and density of wells

While the SEA of DECC's 14th licensing round works on the assumption of an average of 2 wells per shale gas pad,[5] pads with between 6 and 12 wells appear to be standard practice in the US today.[6]

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[2] Broderick et al. *Shale Gas: an updated assessment of the environmental and climate change impacts* 2011 The Co-op, p29 http://www.tyndall.ac.uk/sites/default/files/coop_shale_gas_report_update_v3.10.pdf

[3] Ibid. It is not made entirely clear in the Tyndall report whether a 'truck visit' involves both the outward and return journey to a site, but for the purposes of our assumptions in part 3.1 we have assumed it does.

[4] Australian National Greenhouse Accounts, Coal Seam Gas Estimation and Reporting of Greenhouse Gas Emissions 2012, http://www.climatechange.gov.au/climate-change/emissions/~/media/climate-change/emissions/factsheets/NGA-FactSheet-7-CoalSeamGas-20120430-PDF.pdf

[5] 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

[6] Goodman et al Investigating the traffic-related environmental impacts of hydraulic-fracturing (fracking) operations, ReFINE Feb 2016, http://ac.els-cdn.com/S0160412016300277/1-s2.0-S0160412016300277-main.pdf?_tid=5553530e-5a4a-11e6-aac2-00000aacb361&acdnat=1470318778_7320e92c51ad104530af975c15aff543

Cuadrilla's applications for hydraulic fracturing at Preston New Road and Roseacre Wood are for 4 wells at each of two pads, though the company has indicated their pads would generally have 10 wells;[7] Ineos indicate its plans would involve 10-12 wells per pad or more,[8] and therefore potentially double the number of HDV visits in Table 1. The number of wells per pad will impact on the size of the pad, with larger pads for multiple wells[9] and therefore to some degree on site construction and abandonment traffic. Where drilling and operation of multiple wells at a single site and between sites overlap, the impact of traffic movements is intensified. It is unclear how dense shale gas or oil drilling operations might be in the Scottish context and therefore what the cumulative traffic impact on communities could be. Ineos has, confusingly, variously indicated both a density of approximately 50-60 wells across 100 sq km, as well as 200 wells across the same area, with a potential total of 1,400 wells across approximately 700 sq km.[10] According to Broderick et al, *"Local traffic impacts for construction of multiple pads in a locality are, clearly, likely to be significant, particularly in a densely populated nation such as the UK."*

2.3 Duration of activities and lifetime of wells

The lifespan of a well can vary between 5 and 20 years. The duration and timing of activities during key stages, e.g. the hydraulic fracturing process, and whether they overlap with other activities, e.g. the drilling or re-fracturing of another well at the same pad, or the development of another pad nearby, will have a significant impact on the intensity of traffic movements in a particular area. According to ReFINE Consortium researchers at Newcastle and Durham universities:

"…total operations for [a] six well pad…would span between 500 and 1500 days. However, the peak of HDV demands occur in the delivery of water and proppant between 30–60 days prior to commencement of fracking, with flowback fluid return occurring for 42–56 days after.

"Transport demands may be complicated by the overlapping of phases between individual wells on a pad (e.g. water deliveries occurring during horizontal drilling), or by operation of multiple well activities in parallel (though actual drilling of more than two wells simultaneously is considered unlikely… Phases themselves may overlap in time, both between individual well pads and wells, as well as internally, between activities at a specific pad or well. For example, hydraulic fracturing may be taking place at one well, whilst another well is being drilled, and flowback water is being removed from a third. Likewise flowback water removal may begin whilst a well is still in the process of being fractured."[11]

That study emphasised that the total number of traffic movements over the whole lifetime of a well or pad, can give a misleading impression of the impact of the UOG industry as compared to other developments, since the impact will be concentrated over relatively short periods of intense activity, and repeatedly so:

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[7] Broderick et al p 16

[8] http://www.ineos.com/businesses/ineos-upstream/faqs

[9] *Natural Gas Development Activities & High Volume Hydraulic Fracturing*, New York State Department for Environmental Conservation http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch50911.pdf

