THE ECONOMICS OF SHALE GAS EXTRACTION

Dr. Craig Dalzell

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Authors’

Dr. Craig Dalzell is an MSci and PhD in Laser Physics and Photonics. He is an activist and researcher and runs a politics and economics blog at thecommongreen.wordpress.com
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Abstract

The potential environmental impacts of shale oil and gas extraction (SGE) by means of hydraulic fracturing (“fracking”) have been well explored by various groups concerned by this newly prominent technology but rather less well known by campaigners and activists are the economic impacts. This report looks at key questions regarding the economic structure and impact of the SGE industry and the findings are detailed.

Executive Summary:-

- The SGE market in the US and, so far, in the UK is dominated by larger companies occupying the most profitable licences. There is little scope for community owned or small company development to occupy a significant market share.

- Individual wells become largely non-productive within a few years of development which, due to market demand for constant production, forces companies to continue drilling new wells in new locations at a rapid pace.

- The low recoverable volumes and high capital and running costs of wells may render profit margins comparatively small and extremely sensitive to oil and gas pricing. There appears to be little scope for economic development of SGE in the UK until and unless wholesale prices return to historic highs and even then significant subsidy may be required.

- Communities are likely to be significantly adversely impacted by nearby SGE fields. The concentrated pattern of land ownership and comparatively weak situation of local government renders communities vulnerable to being unable to capture wealth generated by nearby wells whereas the burden of environmental degradation or even simply the threat of such degradation can lead to community stress and negative economic effects.

- The jobs created by SGE appear to be short-lived and highly mobile. The job demographic of the planning, drilling and production phases are each relatively exclusive meaning that they will move to the next site more rapidly than the wells themselves do. This creates the risk of a “Boom-Bust” effect in communities.

- Shale oil and gas is considered a relatively poor source of fuel due to high extraction costs. The UK’s reserves are also likely to have an insignificant impact on global markets and hence a negligible impact on end-user prices.

- Significant externalities have been identified in the form of environmental degradation due to methane leaks. The costs to mitigate these may exceed the lifetime revenues generated by the well which produced them. Further, the UK has a poor record in terms of ensuring adequate decommissioning and restoration bonds which may lead to further public funding being required after the SGE companies have left an area.
1. Introduction

Shale gas extraction (SGE) by means of hydraulic fracturing ("fracking") is a form of Unconventional Gas Extraction currently being explored by the United Kingdom Government as a potential fuel and hydrocarbon feedstock source to be exploited in the coming decades. It is seen as a potential replacement and/or continuation of the maturing hydrocarbon sources of the North Sea and other deposits within the UK’s geographic control. This source of gas, already in use in many forms in the United States, is experiencing significant opposition from many groups concerned chiefly with its environmental impact\(^1\)\(^2\)\(^3\)\(^4\), but somewhat less well explored are the economic impacts. The purpose of this briefing paper will be to outline how SGE sites are financed (“Who pays for them?”), the typical profitability profiles of such wells (“How much money do they earn and who gets that money?”), the economic impact on communities near the wells (“Do they boom or bust?”), the actual effectiveness of SGE as a source of fuel (“Will it reduce fuel prices?”), and the broader costs associated with SGE which may or may not be directly paid for during extraction (“Who cleans up the mess?”).

2. Shale Gas Extraction

The economics of hydrocarbon extraction has always been a balance between the impact of depleting supply of easy-to-reach resources (which increases extraction costs and decreases available reserves), improving technology (which decreases extraction costs and increases available reserves as new deposits become accessible), and the demand for the resources (which influences sale price). In recent years, the technological side of gas extraction has opened up the possibility of exploiting on a mass scale previously inaccessible shale gas reserves.

In a conventional hydrocarbon deposit, the simple view is one of a “pool” of oil and gas loosely bound to the surrounding rock matrix and capped by an impermeable layer of minerals. The layer is pierced by a single drill and the resources from a significant portion of the reserve is recovered through the release of the pressure within the deposit. Additional technology, such as injecting liquids or gas into the reserve, can be used to increase the deposit pressure and extract more resource.

