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Economic modelling for coal bed methane production and electricity generation from deep virgin coal seams

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ABSTRACT

An investigation of the economic potential for recovering methane from virgin coal seams for electricity production at a study area in South Wales, UK, is presented. Utilizing the coal bed methane gas to fuel a CCGT (combined cycle gas turbine) will offer a low carbon option compared to fossil fuel fired power generation for the study area. Cost effectiveness is analysed using both technical and economic data allowing for integration connecting the various sub-processes to the surface processes up to the production of electricity. The model considers both reservoir conditions and engineering factors to calculate the EUR (enhanced ultimate recovery), the CAPEX (capital expenditure) and the OPEX (operational expenditure) of the coupled CBM-CCGT process. The projected UK Navigant gas prices and the DECC electricity prices are then used to estimate the LCOE (levelised costs of electricity) and obtain the financial performance of the coupled CBM-CCGT process. Calculation results showed that the probable cost of electricity (LCOE) amounts to 37 £/MWh and the return on investment could be in the excess of 77%. For the selected study area, the coupled CBM-CCGT process could potentially be an economic option for power generation.

1. Introduction

Meeting the challenges of reduced carbon dioxide emissions and the provision of competitive energy costs is more important than ever. Combine these two vital objectives with maintaining the security of energy supply is considered vital and of strategic importance for Europe. In UK, natural gas forms a key part of the energy supply and is important not only for electricity production, but also for domestic heating, cooking and industrial production [12]. In recent years, the UK has become increasingly dependent on gas imports, with annual UK gas consumption of approximately 85 billion cubic meters; while the Government forecasts that nearly 70% of the UK's gas supply will be imported by 2025. In 2012, the BGS (British Geological Survey) estimated that there are approximately 2900 billion cubic meters of onshore CBM (coal bed methane) in UK [10]. Even with a yield of 10%, the potentially recoverable resources of CBM (at 290 billion cubic meters) could contribute significantly to safeguard the energy needs of the country for the next decades to come and until the transition to renewables. Today, there are a number of active CBM production sites in UK, including the one in Staffordshire and Airth in Scotland [14]. Current success in the production of CBM in these areas shows that it could be implemented in other parts of the UK, including South Wales [34].

Coal bed methane is gas of natural origin formed as part of the geological process of coal generation, and is contained in varying quantities within coal [36]. CBM can be recovered by drilling into the coal seams, initially releasing water to lower the pressure and then allowing the desorption of the methane gas from the internal surfaces of the coal, where it is able to flow either as free gas or dissolved in water towards the production well at the surface. By controlling the release of pressure in the coal seam, methane can be captured [28,36,40]. Occasionally, CBM extraction may need to be enhanced by hydraulic fracturing when insufficient natural permeability of the coal exists [9]. Concentration levels of methane recovered via these techniques can often exceed 95%, making the gas suitable for use as a direct replacement for conventional natural gas in pipeline networks. This gas can then be compressed and supplied to market (e.g. heating, chemicals, gas to liquids etc) [26]. The high quality of the gas recovered from unmined coal seams also renders it suitable for replacing or supplementing conventional

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Abbreviations/symbols

q_o	initial production
q_t	production rate
£	English pounds
£m	million English pounds
A	area
CAPEX	capital expenditure
CBM	coal bed methane
CC	carbon cost
CCGT	combined cycle gas turbine
CF	cash flow
CoI	cost of investment
COE	cost of electricity
d	days
DECC	department of energy and climate change in UK
DR	discount rate
DTI	department for trade and industry
E	percent of efficiency
EG	electricity generation
EIA	environmental impact assessment
EUR	estimated ultimate recovery
G_c	gas content of the coal
GCP	gas collection point
GCP	gas collection point
GCU	gas compression unit
GfI	gain from investment
GP	gas produced
GSU	gas storage unit
h	cumulative height of coal
hr	hours
km^2	square kilometres
LCOE	levelised cost of electricity
LR	loss ratio
m	meters
mD	millidarcy
MW	megawatt
MWhr	megawatt hour
n	time period
NEG	net electricity generation
NG	national grid
NPV	net present value
OGIP	original gas in place
OPEX	operational expenditure
OC	outgoing costs
P10	90% probability of meeting or exceeding the estimated proved volume
P50	50% probability of meeting or exceeding the estimated probable volume
P90	10% probability of meeting or exceeding the estimated possible volume
PEDL	petroleum exploration and development licences
R	revenues
RF	recovery factor
ROI	return on investment
T	time period
t	tonne
TC	total costs
UK	United Kingdom
UoS	use of system
ρ_c	density of coal
a	decline rate
n	years

natural gas in a CCGT (combined cycle gas turbine system). A schematic illustration of the CBM-CCGT process is shown in Fig. 1. Successfully developing a coal bed methane field requires prudently managing the technical as well as the economic aspects of the project. The profitability of a CBM (coal bed methane) project is site specific and is highly dependent on various geological and market dependant factors [19].

2. Objectives and methodology

This study presents a transparent documentation of the development and application of a model to investigate the economic viability of methane recovery from unmineable coal seams and the subsequent electricity generation in a CCGT power plant. The model developed for CBM-CCGT COE (cost of electricity) determination is controlled by geological, technical and market dependant model input variables adapted to site specific boundary conditions for any selected target area worldwide. As a case study, data from a well exploited site in the South Wales, UK is considered. Part of the model is to predict the future gas production and electricity generation from a target site, evaluate the CAPEX (capital expenditure) and the OPEX (operational expenditure) of the coupled CBM-CCGT process and determine the LCOE (levelised costs of electricity). Statistical analyses with the use of Monte Carlo analysis were employed and the degree of certainty defined based on the following three scenarios: a) proved estimates (P10); b) probable estimates (P50); and c) possible estimates (P90). Cash flows for the different scenarios were also determined and compared based on the revenues obtained from selling electricity generated from the CBM-CCGT process to the national grid. The basic process layout for the developed model of the coupled CBM-CCGT process is shown in Fig. 2. A detailed description of the model and an application case study is presented in the following chapters.

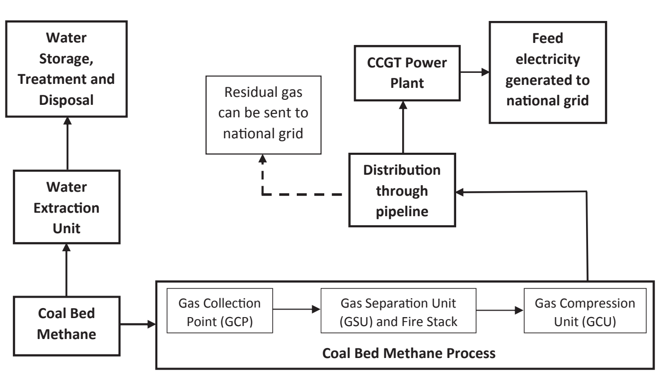

Fig. 1. The coupled CBM-CCGT process.

The innovation provided by the present study is the discussion of a coupling scheme allowing for integration connecting the various sub-processes to the surface processes up to the production of electricity. This procedure allows for flexible adaptation of variations in the model as well as allows the implementation of sensitivity studies which will be discussed in follow up publication.