[10] *"Our current view is that in a licence area of 10km by 10km completely clear of above and below ground constraints, we could extract gas from across the whole area by using ten well pads each hosting 10-12 horizontal wells. We can also envisage a scenario where if it is preferable and feasible to utilise fewer pads with a greater number of wells per pad. Of course the realities of the UK landscape and geology will undoubtedly constrain activities and reduce the number of wells and well pads in any given area…the end result is that developing the maximum number of wells and well pads in any 10km by 10km area is not possible given the surface and subsurface constraints. We anticipate that less than half of a given area is developable when the surface and subsurface constraints are taken into account."* from: http://www.ineos.com/businesses/ineos-upstream/faqs. In September 2014, Ineos announced a £2.5 bn 'giveaway' to 'shale gas communities', noting that *"typically, those living in a Shale gas community (approximately 100 square kilometers) would benefit from the output of 200 wells"*, with each 'community' sharing an estimated £375m. At the time, Ineos had a stake in approximately 700 sq km license area in the Scottish central belt, and no licenses in the rest of the UK, implying a plan to drill a potential 1,400 wells across these areas http://www.ineos.com/businesses/ineos-upstream/news/ineos-plans-25-billion-shale-gas-giveaway.

[11] Goodman et al

"Citing total fracking-related emissions, for an individual well, multi-well pad, or even a region may appear negligible compared to those associated with transport in the region as a whole, or those emissions associated with another, established industrial sector. However, this does not negate discussion and analysis of impacts at the local level, where short duration but large-magnitude events may occur, to the detriment of local ambient air quality and noise.[12]

2.4 Water usage

The hydraulic fracturing phase of UOG extraction will generally involve the highest number of HDV movements because of the need to transport large volumes of water to sites. Volumes of water used in hydraulic fracturing will vary between developments due to differences in geology, porosity of the shale or coal to be fracked. The high and low scenarios in Table 1 reflect water usage of 9 and 29 million litres per well for a single hydraulic fracturing operation, based on figures from the US.[13]

However, a 2015 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. [14] 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, and associated levels of traffic. 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 million litres.

Cuadrilla's proposals at Roseacre Wood and Preston New Road in Lancashire are at the high end of median US water usage in hydraulic fracturing, 22.4 - 28 million litres of freshwater per well, for each of the 4 wells at both sites.[15] Where water can be accessed directly from mains supply this will of course reduce the impacts of traffic associated with the hydraulic fracturing phase of extraction.

2.5 Flowback fluid

The transportation of flowback fluid and produced water for treatment and disposal off site will also involve a high number of HDV movements. The figures in Table 1 assume 50% flowback fluid. However a recent 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.[16] Again, while the US experience should be used with caution, the limited UK experience of shale gas fracking demonstrates high volumes levels of flowback. While Cuadrilla indicate flowback fluid rates of 20-40%,[17] 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.[18]

2.6 Re-fracturing

Re-fracturing, in order to maintain well production, may take place after every 5 years of the operational life of a well. While workovers of tight gas and vertical wells are common practice, it is less

[12] Ibid
[13] Broderick et al p 25
[14] Gallegos et al *Hydraulic fracturing water use variability in the United States and potential environmental implications* 2015 http://onlinelibrary.wiley.com/doi/10.1002/2015WR017278/full
[15] Cuadrilla Roseacre Wood Environmental Statement, Scheme Parameters B7.1
[16] see https://www.sciencedaily.com/releases/2015/09/150915135827.htm, and Kondask and Vengosh 2015 *Water Footprint of Hydraulic Fracturing* http://pubs.acs.org/doi/10.1021/acs.estlett.5b00211
[17] http://www.cuadrillaresources.com/protecting-our-environment/water/water-disposal/
[18] 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

clear what the role of re-fracturing in horizontal unconventional gas wells will be, although there is some expectation that this activity will increase in the coming years.[19] The impacts of re-fracturing, in terms of water usage and flowback, are similar to initial fracturing,[20] and therefore HDV movements can also be expected to be similar at this stage. If re-fracturing of wells occurs, it would both prolong and intensify the impacts of traffic from UOG sites.

3. Potential impacts of traffic associated with UOG

Key community level impacts associated with UOG traffic include:

- climate change
- wildlife and habitat disturbance
- air pollution and related health impacts
- noise pollution and related health impacts
- safety, loss of amenity and road damage

3.1 Climate Change

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*".[21] Global warming of 2^{o}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.[22] 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 commits nations to 'holding' global warming to 'well below 2^{o}C' and pursuing efforts to limit warming to 1.5^{o}C, in recognition of the fact that even 1.5^{o}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.

