Economic viability of UK shale gas and potential impacts on the energy market up to 2030

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HIGHLIGHTS

- UK shale gas is 2 times more expensive than LNG and 3 times more than US shale gas.
- Nevertheless, it is still more competitive than most other sources of electricity.
- Shale gas would have little effect on energy prices and consumer bills.
- The contribution to the GDP is small, an order of magnitude lower than in the US.
- The economic success of shale gas in the US may not be replicated in the UK.

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ABSTRACT

The UK is in the early stages of developing a shale gas industry and to date six test wells have been drilled but none yet exploited commercially. Some argue that shale gas could reduce energy prices and improve national energy security. However, the costs of bringing commercial-size wells into operation are uncertain and the impact shale gas could have on the UK energy market is currently unknown. Therefore, this paper evaluates the economic viability of developing a UK shale gas industry and the impacts it could have on the UK gas and electricity markets and consumer energy bills up to 2030. The estimated life cycle (levelised) costs of shale gas production range from 0.47 to 56.74 pence/MJ (0.61–73 US$ cents/MJ), with an average value of 4.64 pence/MJ. The break-even price at which shale gas can be sold varies between 0.95 and 114.44 pence/MJ, averaging at 9.47 pence/MJ, depending on the volume of gas produced by a shale gas well. The latter is two times higher than imported liquefied natural gas, around 30% more expensive than UK natural gas and three times greater than the price of US shale gas. Electricity from shale gas is on average 17% more expensive than from domestic conventional gas but still more competitive than most other electricity options, including coal and renewables. However, the impact of shale gas on the energy market would be limited across the expected range of shale gas penetration into the gas and electricity mixes, suggesting that it would have little effect on energy prices. This is reflected in an almost negligible impact on consumer energy bills. The potential of shale gas to boost the UK economy is also limited, contributing 0.017–0.033% to the GDP. This is an order of magnitude lower than the contribution of US shale gas to its GDP (0.2%), indicating that the economic success of shale gas in the US may not be replicated in the UK. These findings will be of interest to shale gas developers and policy makers not only in the UK but in other countries considering exploitation of shale gas resources.

1. Introduction

Shale gas is seen by many countries as a future source of affordable energy and improved energy security. Estimates suggest that it could double current global gas reserves, adding nearly 7299 trillion cubic meters to the total [1,2]. Given that gas consumption is expected to increase by up to 50% by 2035 [3,4], it is not surprising that many countries are considering exploiting their shale gas deposits. However, at present, the US is still the only nation to produce it commercially on a large scale. This has led to low gas prices and (almost) self-sufficiency in gas supplies, with the country expected to become a net exporter of gas by 2020 [5]. The contribution of the shale gas sector to the gross domestic product (GDP) and tax revenue is significant, estimated in 2010 at $76.9 m and $18.6 m, respectively [6]. The indirect benefits through

Nomenclature

b	Arps decline exponent (–)
$CC_{E,k}$	capital cost of the power plant in year k (£/year)
$CCO_{2\ k}$	cost to the power plant of emitting CO_2 in year k (£/year)
$CC_{SG,n}$	capital cost of producing shale gas in year n (£/year)
$CF_{E,k}$	cost of fuel to the power plant in year k (£/year)
$CL_{SG,n}$	labour costs of shale gas production in year n (£/year)
$COM_{E,k}$	operating and maintenance costs of electricity generation in year k (£/year)
$COM_{SG,n}$	operating and maintenance costs of shale gas production in year n (£/year)
$C_{SG,n}$	total costs of shale gas production in year n (£)
D_i	initial decline constant (month^{-1})
d_n	the depreciable basis in year n (value of assets minus salvage value) (£/year)
$D_{SG,n}$	depreciation in year n (£/year)
E_k	net electricity generation in year k (kWh/year)
E_{SG}	energy content in shale gas produced over the lifetime of the well (kWh)
EUR	estimated ultimate recovery of shale gas over the lifetime of the well (m^3)
i	discount rate for shale gas (interest charged on loans) (–)
K	lifetime of the power plant (years)
k	year k

