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Implementing a Greener Hydraulic Fracturing in Scotland

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Abstract - The drive to implement unconventional gas drilling by means of hydraulic fracturing in United Kingdom (UK) has been a major issue of concern due to the potential environmental and health impacts. This paper is aimed at examining the following: what triggers the need for the unconventional gas; the process of unconventional gas through hydraulic fracturing method; the potential risks of hydraulic fracturing to the environment and to human health; key success factors for implementing hydraulic fracturing; possible options in fluids to go greener from the traditional approach; pros and cons of the various fluid options to ascertain their sustainability. It also presents a project methodology for hydraulic fracturing and discusses what needs to be determined before it is implemented in the UK.

Index Terms—Hydraulic fracturing, fracking, environmental impact and sustainability.

I. INTRODUCTION

Advances in the oil and gas industry to fully explore the drilling option of hydraulic fracturing known as “fracking” in the United Kingdom has engendered a great deal of controversy.

The need for this unconventional type of drilling is that fossil fuels are the world’s main source of energy, accounting for 81% of global primary energy use in 2010 [1]. More importantly, since the conventional reserves are deteriorating [2] there is a need for alternative measures which can exploit unconventional energy sources [3; 4].

What differentiates conventional gas from unconventional gas is its geophysical location and how the natural gas is extracted. Conventional gas is located in permeable rocks which can escape freely after drilling, as indicated in Fig.1. Unconventional gas is trapped in insufficiently permeable rock formations, such as shale, tight sands and coal beds, which need to be fractured in order to release gas in large quantities (Fig.1). In addition, in terms of their chemical composition (primarily methane), these resources are identical to conventional natural gas. It is called “unconventional” because of their atypical geological locations. Unconventional gas is found in highly compact rock or coalbeds and requires a specific set of production techniques.

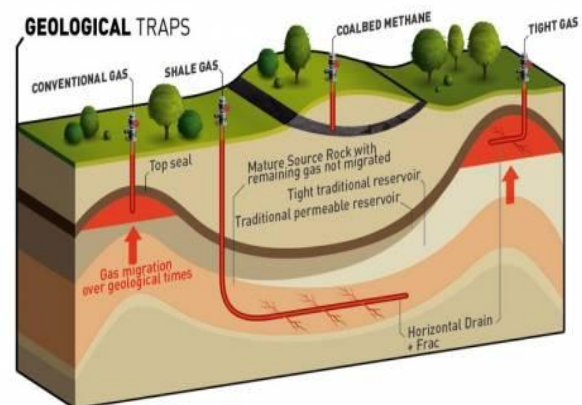


Fig.1 Conventional/Unconventional gass reservoirs [5]

According to the International Energy Agency (IEA) [6], hydraulic fracturing, commonly known as fracking, is a process that injects a large amount of fluids (water with chemicals and sand) at high pressures into rock formations to fracture them, enabling compounds such as gas that are held tightly inside to be released. Some factors have made the unconventional gas production through hydraulic fracturing more attractive ranging from technological advancement, strong desire to decrease dependence from foreign energy, high oil prices and new geopolitical realities [7].

Unconventional gas production is seen as the best option for countries that are dependent on foreign imports in meeting their energy supply in order to reduce this dependency. There is enough unconventional gas world-wide to increase gas from 13% of global energy resource base in 2009 to 25% in 2035 [1]. Milosevic *et al* [7], highlight that as the geographic distribution of unconventional gas differs from that of conventional fossil energy resources, it therefore changes the dynamics of the international geopolitics of energy.

Most of the unconventional gas is trapped deep inside shale formations at depths between 1500 and 3000m [8]. For example, a typical horizontal well has an average lateral extension of 1400m and maximum of 300m [9]. This means that the rock is hydraulically fractured multiple times every

100m along the horizontal degree. Conversely, these fractures can extend between 150 and 250m perpendicular from the horizontal well and should, in theory, not propagate vertically more than the thickness of the gas-producing layer.