Greenhouse gas emissions from UOG transportation will have an impact on our ability to meet national climate change targets, and a knock on effect at community level as emissions savings are sought elsewhere. Broderick et al estimate emissions from traffic movements associated with hydraulic fracturing – transportation of water and flowback fluid only – of a single well ranging at between 38 – 58.7 tCO_2.[23]

On this basis, we should expect a range of 53,000-82,000tCO_2 for the hydraulic fracturing phase should Ineos drill 1,400 wells in its Central Belt licenses.[24] For comparison, this is the equivalent of adding

[19] Broderick et al and http://www.spe.org/news/article/renewing-mature-shale-wells-through-refracturing, http://www.epmag.com/refracture-debate-804401#p=4
[20] New York City Department of Environmental Protection *Impact Assessment of Natural Gas Production in the New York City Water Supply Watershed*, 2009 p44 http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/rapid_impact_assessment_091609.pdf
[21] 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
[22] 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
[23] Broderick et al p 55 from table 3.2
[24] See footnote 10

20,000-35,000 additional cars to the roads for a year, at a time when Scotland is aiming to reduce our emissions by over 1,000,000tCO_2 a year.

The transport study should model the greenhouse gas emissions of UOG extraction under the various scenarios to enable an estimation to be made of the impact of the industry on meeting targets under the Climate Change (Scotland) Act.

3.2 Risks of wildlife disturbance associated with transportation

Increased traffic movements due to unconventional gas extraction may have adverse impacts on sensitive species and habitats. Exposure to noise pollution as a result of increased traffic, particularly from HDVs, may result in wildlife modifying its behaviour and/or spatial distribution.[25]

The level of environmental noise in a territory considerably affects the behavioural ecology of birds and can significantly influence bird distributions. Reijnen et al. found substantial decreases in the density of breeding birds in the vicinity of noisy roads, with a 12–56% decrease in density within 100m of a 5,000 car/day road and a 12–52% loss of birds up to 500m from a 50,000 car/day road.[26] Stone also showed that along a gradient of disturbance, species richness consistently decreased as ambient noise increased[27] (although it should be noted that not all species show a noise dependant decrease in density[28]).

A number of studies have investigated the impacts of traffic noise on bird behaviour. Detectability of territorial calls and territory size (both important for breeding success) have been shown to be reduced in the vicinity of noisy roads.[29] Effects resulting in extra energy costs, even if small, can be significant for survival. Work by Schueck et al.[30] on behavioural responses of raptors to military noise showed increased flight height and fewer prey capture attempts in noisy periods.

Impacts of transport on water environments should also be considered. Entrekin et al.[31] positively correlated stream turbidity with density of gas wells in the Fayetteville shale play in the US. Sediment pollution of streams and rivers arising as a result of the transportation of heavy equipment on rural roads, mobilising minerals in runoff or airborne dust, could harm benthic invertebrates and fish.[32] Risks to species likely to be particularly vulnerable to changes to the local water environment, such as freshwater mussels (critically endangered globally, Scotland contains one of the world's most important populations) should be considered.

The land required for the construction of access roads, in addition to well pads, drainage and storage systems, pipelines and other associated infrastructure may result in significant habitat loss and fragmentation at landscape level, depending on the sensitivity of the sites in question.

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[25] Barber et al *Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences* Landscape Ecology, 26 (9): 1281–1295, 2011

[26] Reijnen et al. *The effects of traffic on the density of breeding birds in Dutch agricultural grasslands* Biological Conservation, 75(3): 255–260. 1996, Disturbance by traffic of breeding birds: Evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation, 6(4): 567–581. 1997

[27] Stone *Separating the noise from the noise: A finding in support of the "Niche Hypothesis," that birds are influenced by human-induced noise in natural habitats*. Anthrozoos, 13(4): 225–231 2000

[28] Kaseloo, *Synthesis of noise effects on wildlife populations*. In Proceeding of the International Conference on Ecology and Transportation, North Carolina State University, Raleigh, NC, 33–35. 2005

[29] Mockford and Marshall, *Effects of urban noise on song and response behaviour in great tits*. Proceedings of the Royal Society B-Biological Sciences, 276(1669): 2979–2985. 2009; Parris and Schneider, *Impacts of Traffic Noise and Traffic Volume on Birds of Roadside Habitats*. Ecology and Society, 14(1): 23 2009; Brumm, *The impact of environmental noise on song amplitude in a territorial bird*. Journal of Animal Ecology, 73(3): 434–440 2004

[30] Schueck et al. I*nfluence of military activities on raptor abundance and behavior*. Condor, 103(3): 606–615 2001

[31] Entrekin et al. *Rapid expansion of natural gas development poses a threat to surface waters*. Frontiers in Ecology and the Environment, 9(9): 503–511, DOI: 10.1890/110053. 2011

[32] Kiviat, *Risks to biodiversity from hydraulic fracturing for natural gas in the Marcellus and Utica shales*. Annals of the New York Academy of Sciences, 1286 (1): 1–14, doi: 10.1111/nyas.12146. 2013

The study must assess the potential impact of UOG transportation on wildlife, especially birds and other sensitive species under the various scenarios, particularly in terms of noise pollution, pollution of water environments and habitat loss and fragmentation.

