



CUADRILLA

SHALE GAS PRIZE WITHIN THE UK'S GRASP



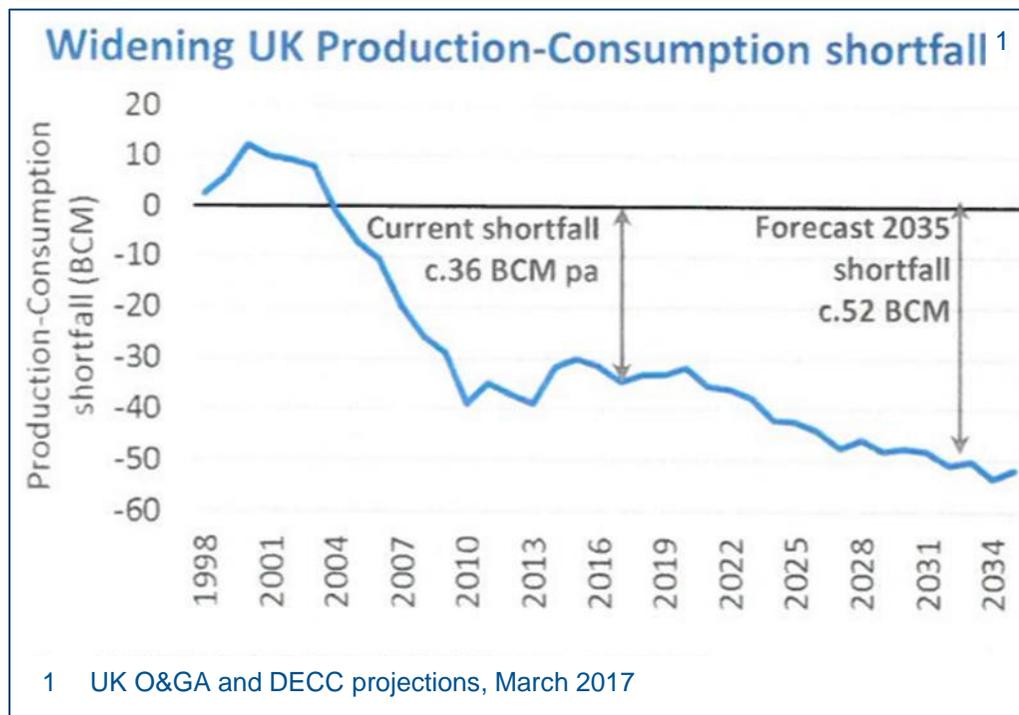
Preston New Road – Gateway to UK Shale Gas