It is very important to note that as unconventional gas production provides both economic and energy security benefits, there are also accompanying environmental risks which must be taken into consideration. The potential risks include; water and soil contamination from the surface leaks or from indecorously designed well-casing, environmental degradation, air pollution, noise pollution, biodiversity losses, negative impact on ecosystem and landscape disruption. In densely populated areas, the most direct concern is the risk of explosion from the construction of new pipelines [10].

Hydraulic fracturing is yet to gain full acceptance in Scotland. In order for informed decisions regarding implementing the practice to be made, answers to the following questions must be sought:

1. Why is greener hydraulic fracturing necessary in Scotland?
2. What are the possible fluid options that are environmental and health friendly?
3. Is there enough unconventional gas in Scotland to give consideration to fracking?
4. What are the benefits associated with the implementation of hydraulic fracturing in Scotland.
5. What are the key success factors of implementing greener hydraulic fracturing in Scotland?
6. What impact would the implementation of hydraulic fracturing in Scotland be in the next 10 years?
7. What realistic Project Management methodology is in place for conducting and monitoring greener hydraulic fracturing in Scotland?
8. What are the possible risks involve with the greener hydraulic fracturing practice?
9. Would the key stakeholders in Scotland responsible for environmental protection welcome the new concept of implementing the greener hydraulic fracturing in Scotland?

The research work currently being undertaken is attempting to provide the answers to these questions.

This paper presents the initial findings of this study which aims to develop a Project Management methodology for implementing a greener hydraulic fracturing in Scotland at the same time minimizing the impact on health and the environment. The main objectives of the study are to:

1. To determine To determine if more environmentally friendly best practice methods can replace the current methods to help increase sustainability of fracking
2. To identify the key stakeholders responsible for the environmental protection in Scotland and assess the views of these stakeholders in the proposed greener hydraulic fracturing practice as well as its application by the potential oil and gas industry in Scotland.

3. To find out the real benefits associated with greener hydraulic fracturing over the traditional hydraulic fracturing practices.

II. LITERATURE

Hydraulic fracturing which is also known as “Fracking” is a technique for tapping unconventional oil and gas reserves that are otherwise inaccessible. In the early 2000s, energy companies began combining the horizontal (or directional) drilling with hydraulic fracturing to tap these reserves [11]. The process involves drilling horizontally through a rock layer and injecting a pressurized mixture of water, sand, and other chemicals that fractures the rock and facilitates the flow of oil and gas [12].

Hydraulic fracturing or fracking is an innovation in the world of natural gas and it has already achieved significant results in United States and some parts of Europe. As fracking is in its early stage in the UK, only one shale gas has been so far tested in order to ascertain the health and environmental impact before any large-scale development [13].

One of the major impacts of the traditional fracking method relates to water availability and quality since the Hydraulic fracturing requires 2 – 10 million gallons of water per well per fracture [14], equivalent to nine Olympic-size pools, using an average of 22.7 million litres of water [15]. However, the exact amount of water varies depending on the size of the area being exploited, the depth of the well and the geological characteristics of the formation [47; 48].

Jacquet [16;17], highlighted that communities may face strains on public services such as schools, recreation facilities, water and sewage, and healthcare as well as infrastructure such as roads, all due to increased demand as new workers and industry move into an area.

Simon Johnson [18] comments on the state of indecision by the SNP ministers over allowing fracking in Scotland as well as the controversial consideration of best shale gas reserves in the County’s most densely populated parts. This is due to the impact of fracking on both health and environment if operated in a traditional way.