3.3 Air Pollution

Air pollution causes thousands of early deaths each year in Scotland and reduces the quality of life for many more, with a disproportionate effect on children, older people and those with chronic health conditions. Emissions from road traffic are by far the largest contributor to air quality problems.

According to 2014 research published by Public Health England, air pollution from fine particles ($PM_{2.5}$) is responsible for 2000 early deaths in Scotland each year.[33] Exposure to NO_2 also causes early death and the Committee on the Medical Effects of Air Pollutants is due to publish figures on how many early deaths are caused by NO_2 in 2016. The World Health Organisation's specialized cancer agency, the IARC, has classified the combined effect of outdoor air pollution as carcinogenic to humans and named it as a leading cause of cancer deaths, with these conclusions applying to all regions of the world.[34] In January 2014, research from a European study found that long-term exposure to small and fine particles (PM_{10} and $PM_{2.5}$) increases the risk of coronary events including heart attacks and unstable angina, with the link being seen even at levels of exposure below the current European and Scottish pollution standards.[35] Ambient air pollution has been linked with restricted foetal growth in European countries, which is linked with adverse respiratory health in childhood.[36] It is estimated that air pollution costs the Scottish economy over £1.1 billion each year in days lost at work and costs to the NHS.[37]

There are 32 Local Air Quality Management Areas (AQMAs) across Scotland[38] where local authorities have had to declare that levels of pollution are dangerously high and breaking Scottish Regulatory Standards for Nitrogen Dioxide (NO_2) and coarse particles (PM_{10}). [39] A number of Local Authority areas with AQMAs correspond with where shale oil and gas and coalbed methane resources and licenses are located, including East Lothian, Falkirk, Fife, Mid Lothian, North Lanarkshire and West Lothian. The first priority in any AQMA should be to make sure no planning decision makes the situation worse.

Any further worsening of ambient air quality, particularly of Nitrogen Dioxide, would potentially constitute a further breach of Scotland's air quality obligations under European law. The European Ambient Air Quality Directive (Directive 2008/50) on Nitrogen Dioxide required all Member States to have achieved annual ambient concentrations of pollutants below a specified concentration level by an original deadline of 1 January 2015. Scotland continues to be in breach of its obligations on NO_2, and in April 2015 the UK Supreme Court ordered the UK Government to submit fresh plans to the European Commission as to how it would comply with its obligations as quickly as possible.

For the Scottish Government's part, "Cleaner Air for Scotland" constituted the its plan for compliance, which was published in November 2015. Its stated objective on Placemaking is for "A Scotland where

[33] Public Health England, "Estimating Local Mortality Burdens associated with Particulate Air Pollution" (April 2014), https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution

[34] IARC Press Release, 17 October 2013, "Outdoor air pollution a leading environmental cause of cancer deaths" http://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf

[35] Research published in the British Medical Journal, "Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project" (Jan 2014) BMJ 2014;348:f7412, http://www.bmj.com/content/348/bmj.f7412

[36] "Ambient air pollution and low birthweight: a European cohort study (ESCAPE)" The Lancet Respiratory Medicine, Volume 1, Issue 9, Pages 695 - 704, (Nov 2013), http://www.thelancet.com/journals/lanres/article/PIIS2213-2600(13)70192-9/abstract

[37] Extrapolated from a Defra assessment that air pollution costs the UK economy as a whole £16 bn per year, based on 29,000 UKwide deaths from air pollution: Defra, "Impact pathway guidance for valuing changes in air quality" (May 2013), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197900/pb13913-impact-pathway-guidance.pdf

[38] An indicative list of air quality management areas can be found at http://www.scottishairquality.co.uk/laqm/aqma

[39] The Scottish Standards are set out in the Air Quality (Scotland) Regulations 2000 and the Air Quality (Scotland) Amendment Regulations 2002

air quality is not compromised by new or existing development and where places are designed to minimise air pollution and its effects."[40] Any policy decision that would run against the stated aims of CAFS or further undermine the Scottish Government's efforts to comply with its obligations on NO_2 concentration levels could potentially bring Scotland into further breaches of European Law.