- Context
- Progress
- Next steps to success



Context – natural gas is critical for the UK

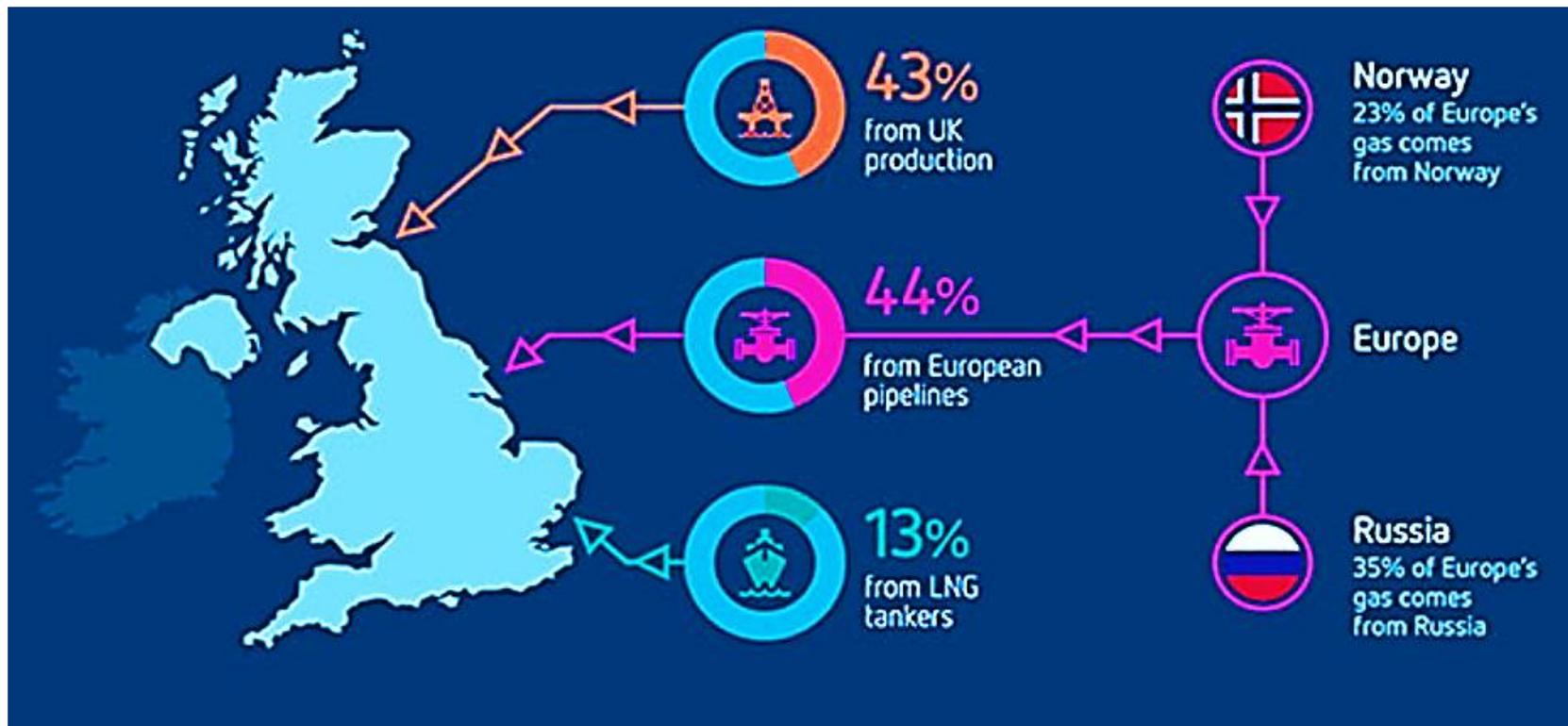


- More than a third of the UK's energy comes from natural gas
- UK remains and will remain heavily dependent on gas for domestic, commercial and industrial use
- Commitments to close coal fired generation and recent setbacks in new-build nuclear will increase UK reliance on gas for base-load power generation
- Over 80% of UK homes are heated by gas
- More than half of UK's gas demand is currently imported and this % is set to significantly increase
- Natural gas demand for UK power generation set a new record on January 23rd 2019 at 97 million cubic metres

...and reducing CO₂ emissions

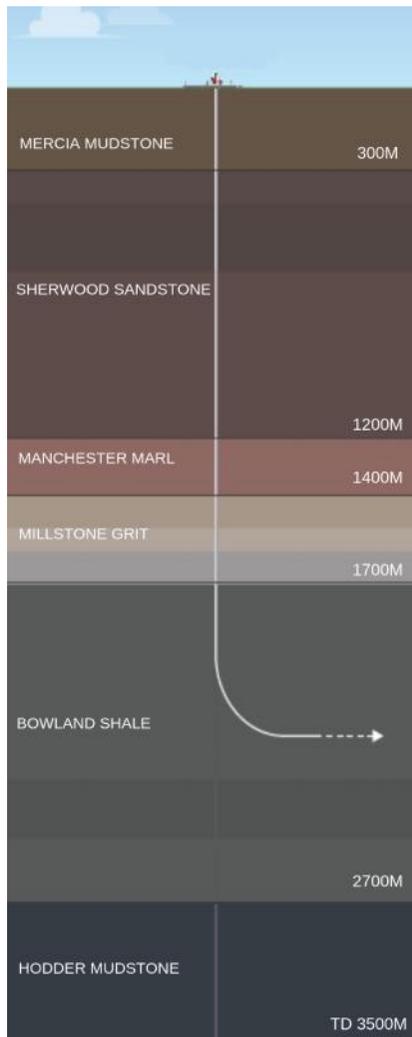


Committee on Climate Change analysis and Professors Mackay and Stone calculated that UK shale gas could offer a 50% emission saving compared to imported LNG (including US shale gas) and long distance pipeline supplies...