A study published by the British Geological Society and Survey [19; 20; 21; 22; 23] on the Carboniferous shale of the Midland Valley of Scotland: geology and resource estimation shows there are 80 trillion cubic feet of shale gas in central Scotland and six billion barrels of shale oil. The map of the most promising areas highlighted the Midland Valley, also known as the Central Lowlands, a swathe of the Central Belt that includes Edinburgh, Glasgow, Stirling, Motherwell, Falkirk and a large part of Fife. Other possible areas for this development include Caithness, Orkney, the Moray Firth coast and the Inner Hebrides. Murdo Fraser, the Scottish Tory energy spokesman (Telegraph 2014) categorically affirmed thus “Fracking has revolutionised the US market, and Scotland cannot afford to be left behind on this matter.” [24]

According to Lloyd-Smith and Senjen [25], the major drivers regarding the implementation of fracking practice in US and part of Europe are change of climate, sustainable/renewable energy. The main issues of concern

include hazardous waste dumping, air pollution, soil and water contamination.

The United States, in particular, has aggressively embraced this unconventional drilling technology “hydraulic fracturing” regardless of its detractor’s opposition to avoid such practice at all cost. However, this shale gas boom has positioned the United States to become an overall net exporter of natural gas.

Unfortunately in some countries, adequate measures and safeguards have not been fully employed in order to protect people and the environment from the potential hazards of fracking. Owing to this singular reason, the general view regarding fracturing is rather negative, with fracking having the propensity to be dangerous, destructive and polluting. In an attempt to resolve the current controversy regarding hydraulic fracturing in Scotland, there must be well-structured safeguards which are strictly adhered to and duly endorsed by the Oil and Gas industry. These will then give Scotland the assurance that the health of citizens, safe drinking water and property values will not be heavily impacted and that a more defined healthy and sustainable hydraulic fracturing which is known as a greener fracking will be pursued.

III. KEY ISSUES FOR IMPLEMENTING HYDRAULIC FRACTURING

In the UK at large, the supply chain of drilling rigs as well as fracking units is in its infancy as compared to the US. This implies that comparatively, the UK cannot, for now, measure up with the US in terms of cost advantage. Also there is a scarcity of rigs capable of drilling horizontally. Regardless of any challenging economics, Scotland is likely to pursue fracking if there is interest and determination to look at tapping unconventional gas from their vast shale through hydraulic fracturing technique owing to its benefits both now and in the nearest future.

In terms of regulatory barriers and populated areas, Hydraulic fracturing could be circumvented in the following areas [6];

1. Where there is water scarcity.
2. In a close proximity to densely populated areas.
3. In areas where agricultural production is promoted.

For education and training, developers should be trained and encouraged to implement a Zero-venting and minimal flaring policy in order to minimize climate impacts. Regarding skills and expertise, professional training should be given on how to handle surface spills and leaks from wells to ensure that any waste fluids and solids are disposed off appropriately.

Injection wells should to minimize any risk of corrosion since CO₂ has the tendency to corrode steel and also has the potential to react with materials used in well construction [26].

Regarding environmental concerns, in order to gain support from the Government and local population, the industry must provide a full disclosure of products used in the hydraulic fracturing process to exclude any harmful substances.

Well design and cementing should be completely quarantined from other strata especially from freshwater aquifers.

Monitoring and enforcement procedures ensure that this framework is always strictly adhered to.

Therefore the following factors are of utmost importance for implementing hydraulic fracturing in Scotland.

1. Challenging economics
2. Regulatory barriers
3. Environmental concerns
4. Government and local population support
5. Lack of skilled labour unlike the US
6. Education and training
7. Population density
8. Monitoring and enforcement procedures

IV. GREENER HYDRAULIC FRACTURING OPTION

Results from the feasibility study indicate that the traditional way of operating fracking is generally seen as bad practice primarily due to water contamination issues [27], particularly the correlation between hydraulic fracturing and drinking water and its negative impacts on public health and the environment. Many people have already come to the conclusion that any efforts made to regulate fracking to make it beneficial and safe will not make a difference, and that fracking will lead to the destruction of the local environment. No amount of safeguarding will prevent this. The environment will be destroyed if fracking goes ahead.

The only way to address this barrier is to introduce a greener and better way of conducting fracking with other fluid options which will make the whole cycle sustainable with minimum impact on health and environment.

