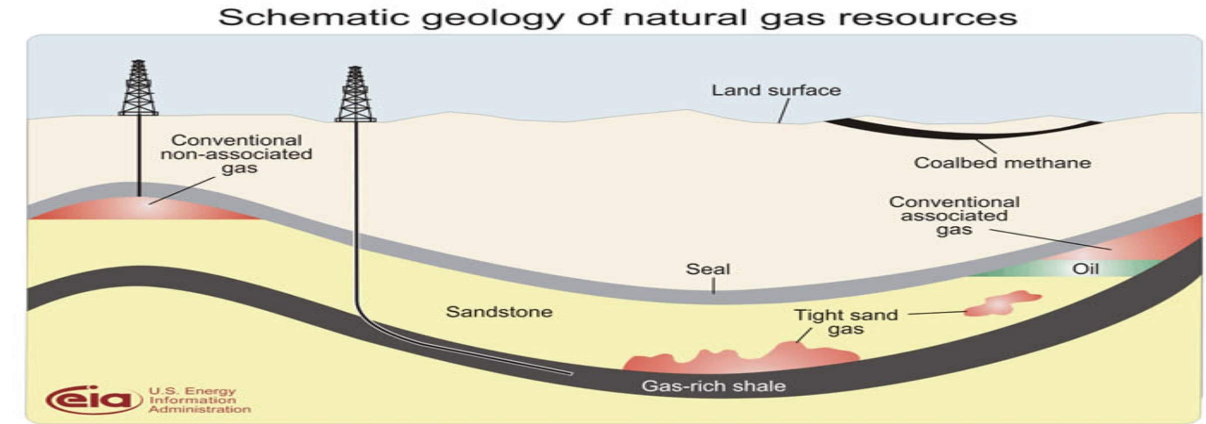
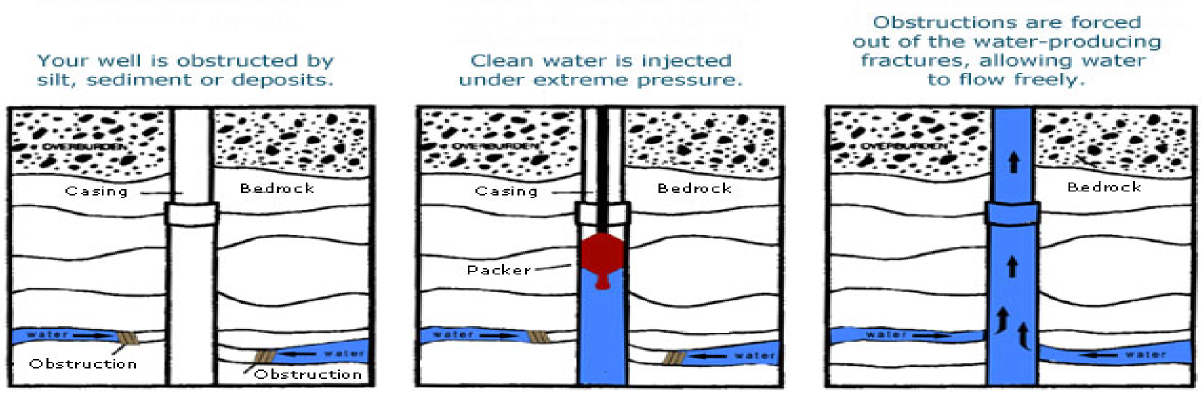
Appendix 'A'

Difference between conventional and shale gas exploration

In the UK, there has been a long history of extraction of natural oil and gas from ‘conventional’ onshore fields, where the gas comes from absorbent reservoirs, usually composed of sandstone or limestone. Conventional gas extraction is relatively straightforward because the gas generally flows freely, unlike unconventional gas where it is situated in rocks with extremely low absorption ability, making it very difficult to extract (see diagram below):



Industries use advanced technologies to extract the unconventional gas following a process commonly known as 'hydraulic fracturing' or 'fracking'. This involves pumping water, mixed with a small proportion of sand and chemicals, underground at a high enough pressure to split and keep open the rock and release natural gas that would otherwise not be accessible. The diagram below shows the process of hydraulic fracturing:



Stages of high volume hydraulic fracturing and differences from conventional hydrocarbon production (copied from Evidence: Monitoring and control of fugitive methane from unconventional gas operations, Environment Agency, 2012