UK gas sources – British Gas 2017

Lancashire Bowland Shale – ideal for commercialisation



Shale thickness (>1 km) enables multiple horizontal wells at different levels

Shale located several thousand feet below aquifers

Size of the gas resource and quality of the reservoir clearly proven

Bowland shale ideally suited to hydraulic fracturing

Complex network of fractures created and excellent sand retention

Close proximity to local and national gas pipeline infrastructure

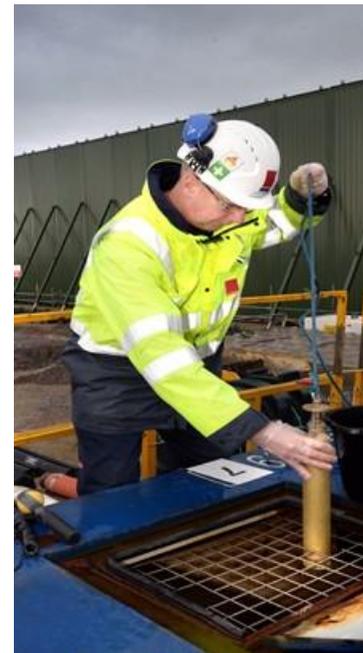
Thickness/spread of shale = multiple wells per production pad (cost efficiencies, reduced surface footprint)

UK natural gas prices at substantial premium to US

Excellent gas quality with high methane

UK oil & gas experience & expertise (Aberdeen) pre-eminent outside US

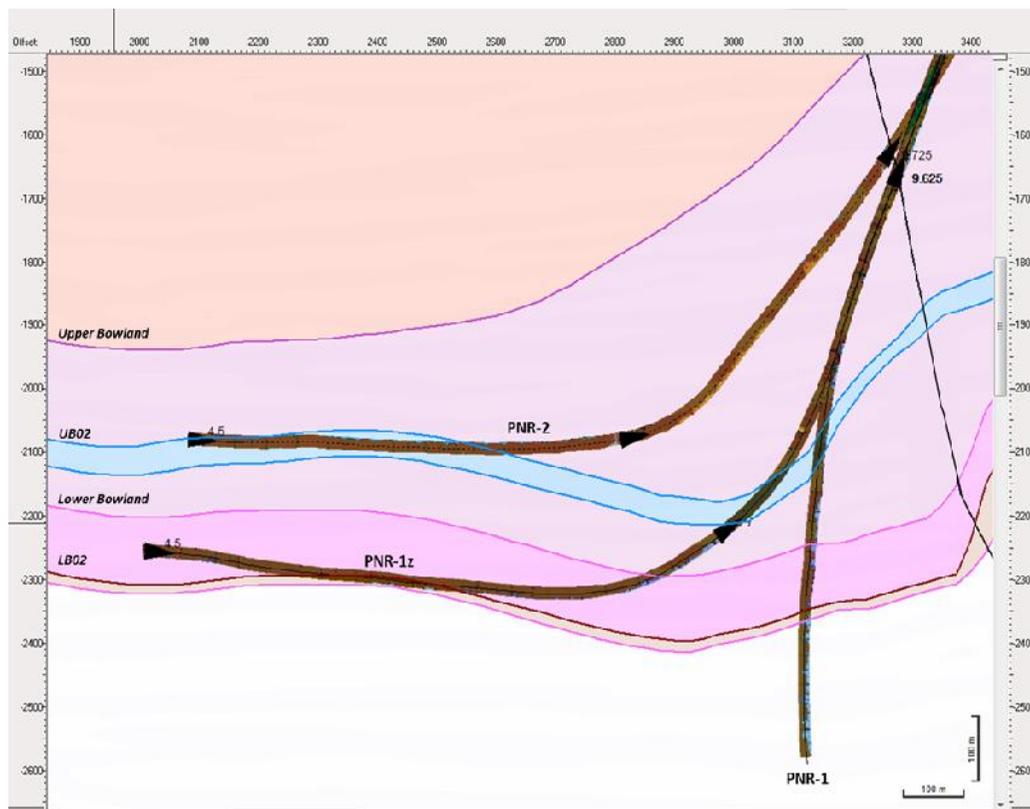
Preston New Road – Leading the way



Construction, drilling and fracturing operations all completed with no material impact on, or harm to, people, property or the environment