The chief executive of the Calgary Alberta-based energy services firm GasFrac, made it clear "We're actually using hydrocarbons to produce hydrocarbons" [29]. For this practice to be fully implemented in Scotland, effort could be made in exploring and expanding fluid options that are sustainable, looking at the benefits as well as pros and cons which will then convince our people that our environment and people’s health are protected.

Possible fluid options other than using 100% water would be looked at in detail, with comparison in terms of benefits and environmental impacts in order to recommend the best form of greener fracking practice in Scotland.

A. Recycling and Flow-back Water at the Drill Site

Professor Benny Freeman and his research team in the McKetta Department of Chemical Engineering, at The University of Texas at Austin, demonstrated the possibility of using recycling flow-back water at the drill site as the most advantageous way of conducting hydraulic fracturing processes. Below are the pros of using recycling flow-back water at the drill site:

1. A cost-effective way of conserving water and energy.
2. Saves roads from wear and tear.
3. Keeps production costs down.
4. Reduces the environmental impact

B. Use of Poly C₃

Poly C₃ is a stimulant used in hydraulic fracturing which is an energized blend of 70% propane and 30% water. Its benefits include:

1. Enhanced proppant placement with Emulsion/ Foam based viscosity.
2. Compatible with Hybrid LPG delivery system.
3. Over 400 tonne delivery capacity, for multiple proppants.
4. 100 MPa pressure rating and pump rates up to 10 m³ per minute.
5. Utilizes propane as the energizing phase of the Emulsion/Foam.
6. Minimal Flaring – immediate sales: early recovery of flow back down sales line, as compared to alternative energizers of CO₂ and N₂.
7. Propane is pumped in liquid phase on surface, resulting in an increased hydrostatic head, as compared to gaseous based energizers.
8. On formations above 96°C, the propane will become a supercritical fluid with properties of a gas, resulting in increased diffusion and zero surface tension, which enhances mixing with formation hydrocarbons and improves fracture clean up.
9. Customer supplied NGL fluids could be designed to replace the Propane. (Poly NGL)

C. Use of Hybrid LPG

Liquefied petroleum gas, commonly called LPG, is also known by the names of its principal generic components, propane and butane. The use of Hybrid Liquefied Petroleum Gas option is a waterless fracturing process. Benefits of using the hybrid LPG include:

1. More productive wells and easier cleanup of wells.
2. Increased long term production and lower Life cycle of well costs
3. Potentially fewer wells and enhanced recovery rates
4. No investment in water handling infrastructure
5. Lower environmental and ecological impact and what is seen as a liability of existing water methods can be turned into an asset.
6. Minimized flaring and thereby, immediate to gas sales.
7. Does not cause clay swelling.
8. Maintains higher relative permeability to oil.

In view of the possible fluid options of implementing a greener hydraulic fracturing in Scotland and to gain a wider acceptance, Option C which is the use of Hybrid Liquefied Petroleum Gas is recommended. Hybrid LPG is considered as the best option because the technology eliminates water requirements for hydraulic fracturing process and also eradicates the need to remove waste water from fracking sites, which is difficult to dispose of. Avoiding the use of water in fracking will certainly help to minimize general negative perception regarding fracking.

V. PROJECT MANAGEMENT METHODOLOGY FOR GREENER HYDRAULIC FRACTURING

Project management methodology is commonly defined as a set of methods, techniques, procedures, rules, templates, and best practices used on a project. Project management methodology is defined as a structured way to manage projects consisting of rules and directions and is based on specific way of thinking [30]. Additionally, project management methodology can be defined as set of guidelines and principles that can be tailored and applied to specific situation, where guidelines could be as simple as a task list, or it could be specific approach to project with defined tools and techniques [31].