The ReFINE study, which developed a model to assess the impacts of traffic movements associated with shale gas extraction based on the numbers in Table 1, indicates that substantial increases in air (and noise) pollution are to be anticipated from any UOG extraction:

"Exploratory analyses using the model have revealed that the traffic impact of a single well pad can create substantial increases in local air quality pollutants during key activity periods, primarily involving the delivery of water and materials for fracking to the site. Modelling of NO_x emissions showed increases reaching 30% over non-fracking periods and noise levels doubling (+3.4 dBA), dependent on access policy implemented to the site, potentially exacerbating existing environmental issues. Normalisation of these values over a longer period, such as the time to completion of all wells on a pad, mitigates the 'raw values' but may present a distorted picture of the actual impact on the local populous."

We are particularly concerned about a number of specific well-documented health risks associated with UOG,[41] for which, traffic is potentially a contributing factor:

- Low birth weights and congenital disorders linked to air pollution from 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
- 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

It is critical that the cumulative impact of air pollution from transport associated with UOG extraction alongside other sources of air pollution from the industry, e.g. the operation of heavy equipment onsite and fugitive emissions from wellheads and pipelines, both for workers on site and for nearby residents and public, are properly assessed and understood.

3.4 Noise Pollution

Exposure to excess noise can seriously harm human health and detrimentally impact on day-to-day activities, with exposure to noise at night significantly worse than during the daytime. According to the World Health Organisation: *"at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe. Sleep disturbance and annoyance, mostly related to road traffic noise, comprise the main burden of environmental noise."*[42]

Cardiovascular disease, cognitive impairment and tinnitus are amongst the diseases linked to excess noise exposure. Further, MedAct note that: *"The stress and loss of sleep that may be caused by nuisances*

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[40] Scottish Government, "Cleaner Air for Scotland: The Road to a Healthier Future" (2015), p 3, http://www.gov.scot/Resource/0048/00488493.pdf

[41] For example in http://concernedhealthny.org/wp-content/uploads/2012/11/PSR-CHPNY-Compendium-3.0.pdf. 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, and fed in these concerns.

[42] World Health Organisation *Burden of Disease from Environmental Noise: Quantification of healthy life years lost in Europe*, 2011 http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf?ua=1

such as traffic congestion, noise and light pollution are forms of ill health in their own right, but are also factors in the genesis of a range of other diseases and illnesses."[43]

As above, ReFINE consortium researchers found significant increases – doubling in overnight scenarios – in noise levels in modelling impacts of UOG transportation based on the numbers in Table 1.

Noise from traffic movements will be in addition drilling noise from UOG sites. UOG extraction involves sustained periods of constant noise, particularly during drilling operations. On the basis of figures from the US, Broderick et al found that:

"…each well pad (assuming 10 wells per pad) requires a total of around 800-2,500 days of noisy surface activity. Of all of these activities, drilling of wells is likely to provide the greatest single continuous noise (and, light) pollution as drilling is required 24 hours a day. Here, New York State (2009) estimates that each horizontal well takes four to five weeks of 24hours/day drilling to complete. The UK operator Composite Energy estimates 60 days of 24 hour drilling. On the basis of this, each well pad will require 8-12 months of drilling day and night. This would be significant even if it were only a single pad that was being developed, but with development of multiple pads in a locality, the noise impacts to be locally considerable and prolonged." [44]

The cumulative effect on health and wellbeing from regular noisy peaks from transportation, as well as longer continuous periods of noise from UOG extraction both for residents within the proximity of drilling sites and transportation routes, and for workers, must be understood and assessed.

3.5 Safety, loss of amenity and road damage

Loss of amenity on local roads due to perceived and actual threats to safety from excessive HDV movements, transportation of toxic chemicals and waste, road damage and increased congestion could have a significant detrimental effect on local communities where UOG extraction takes place. Any such impact, for example on use of local roads for walking and cycling, could exacerbate adverse health impacts of air pollution from transportation and other UOG production emissions.