Development and production stage	Step	Decision factors	Differences from conventional hydrocarbon production
Site selection and preparation	Site identification	Production yield versus development cost	None
	Site selection	Proximity to buildings / other infrastructure Geologic considerations Proximity to natural gas pipelines Feasibility of installing new pipelines	None None None None
		Site area (around three hectares/well needed during fracturing)	More space required during hydraulic fracturing for tanks / pits for water / other materials required for fracking process
		Access roads / requirement improvements	More lorry movements during hydraulic fracturing than conventional production sites due to need to transport additional water, fracking material (including sand/ceramic beads) and wastes
		Availability and cost of water supply and wastewater disposal	Obtaining/disposing of large volumes of water (10,000–20,000 m^3 per well)
		Availability of space to store make up water and wastewater	For example may require 20,000 m^3 of make-up water onsite before fracturing Will require sufficient trucks / tanks onsite to manage flowback (e.g. 40–50 trucks at 90 m^3 per tank)
	Site preparation	Number of wellheads per pad and per hectare Well pad design to control run off and spills and contain leaks Amount of water / proppant needed for production activities	Installation of additional tanks / pits More wells/pad Fewer wells/hectare
Well design	Deep well (directional) Shallow vertical	Separation of aquifer from hydrocarbon bearing formation by impermeable layers Existence of fault / fracture zones	Both conventional and unconventional wells are drilled through water-bearing strata and require same well design

Development and production stage	Step	Decision factors	Differences from conventional hydrocarbon production
		Maximising access to hydrocarbon in strata	standards
Well construction and development	Drilling	Depth to target formation (vertical or horizontal)	Horizontal drilling produces longer well bore (vertical depth plus horizontal leg) requires more mud and produces more cuttings/well Horizontal drilling requires special equipment, larger diesel engine for the drill rig, burns more fuel produces more emissions. Equipment is on site for a longer time. However, fewer horizontal wells would be needed to extract a similar quantity of gas
	Casing	Casing required or open hole construction (competent conditions only): casing would normally be required Conductor (for wellhead) Surface (to isolate near-surface aquifer from production) Intermediate (to provide further isolation) Production (in target formation) Centred casing to enable cementing	Casing material must be compatible with fracking chemicals (e.g. acids) Casing material must also withstand the higher pressure from fracturing multiple stages
	Annular packers Inflatable downhole tools installed on the outside diameter of a casing can provide a back-up to cement in hydraulically fractured wells	Need to prevent annular gas migration or separate horizontal wells into segments.	Could be used on both conventional and unconventional wells
	Cementing	Correct cement for conditions in well (e.g. geology	Hydraulic fracturing has the potential to

Development and production stage	Step	Decision factors	Differences from conventional hydrocarbon production
		Number, size, timing and concentration of delivery slugs of fracturing fluid and proppant	depending on formation thickness) More equipment required: Series of pump trucks, frack tanks, much greater intensity of activity.
	Hydraulic fracturing: pressure reduction in well / to reverse fluid flow recovering flowback and produced water	Chemical additions to break fracking gels (if used) Planning for storage and management of flowback recovered before the well starts gassing (varies from 0%-75% but strongly formation dependent). Planning for storage and management of smaller volumes of wastewater generated during production (decreasing flow rates and increasing salt concentrations)	'Flowback' of fracturing fluid and produced water containing naturally occurring materials (mostly salt) and hydrocarbons
	Connection of well pipe to production pipeline		None
	Reduced emission completion	Capture gas produced during completion and route to production pipeline or flare it if pipeline is not available	Larger volume of flowback and sand to manage than conventional wells
	Well pad removal	Amount of wastewater storage equipment to keep on site Remove unneeded equipment and storage ponds. Re-grade and re-vegetate well pad.	Larger well pad (with more wells/pad) with more ponds and infrastructure to be removed
Well production	Construction of pipeline	May need to construct a pipeline to link new wells to gas network.	Exploitation of unconventional resources may result in a requirement for gas pipelines in areas where this infrastructure was not previously needed
	Production	May need to re-fracture the well to increase recovery (e.g. after five years of service). Wastewater management (e.g. discharge to surface water bodies, reuse or disposal via	Produced water will contain fracturing fluid as well as hydrocarbon Conventional wells are often in wet formations that require dewatering to

Development and production stage	Step	Decision factors	Differences from conventional hydrocarbon production
		underground injection including transport to disposal site)	maintain production. In these wells, produced water flow rates increase with time. In shale and other unconventional formations, produced water flow rates tend to decrease with time.
Well site closure	Remove pumps and downhole equipment Plugging to seal well	Need to install surface plug to stop surface water seepage into wellbore and migrating into groundwater resources Need to install cement plug at base of lowermost underground source of drinking water Need to install cement plugs to isolate hydrocarbon, injection/disposal intervals	Likely to be similar to conventional well
Post-closure	Long-term monitoring to ensure well integrity	Methane can continue to be produced after well closure, at rates which are not commercially viable but which could result in methane seepage in the long term if seals or liners break down.	None