Horizontal shale wells successfully drilled – a UK First

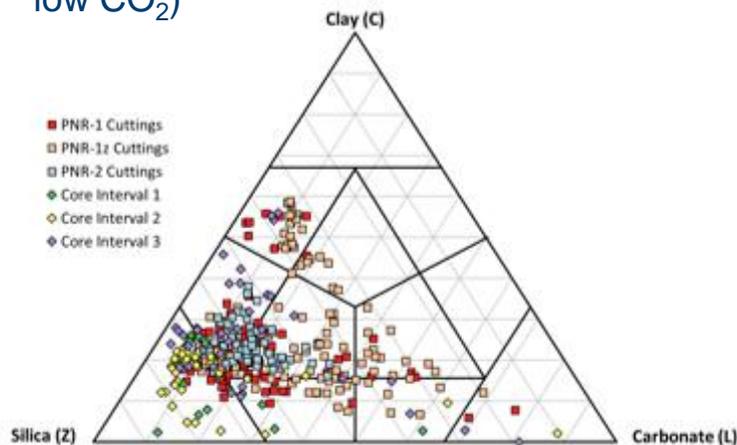


- Vertical pilot well drilled through Upper and Lower Bowland Shale to a depth of 2,614 metres
- >300metres core samples taken from shale
- 6 prospective production zones, high graded
 - 3 in Upper Bowland Shale
 - 3 in Lower Bowland Shale
- Horizontal well 1 drilled for 780m in Lower Bowland Shale
- Horizontal well 2 drilled for 750m in Upper Bowland Shale

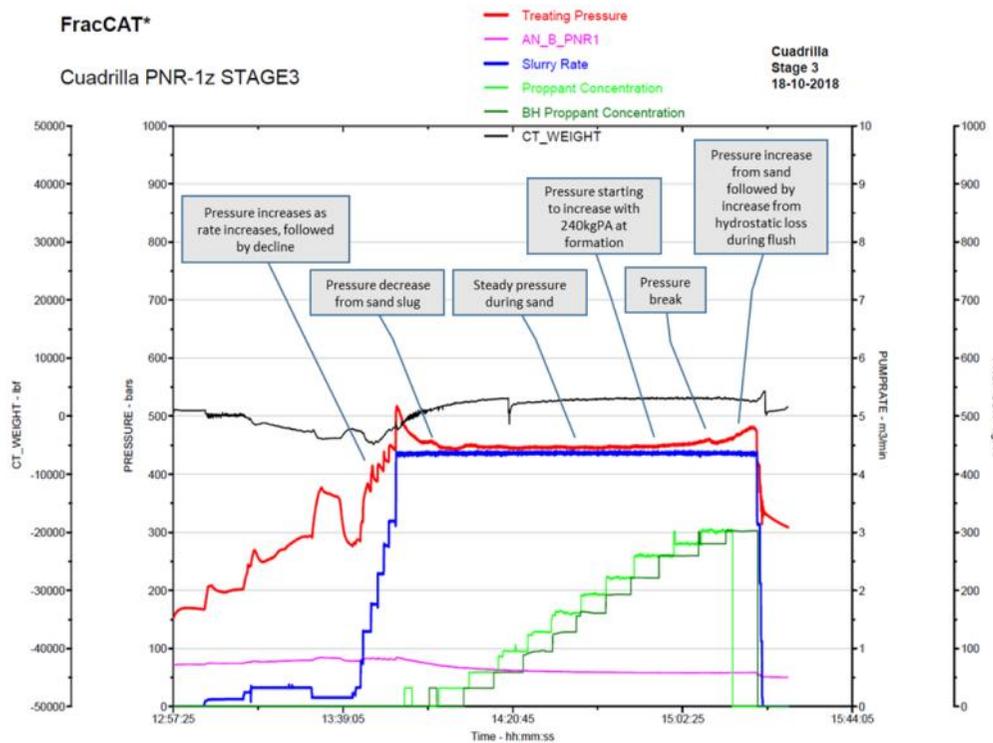
Bowland Shale - outstanding rock quality