An enforcement period targeted at the UOG industry by Pennsylvania State Police of just 3 days in 2010 resulted in almost 669 traffic citations and 818 written warnings, with 250 commercial vehicles taken off the road, due to environmental and safety violations.[45] A 2011 survey in eight of the Pennsylvania counties with most natural gas drilling activity found increases of up to 49% in the number of emergency 911 calls, despite a falling population, largely due to increased incidents with site traffic.[46] A 2015 study found increases of between 15-65% in the number of vehicle crashes in Pennsylvania counties where shale gas drilling took place compared with those without drilling.[47] Similarly, the Bakken Shale in North Dakota has seen the overall number of highway crashes between 2006-2010 increase by 68%, with a rise in those involving HDVs.[48]

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[43] MedAct *Shale Gas Risks and Benefits to Health: Notes from the Literature*, 2016 http://www.medact.org/wp/wp-content/uploads/2016/07/Medact-Notes-on-Shale-Gas-July-5.pdf 189
[44] Broderick et al p114
[45] Riverkeeper *Fractured Communities: Case studies of the Environmental Impacts of Industrial Gas Drilling* p 5, 2010 https://www.riverkeeper.org/wp-content/uploads/2010/09/Fractured-Communities-FINAL-September-2010.pdf and http://www.waterworld.com/articles/2010/06/trucks-hauling-drilling-wastewater.html
[46] https://stateimpact.npr.org/pennsylvania/2011/07/11/emergency-services-stretched-in-pennsylvanias-top-drilling-counties/
[47] Graham et al. *Increased Traffic Accident Rates Associated with Shale Gas Drilling in Pennsylvania*. Accident Analysis and Prevention, 74:203–209, 2015
[48] Environment America Research and Policy Centre *Fracking by the Numbers: Key Impacts of the Dirty Drilling at the State and National Level* 2013 http://www.environmentamerica.org/sites/environment/files/reports/EA_FrackingNumbers_scrn.pdf

HDVs can place considerable stress on roads not designed for heavy traffic, and the cost of increased maintenance and repair will inevitably fall on the public purse. Researchers at ReFINE note that detailed assessment of impacts on road structures from UOG extraction:

"…is problematic, given the diverse range of road ages and construction types possible. In older bituminous roads the main structural element of the roads, the roadbase, may have cured sufficiently to be able to withstand HDV loading, though surface layers may have aged, become brittle and be subject to cracking. Conversely, newer roads that have not reached full structural strength could be induced to failure early in their lifetimes."[49]

Repairing road damage in Pennsylvania caused by drilling in the Marcellus Shale is estimated to cost $265million.[50] The Department for Transport in West Virginia has apparently increased bonds paid by natural gas operators from $6,000 to $100,000 per mile, and Pennsylvania is contemplating a similar rule.[51]

The ReFINE Consortium's study on transportation impacts found:

"…even for a single, multi-well pad, relative impacts are disproportionate to VKT (vehicle kilometre travelled) increases, especially for the case of axle loadings…[the] disproportionate increases in ESAL (equivalent standard axel loads) found in the non-motorway cases are a cause for concern. It is likely that such roads were not originally designed with substantial volumes of HDV traffic in mind, and, given current economic conditions, may not fall on relevant authorities priority lists for reconstruction."

The transportation impacts study should assess the potential loss of amenity on local roads, increases in traffic accidents and damage to roads, and provide some commentary on the additional burden these impacts could place on the public purse.

3.6 Other Comments

It is worth noting that the impacts of traffic movements associated with UOG production will not only be felt in the immediate vicinity of extraction sites. Areas where waste treatment facilities and suppliers of key ingredients such as water and silica sand will also feel the impacts of increased traffic associated with any development of the industry. Given that significant silica resources are located in Scotland,[52] and that silica use in hydraulic fracturing operations appears to be on the increase,[53] **it would be helpful if the report could provide commentary on the potential impact of the expansion of silica mining to supply a Scottish and UK domestic shale gas industry.**

[49] Goodman et al
[50] Scott Christie, Pennsylvania Department of Transportation, Protecting Our Roads, testimony before the Pennsylvania House Transportation Committee, 10 June 2010 in *Fracking by the Numbers* http://www.environmentamerica.org/sites/environment/files/reports/EA_FrackingNumbers_scrn.pdf
[51] Broderick et al p92
[52] British Geological Survey Silica Sand Mineral Planning Factsheet http://www.bgs.ac.uk/mineralsUK/planning/mineralPlanningFactsheets.html
[53] http://www.bloomberg.com/news/articles/2016-08-03/one-nook-of-america-s-shale-industry-is-eyeing-a-big-comeback