The key objective of the project management methodology is to upsurge the likelihood for successful project delivery [33; 34; 35], which will invariably convey consistency and flexibility that will lead to project team efficiency [31; 34; 36; 37]

The realistic Project Management methodology for conducting and monitoring greener hydraulic fracturing in Scotland are:

1. **In initiation state-** The United Kingdom is seen as a new entrant into the Hydraulic fracturing industry, which is yet to operate on a commercial scale. The fact that this industry is in its infancy can help in the implementation of greener hydraulic fractioning measures early on in its development to prevent future negative impacts. However, adopting the recommendations of Mair et al [38], will help to ensure that the prospective well is designed and built to the highest possible standards. Also, these engagements will guarantee that wells are properly designed and any known potential risks are being reduced or mitigated beforehand.
In addition, the prospective fracking company must concede to all the greener fracking practices and this must be clearly defined ranging from the business case, Scope and deliverables, objectives as well as risks and mitigation.
2. **Planning and Design** – The industry must ensure that wells are properly designed, cemented and completely quarantined from other strata especially from freshwater aquifers. Injection wells should be designed to minimize any risk of corrosion since CO₂ has the tendency to corrode steel and has the potential to react with materials used in well construction [26]. All wells also need to be designed and constructed to provide long term operational integrity through adherence to the Well Integrity Guidelines, [39] and enables abandonment in accordance with the Well Abandonment Guidelines, [40].
3. **Execution** –It is imperative that the regulations laid down by the governing bodies to implement greener hydraulic fracking be implemented by industry and monitored by the appropriate agencies. The agreed more environmentally acceptable options must

always be implemented with failure to comply resulting in an exorbitant fine or license forfeiture. If for example waterless hydraulic fracturing is being used, it must be waterless hydraulic fracturing without any compromise. The project manager responsible must always check and confirm that whatever process to be carried out is in line with the agreed endorsed regulation. Also, effective sealing of the methane leakage is very and will help to limit harmful emissions as a fracking byproduct. Methane is the main ingredient of natural gas, and the hydraulic fracturing operation whether by greener or traditional method has the capability to cause methane to escape from the ground. If lost to the atmosphere, this methane becomes a significant global warming agent which is 34 times more effective than Carbon dioxide [41]. In practice, studies have revealed a high level of methane leakage [42; 43; 44]. However, the production of unconventional gas without methane leakage is technically achievable [45]. There must be adequate measures to reduce or control the methane leakage during the hydraulic fracturing process. According to the Environmental Protection Agency, methane accounts for 9 percent of the U.S. greenhouse gas emission inventory, but its share is expected to grow over time.

4. **Monitoring and Controlling** – Effective control and better monitoring is a must and is essential to understand and prevent the chances of well integrity failure and the resulting impacts. It must be categorically stated and agreed that a project may be stopped before completion if various specific requirements are not met, thus ensuring the legal and environmental as well as project requirements are strictly adhered to. There is currently no monitoring of abandoned wells in the United Kingdom [46]. This should be rectified as it is likely that if fracking proceeds, these wells will become abandoned in the future. For this reason it is necessary that appropriate controlling and monitoring processes are in place to minimize after well abandonment legacy issues associated with hydraulic fracturing.
5. **Closing** – It is very important to be aware that like any other well, a shale gas well is abandoned once it reaches the end of its producing life when extraction is no longer economical. It must be agreed that sections of the well are properly filled with cement to prevent gas flowing into the water-bearing zones or up to the surface. Also, a cap must be welded into place and then buried. In addition, abandoned wells could be checked 2 to 3 months after cement plugging for sustained casing pressure and gas migration. In the event that the well has no evidence for barrier or integrity failure, it could be cut and buried as per regulations.

VI. CONCLUSION AND FUTURE WORK

This paper discussed Hydraulic fracturing as a potential process for extracting oil and gas that is inaccessible via other means. The paper also highlighted the possible environmental greener options which could help to reduce the opposition to implementing hydraulic fracturing in Scotland. A project Management methodology was proposed as a guide to ensuring proper implementation with a focus on environmental considerations.

This paper presents the initial findings and recommendations. Further work includes interviews with major stakeholders and environmentalist in Scotland.

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