- Core samples subject to detailed lab analysis
- Quartz-rich, brittle rock, excellent properties for fracturing
- Highly naturally fractured shale
- Gas content comparable to Preese Hall exploration well (PH-1) at 40 scf/ton
- Gas composition comparable to PH-1, 96% methane
- Minimal gas processing required (no H₂S, low CO₂)



Textbook fracture effectiveness



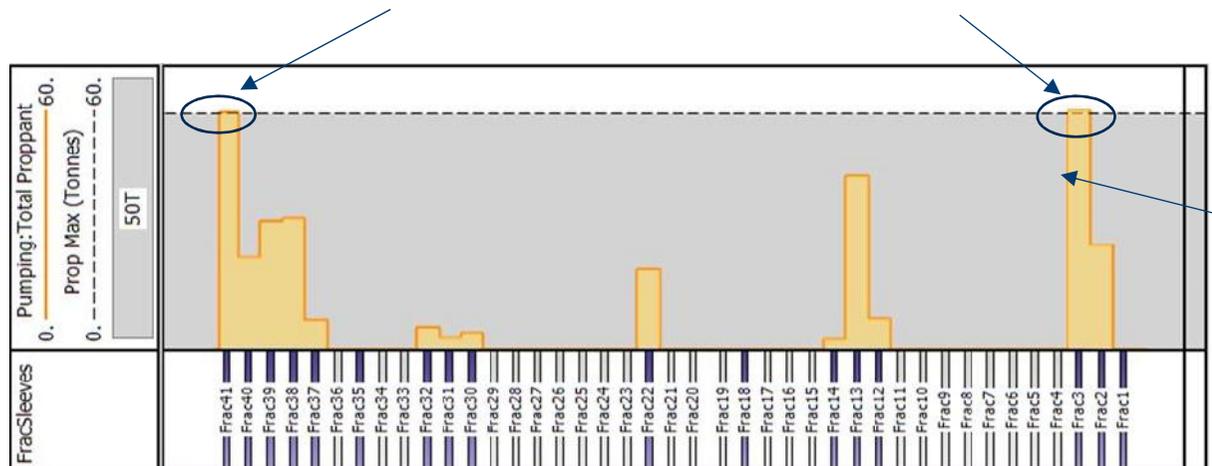
Job pumped as designed with 375 m³ (2,360 bbl) slickwater and 50.8 t (112,000 lbs) S100 sand at 4.2 m³/m slurry + 0.15 m³/m coil rate (26.4 + 0.9 bpm) into a single sleeve

- The shale surrounding PNR horizontal well #1 was hydraulically fractured between October and December 2018
- The PNR1 horizontal well was completed with 41 separate sliding sleeves, allowing fracture fluid to be pumped separately through each sleeve
- Stage (sleeve) 3 was hydraulically fractured to plan (illustrated left) – a textbook injection
- Pressure characteristics during fracturing were analogous to US Shale Gas well fracturing operations
- The Bowland shale is ideally suited for fracturing

Micro-seismic Traffic Light System – significantly constrained outcome



Only 2 of 41 stages fractured with 50 tonnes of sand (as designed)



- World's most comprehensive micro-seismic data set for hydraulic fracturing acquired – approx. 40,000 data points
- Hydraulic fracturing effectiveness significantly constrained by intentionally conservative 'red light', set at just 0.5 on the Richter scale – sand could not be injected into shale after red light trigger

- Proppant actually injected (yellow), total 278 tonnes, approx. 13% design
- 41 sliding sleeves (frack stages) installed along the length of PNR1 horizontal section
- Planned to inject 50 tonnes proppant (sand) into each sleeve i.e. 2,050 tonnes in total
- Fracture network created does not remain open without injected sand