In a shale deposit, however, the oil and gas is far more tightly bound to the surrounding rock matrix and the intrinsic pressure of the deposit is insufficient to release the resources. Therefore methods such as hydraulic fracturing (known popularly as “fracking”) may be deployed whereby the rock is injected with fluid, chiefly water, sand plus a (usually propitiatory) mixture of chemicals under high pressure which fractures the rock matrix and widens and keeps open the cracks produced. Further fluid is then injected to push the oil and gas out of the rocks and to the extraction well.\(^5\)

3. The Market Structure of the SGE industry

The US SGE industry has been popularly typified as one in which many small companies, known as “mom-and-pop companies” can easily enter and profit. A significant study of the demographics of the industry\(^6\) however has shown this idea to be “inaccurate and misleading”. In reality, a significant power law is in effect. Whilst in many areas where marginal costs are higher and resource “plays” (a play is a more-or-less continuous deposit of hydrocarbons) are smaller, the larger companies appear to have less interest in exploiting and smaller companies can enter, the larger companies have both the financial and lobbying power to buy up the large, more profitable licences and they have the capital power to link their wells into the national infrastructure. The study found that of the 1,818 extraction companies within the study area, 71% of them drilled only a single well but that just four companies (Chesapeake Energy, Devon Energy, XTO Energy, and Southwestern Energy) drilled more than 40% of all the wells in the area. This mirrors closely the current UK situation where a few large companies (such as Cuadrilla Resources, Igas Energy, Dart Energy and INEOS) dominate the licensing market so far with numerous smaller companies coming in behind them. Unlike the US situation however, there appears to be negligible information regarding independent single well operators run by individuals or communities. Instead, the focus appears to be towards land leasing, revenue shares and community benefit funds. The impact of these shall be discussed in a later section.
4. Direct Profitability of SGE

Due to the tightly bound nature of shale oil and gas to its surrounding rock matrix a single well is only able to extract gas from regions of rock which have been directly drilled and fracked. Whilst advances in well technology such as horizontal drilling allow extraction from a far larger region of shale than early wells, they do not typically significantly increase well lifetime. The fact remains that wells in the United States are typified by high initial extraction rates and a very rapid drop off with an extraction rate half-life (the time taken for extraction rates to drop by a factor of two) of around six months⁷ and a total well lifetime of 3.5 years, far shorter than the decades long experiences of rigs in the North Sea.

Estimating the costs of extraction are somewhat harder and more involved as upfront land, capital and ongoing running costs, as well as local taxes and levies need to be considered. These factors have been studied in detail¹²¹³ but still provide a very wide range of lifetime costs for an individual well of between $3.0 million and $8.0 million per well. On these estimates and using the IOD’s central estimate for production we can therefore roughly estimate the floor gas price required to break even on these wells. For the lower bound of $3.0 million per well, the break even point occurs at gas prices of a little under $10 per thousand cubic feet. The higher bound break even isn’t reached until $26 per thousand cubic feet which is twice the all time gas price high which was $13 per thousand cubic feet seen in June 2008. (For comparison, though oil prices are only loosely correlated to gas prices¹⁴, if one converts based on energy content, this roughly corresponds to an oil price of $156 per barrel, significantly above recent historical highs.)

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From this, it can be concluded that both shale oil and shale gas are unlikely to be economically viable in this current low hydrocarbon price environment and even if there is a return to recent higher prices; it is likely that the industry would require significant subsidy or significant efficiency progression before it could be used at any kind of scale.

For comparison, the Institute of Directors’ study of UK shale gas potential used estimates for initial production rates of around 2.5 million cubic feet per day¹⁰ which could imply a recoverable resource per well of around 310 million cubic feet.

The production decline curve typically follows a hyperbolic function in which 50% of the total recoverable resources are extracted within the first six months of production, 80% within the first year and 95% within the first five years. If required, a detailed analysis of this decline is provided.⁸

For the purposes of this brief, however, it can be useful to approximate this decline curve to an exponential decline curve, and from that estimate the total recoverable resources, $R$, from a single well at approximately:

$$R = P_{initial} \cdot t_{half} \cdot \frac{1}{\ln(2)}$$

Where $P_{initial}$ is the initial production rate per day and $t_{half}$ is the production rate decline half-life in days.

For the well shown in Figure 2⁷, with an initial production rate of 550 barrels per day this would imply a recoverable resource of approximately 82,000 barrels of oil equivalent with a gross market value of between $2.7 million and $8.2 million assuming an oil price of between $45 and $120 per barrel.

It should be recognised that well yields themselves will vary significantly and cannot easily be predicted ahead of time. Typical initial yields found in the US are highly dependent on the geology of the shale oil deposits and can lie at anywhere from less than 100 barrels per day to above 800 barrels. Shale gas deposit initial production rates appear to range between 1 and 11 million cubic feet per day⁹ which would imply total recoverable resources per well of around 125 – 1370 million cubic feet of natural gas with a value of $430,000 - $4,800,000 at current wholesale prices of $3.5 per thousand cubic feet (a price which is near a 15 year low).¹⁰

Figure 2: A typical production decline curve of a shale gas well in the United States.

![Williston Basin Production Type/Decline Curves](image)
5. Economic impact on communities

Much of the positive encouragement for SGE has been focussed around “community benefit” either in terms of high skill jobs brought into an area or in terms of direct financial reward due to the presence of the industry. Both of these arguments have been challenged in the experience of the United States.