LCC_E	life cycle costs of electricity generation, also known as levelised electricity costs (pence/kWh)
LCC_{SG}	life cycle costs of producing shale gas (pence/kWh)
LHV	lower heating value of shale gas (kWh/m^3)
m	month m (month)
M	total number of months over the lifetime of the well (months)
N	lifetime of the shale gas well (years)
n	year n (year)
$NE_{SG,n}$	net earnings from shale gas in year n after tax (£)
NPV_{EC}	net present value of total expected costs of electricity generation (£)
NPV_{EG}	net present value of expected electricity generation over the lifetime of the plant (kWh)
NPV_{SG}	net present value of total expected costs of shale gas production (£)
p	unit price at which gas is sold (£/kWh)
q_i	initial shale gas production (m^3)
r	discount rate for power plant (interest charged on loans) (–)
$R_{SG,n}$	gross revenue from shale gas in year n (£/year)
t_d	depreciation tax allowance (–)
t_r	tax rate (–)
$V_{SG,n}$	volume of shale gas produced in year n (m^3/year)

boost to industry in general are estimated to be worth billions, including a $72 bn in investment by 2020 [7].

Elsewhere, exploitation of shale gas is lagging behind so that economic impacts in other countries can only be estimated; these estimates are summarised in Table 1 [8]. As can be seen, shale gas is much more expensive to produce in other countries than in the US. One of the reasons is the lack of infrastructure and expertise available in the US. Furthermore, all shale gas wells are different, requiring different equipment and, consequently, the investment required is too high for many companies [9–11]. In addition, test wells have been reported to be less productive than expected [8], making them uneconomic for development.

Hoping to emulate the US experience, the UK government is trying to promote shale gas development and has introduced a favourable tax regime to encourage investment [12,13]. However, shale gas is a contentious issue in the UK with significant public opposition, largely because of potential environmental impacts and effects on local communities [14–17]. In an attempt to address some of these concerns, the government has set up a fund to be financed through shale gas tax revenue, aimed at benefiting communities affected by its development [13].

Despite this, the UK's shale gas industry is still in its infancy. Only six wells have been drilled and one hydraulically fractured since drilling began in 2010, all of which are exploration wells [18–20]. At the time of writing, the seventh well is being drilled in the north of England, with the aim of commercial exploitation [21]. As a result of the slow progress and small scale of activity, the economic viability of producing shale gas is still uncertain.

Therefore, this paper sets out to estimate, for the first time, the costs of producing shale gas in the UK and the implications this could have for electricity prices and for the UK economy. Taking a life cycle approach, the costs of producing and utilising shale gas to generate electricity are estimated, alongside the effects on gas and electricity prices up to the year 2030. The estimated costs are also compared to alternative sources of electricity, including other fossil-fuel options, renewables and nuclear power. While previous studies considered different cost aspects of shale gas [22–28], as far as we are aware, this is the first study to integrate different aspects and estimate full life cycle

costs (LCC) of shale gas from 'cradle to grave'. It is also the first study to compare its cost to other gas and electricity options as well as to consider the potential future effects of shale gas on the UK economy and household energy bills. A summary of the costs and other related aspects considered in this study in comparison to the literature can be found in Table 2.

2. Methods

The method for estimating the LCC of shale gas production and electricity generation is detailed in the next sections, together with the data and key assumptions. Prior to that, the goal and scope of the study are defined below.

2.1. Goal and scope of the study

The main goals of this study are:

- to estimate the LCC of UK shale gas, considering its production and utilisation for electricity generation;

Table 1
Estimated costs, investment and revenue for exploiting shale gas in the US in comparison with other countries (based on [8]).

Country	Estimated costs, investment and revenue
US	Breakeven cost: 2.37–6.47 US$/GJ[a]
Canada	Investment needed (in Quebec): US$5.9–17.7 bn; contribution to GDP: US$27.8–83.3 bn[b]
China	US$1.16 bn invested for surveying and exploration[c]
Australia	Production costs: 4.76–7.14 US$/GJ[d]
Germany	Investment needed: US$7.5–28.4 bn; average production costs: 9.35 US$/GJ[e]
UK	Investment needed: US$50 bn[f]

[a] Estimated from Weijermars [27].
[b] Estimated from Mersich [82].
[c] Estimated from Chou [83].
[d] Estimated from Cook et al. [84].
[e] Estimated from Bonetti [85].
[f] Estimated from AMEC [49], Lewis et al. [25] and Taylor and Lewis [26].