Natural gas flowing to surface from shale with minimal sand injected



- Less than 14% of proppant (sand) design quantity was injected into the shale due to 0.5 micro-seismic limit
- The stages that were hydraulically fractured proved that the shale has excellent mechanical properties for both fracturing and sand retention
- **Natural gas flowed to the surface, from the very few stages of fully fractured shale, reaching a peak rate of more than 200,000 standard cubic feet per day (scfd) and a stable rate of over 100,000 standard cubic feet per day (scfd)**
- Initial sampling confirms gas has very high methane content (mid to high 90%), no H₂S, and could be delivered to the local gas grid with minimal treatment
- Our preliminary scaling up of the PNR-1z flow results yield a flow range of between **3 and 8 million standard cubic feet per day gas for a 2.5km lateral section with all stages effectively hydraulically fractured**
- **More production data is required to refine this preliminary scale up**
- All the indications are that this shale is comparable with US gas producing shale plays

The UK Shale Traffic Light System – Intentionally Conservative



Traffic Light Systems in Other Jurisdictions

	US, where a traffic light scheme has been introduced for hydraulic fracturing , the red light is set at magnitudes of 2.7 to 4.5 depending on the state.
	Western Canada the red traffic light for hydraulic fracturing injection has a high threshold (magnitude 4)
	In Switzerland, earthquakes resulting from geothermal operations use a similar traffic light system that incorporates both magnitude and ground motion monitoring (Red = 2.9 magnitude and >5mm/s ground motion).
	In the UK, the red traffic light for (shale only) hydraulic fracturing injection has a magnitude of 0.5 .

UK Written Ministerial Statement 2012

“The controls are not at this stage to be regarded as definitive, but as appropriate precautionary measures for our present state of knowledge. Initial operations under these controls will be subject to careful scrutiny to ensure the effectiveness of the controls. And they will be reviewed, as experience develops, to ensure that they are proportionate to the risks...”

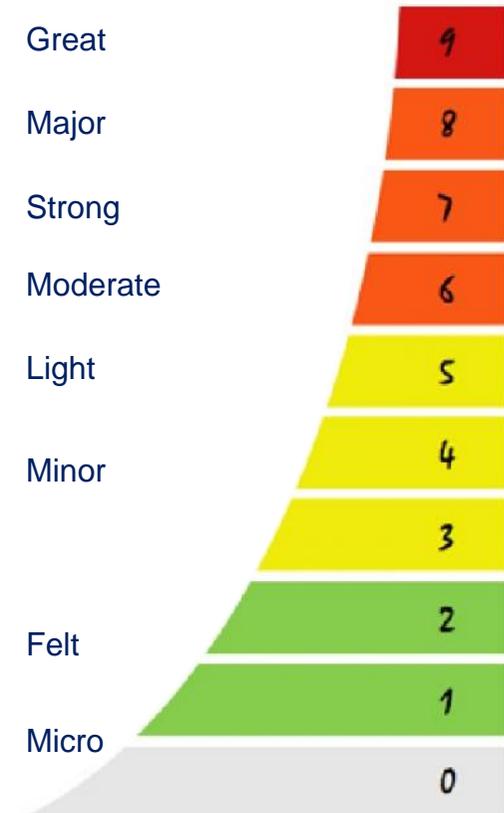
“It may well prove to be the case that, as our experience of applying this type of control to fracking operations develops, it can be confirmed that trigger levels can be adjusted upwards without compromising the effectiveness of the controls.”

Ed Davey Secretary of State for Energy – Dec. 2012

The Richter Scale:



- The Richter scale is used to rate the magnitude of an earthquake - the amount of energy it releases
- The Richter scale is logarithmic, meaning that whole-number jumps indicate a tenfold increase in magnitude i.e. a measurement of 2 is ten times higher than a measurement of 1, 3 is 100 times higher than 1 etc.
- For comparison, the red light micro-seismic threshold within North America has been set as high as 4.0
- Coincidentally this level is also observed for geothermal projects in the UK
- Magnitude 4.0 is 3,162 times higher than magnitude 0.5 and 177,827 times stronger in terms of energy release