The workforce structure has been documented in detail by the SGE industry and estimates that each SGE well would directly employ around 9.82 Full Time Equivalent (FTE) jobs directly. Some promotional material will also produce figures for indirect jobs created or sustained by an industry but there must be caution over such numbers as they are often unverifiable and highly inflated. In particular, examples are found where a “FedEx” driver who already had a sustainable job but made a single delivery to an SGE company were claimed as “created or sustained” by the SGE.

Of the jobs directly created or sustained by a well, these can be examined to find their role within each particular phase of a well’s lifetime.

"The experience in America has often been one of “Boom and Bust” in which a community has grown rapidly then crashed. Across all energy mineral extraction industries, the median time for a community to recover to pre-Boom economic activity after a Bust has been 20 years."

The second community “benefit” of SGE, the direct financial rewards, come from three primary sources. The leasing and/or sale of land on which the wells are built. The revenue generated from each well either by individual and community ownership, or direct royalty income and community managed benefit funds similar to those familiar within the onshore wind industry in Scotland. It is noted in the US case that there is a severe risk of uneven distribution of income generated by such means, as leasing and direct royalty share is highly dependent on even ownership of land. Where large blocks of land are held by few landowners, they will disproportionately reap the majority of the income. It has also been noted that the effectiveness of indirect community funds is directly proportional to the strength and effectiveness of local government to administer them. In Scotland, with our extremely concentrated patterns of land ownership and comparatively weak local and regional governments, it can be surmised that the risks of uneven wealth distribution would be even greater than that seen in the US. Further, with the rapid decline in production yields from each well, even in the case of effective and even distribution of income, a community may be left paying for the negative consequences of the drilling (either from economic bust or from environmental degradation) long after the income from the well has literally dried up.

In addition to the direct impact of SGE, a high risk of socio-psychological stress and disruption has been identified. A rapid boom may lead to rapid industrialisation and subsequent collapse of a rural community leading to a loss of identity as what may have, in one example, previously identified as a “fishing village” becomes a derelict industrial estate. Community stigma has also been identified as a risk factor. The activities of environmental activists have raised the negative profile of SGE through examples of pollution, gas leaks and even burning tap water to the point that even if a community heavily involved in SGE doesn’t actually experience any of these negative effects there is a widespread identification that it might. As one person in a SGE study said: “I don’t think the problem is our water is bad. I think the problem is everyone thinks the water is bad.”

This effect can have significant implications both on community health and on the potential for economic sustainment and recovery after SGE operations have concluded as it could be seen as a barrier to attracting replacement investment.

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* When reviewing the literature on this topic there must be great care in the definition of terms. Some measures of EROI will measure at wellhead. Some will include transmission losses. Some will go further and attempt to include final end-user calculations including losses in converting fuel to electricity (usually ~40% of the EROI value at delivery to the plant).
6. Economics of SGE as a fuel source

One of the touted benefits of shale oil and gas is in its potential as a replacement fuel for dwindling offshore reserves and its potential to significantly reduce energy bills for consumers. To investigate this, an exploration of the Energy Return on Investment (EROI) should be conducted. EROI is, as implied by the name, a measure of the usefulness of an energy source as a fuel. If EROI is less than 1.0, then more energy is required to extract, transport, process and deliver the energy source than will be gained in its use. This would obviously render it useless as a fuel. But it turns out that an EROI of just above 1.0 is insufficient. There must be a degree of free energy released for it to be usefully used after various losses and inefficiencies are accounted for. For a modern, advanced industrial economy as found in the UK an EROI somewhere in the region of 5-9\(^\text{25}\) is considered the minimum bound for a useful fuel source. The table below outlines a few common fuel and electricity sources with their EROI values.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>EROI</th>
<th>Measured At</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>20</td>
<td>Generator</td>
<td>26</td>
</tr>
<tr>
<td>Hydro</td>
<td>40-250</td>
<td>Generator</td>
<td>27</td>
</tr>
<tr>
<td>Solar</td>
<td>6</td>
<td>Generator</td>
<td>28</td>
</tr>
<tr>
<td>Nuclear</td>
<td>5</td>
<td>Generator</td>
<td>29</td>
</tr>
<tr>
<td>Conventional Oil</td>
<td>10.7</td>
<td>Pipeline</td>
<td>30</td>
</tr>
<tr>
<td>Shale Oil</td>
<td>11-1.8</td>
<td>Pipeline</td>
<td>31</td>
</tr>
<tr>
<td>Conventional Gas</td>
<td>10-18</td>
<td>Consumer</td>
<td>32</td>
</tr>
<tr>
<td>Shale Gas</td>
<td>8-12</td>
<td>Consumer</td>
<td>33</td>
</tr>
</tbody>
</table>

From this, it can be seen that shale gas has an energy return which is significantly less than conventional gas sources therefore could never, in terms of energy efficiency and hence CO2 emissions, be more than a partial replacement for conventional gas. With more shale gas being burned per unit energy than conventional gas, it therefore cannot be assumed that prices will reduce in the long term due to the introduction of SGE.