The Traffic Light System – Cuadrilla has requested UK regulator review



- A total of 39,164 micro-seismic measurements were recorded by ultra sensitive monitors during fracturing operations at PNR1 – the most intensive micro-seismic monitoring operations ever undertaken on a shale well
- Only 21 of these micro-seismic measurements were equal to or greater than 0.0 on the Richter Scale and only 7 were equal to or greater than 0.5 on the Richter Scale
- No issues with PNR1 well integrity
- Only two reports were made by the public to the British Geological Survey (BGS) of “felt” ground vibrations
- Ground vibration was also recorded throughout, typically less than 0.5 mm/second
- British Standard recommends threshold of 15 mm/second vibration for construction operations, designed to avoid even cosmetic damage to vulnerable structures – 30 times higher than PNR red light levels
- No red light threshold is applied to UK geothermal operations
- Cuadrilla has formally asked the UK Regulator (Oil and Gas Authority) to review the TLS for future fracturing operations planned for PNR wells 1 + 2



Recent Expert Opinion Supports TLS Review



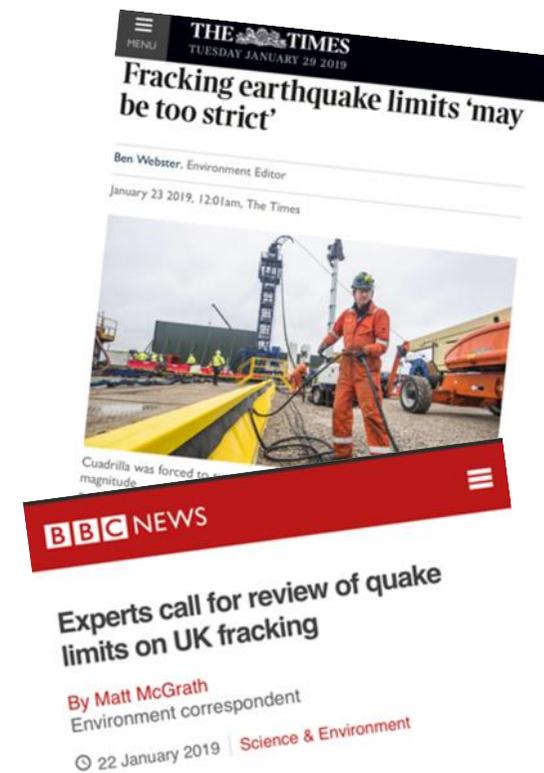
“When earthquakes occur they cause shaking, so could that shaking damage the wells? I think the risk of that is vanishingly small. The existing regulations are really quite conservative, they are set at a level of earthquake that is really very unlikely to be felt. I think it is something we ought to have a look at.”

Dr Brian Baptie, Head of Seismology at the British Geological Survey. January 2019

“If you want to go to a risk-based approach, where you allow events that do not pose any risk to humans or structures, then there is scope to review the current system.

That could be raised to 1.5 and that would still arguably be conservative.”

Dr Ben Edwards, Reader in Seismology at the University of Liverpool. January, 2019



Summary and next steps:



- Due to an intentionally conservative TLS only a small proportion of PNR1 well was effectively fractured
- The stages that were hydraulically fractured demonstrated that the shale has excellent mechanical properties for both fracturing and sand retention
- **Natural gas flowed to the surface, from the very few stages of fractured shale, reaching a peak rate of more than 200,000 standard cubic feet per day (scfd) and a stable rate of over 100,000 scfd**
- Initial sampling confirms gas has very high methane content (mid to high 90%) which could be delivered to the local gas grid with minimal treatment
- Our preliminary scaling up of the PNR-1z flow results yields a flow range of between 3 and 8 million standard cubic feet per day gas for a 2.5km lateral section with all stages effectively hydraulically fractured
- Cuadrilla has requested that the regulator reviews the TLS to enable the valued Bowland Shale resource to be extracted effectively without comprising on safety or environmental protection
- Subject to outcomes of TLS review Cuadrilla plans to complete the fracturing of PNR well 1, fracture PNR well 2 and continue flow testing in 2019