A particular concern is raised with tightly bound shale oil which has an EROI which barely breaks even. If an economic energy efficiency case is to be made for any particular fuel source then the clear front-runners are the renewable sources, even solar which whilst at the lower end of acceptable is surely rising as technology improves. Any energy policy which diverts investment, public or private, away from renewables and towards SGE should therefore be regarded as sub-optimal.

Further, evidence taken by the House of Lords, which looks at the overall potential impact of UK shale gas on the global market stated that the volumes that the UK is capable of bringing to market, even in optimal conditions represents only a small fraction of the global market and hence will have negligible impact on global pricing.\(^\text{31}\) Simply put, the UK will not be creating a resurgence of cheap fuel due to it's use of SGE.

7. Externalities — Cost of decommissioning and clean-up

Whilst the negative environmental impact of SGE has not been the focus of this briefing, the economic impact of those negative effects should be considered. It is not currently usual for the sources of atmospheric pollution to be directly and preemptively responsible for paying for the mitigation of the effects of that pollution (be it direct contamination of an area or economic degradation of land due to climate change or suchlike) as it is often difficult to quantify. One study into the actual economic costs of CO2 emissions\(^\text{32}\) put the “price tag” of a releasing greenhouse gases into the atmosphere at $220 per short ton of CO2 equivalent. In a shale gas well, a quantifiable volume of the total resources will leak either during the drilling process or throughout production. Evidence from the US suggests that, typically, a shale gas well can leak some 3.6 – 7.9% of its total recoverable resource into the atmosphere\(^\text{33}\) with some studies finding evidence of wells leaking up to 12% of their methane into the atmosphere.\(^\text{34}\) Shale gas is mostly comprised of methane and that methane is approximately 25 times as powerful a greenhouse gas as carbon dioxide when considered over the course of a century. If we assume a fairly conservative leakage rate of 4%, and apply that to the IOD’s estimate for a typical UK well as outlined in Section 4, we can estimate that one such well could leak some 265 short tons of methane into the atmosphere over its lifetime. This would be the equivalent of 6,635 short tons of CO2 and would, on the basis of the clean-up costs study, have a mitigation price tag of a little under $1.5 million. Combined with the high capital and running costs of the wells and especially in this era of low prices, this clean up cost could very well exceed the total lifetime revenues of the well. In short, whilst SGE may earn significant revenue for the owner, it may come at a net negative economic price for the surrounding community and the planet itself.

"Combined with the high capital and running costs of the wells and especially in this era of low prices, this clean up cost could very well exceed the total lifetime revenues of the well."

Another external factor of particular note in Scotland is the responsibility for cleaning and restoring the landscape of the drilling area after the well has been decommissioned. In theory, the company drilling is either directly responsible for clean-up or must put in place some kind of bond or investment fund so that clean-up can still occur even if the company collapses, liquidates or is bought over and no longer exists at the time of decommissioning. Scotland has had long examples of failures of this system within the coal\(^\text{35}\) and, more recently, the steel industry\(^\text{36}\) which have been documented elsewhere. Companies have sometimes put significant effort into avoiding their responsibilities to decommission and, especially when governance has been
weak or corrupted, there often has been a lack of political will to enforce regulations to its full effect. A failure of this kind would represent yet another effective subsidy to the industry and a cost to the public purse which may have knock on feedbacks in the form of deeper than required cuts to public services or tax rises to compensate.

8. Conclusions and Recommendations

It is the opinion of the author that the economic case for shale gas and oil extraction has not been sufficiently made to warrant expansion of the industry in Scotland or the UK. It will likely require substantial subsidy to overcome weak and volatile wholesale prices, will not itself provide an inexpensive or effective source of fuel for end users and carries with it the risks of substantial costs to community health, cohesion and wellbeing as well as external costs to the environment which may not be paid for by those who cause the damage. Further, Scotland appears to be at particular risk to issues arising from unequal wealth creation due to concentrated land ownership and weak regulatory enforcement due to potentially poor local governance and oversight. Until and unless these issues are adequately resolved, investment resources should be deployed into more effective energy sources such as renewables and the current Scottish moratorium on SGE should be rolled out geographically to the whole of the UK and extended indefinitely.
9. References


24. ibid


