

Environmental and Sustainability Assessment of Current and Prospective Status of Coal Bed Methane Production and Use in the European Union

Prepared by:
Karl H. Schultz & Linus M. Adler

Edited by:
Boyan Kavalov & Jorge Cristobal Garcia

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Contact information

Name: Boyan Kavalov

Address: Joint Research Centre, via E. Fermi 2749, 21027 Ispra (VA), Italy

E-mail: Boyan.KAVALOV@ec.europa.eu

Tel.: +39 0332 78 56 79

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NOTE TO THE READER

The overall goal of this study is to support the Joint Research Centre (JRC) of the European Commission in assessing the environmental impacts and sustainability of energy sources in the EU. In particular, it provides an analysis of the status and prospects (up to 2030) of Coalbed Methane (CBM) from the sustainability point of view, i.e. economic, environmental, and social implications. The study has been produced by Mr. Karl H. Schultz, Managing Director of Climate Mitigation Works, www.climate-mitigation.com and Managing Director / Climate Practice Director of Energy Edge Ltd., www.energy-edge.net, and by Mr. Linus M. Adler, Energy Analyst at Energy Edge Ltd., www.energy-edge.net, as external contractors. The final report has been reviewed and edited by Boyan Kavalov and Jorge Cristobal Garcia (JRC). The study was finalised in December 2015.

The study begins by defining CBM and contrasting it to Coal Mine Methane (CMM) and Shale Gas. It discusses historical developments of CBM around the world and in the EU context, and considers the sustainability of CBM in the EU context from environmental, economic, and social perspectives while focusing on CBM terminology, geo-technics, production, and impacts on land use and water resources. It also considers how technologies, markets and government interventions have all played roles in its development.

Three scenarios for CBM development are summarized, along with the manner in which their outputs will be used to assess impacts in Poland, Germany and the UK.

1. A Technically Possible CBM production scenario, not taking into account gas prices or climate policies
2. CBM Production constrained by EU Climate Policy and existing environmental legislation, but otherwise undertaken at least cost/unit production
3. CBM Production constrained by proposed stricter climate policies and limited by higher production costs associated with minimizing local/regional environmental impacts in terms of water use/impact and aggregate land demand.

The study outlines the potential environmental impacts by country studied and scenario, and also considers likely impacts for other countries and the EU as a whole. Emphasis is on water resource and quality, land use and fugitive greenhouse gas emissions.

The socio-economic impacts of each scenario are also analysed based upon stated assumptions regarding technology choices and related costs, and market pricing structure for each of the two climate policy constrained scenarios. Analyses of potential technology uptake in the form of discounted cash flow models are used to develop scenario-driven schedules for additional gas input/production.

The primary output factors of interest in the socioeconomic impacts section are impacts on natural gas prices, effects on local, regional, and national utility in terms of revenue effects (including taxation), and job creation.

“Barriers to economic development” are considered, taking into consideration of experiences of different policies and programmes.

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ABBREVIATIONS AND UNITS

bcm	billion cubic meters (methane)
CBM	coalbed methane
CCS	carbon capture and storage
CMM	coal mine methane
CO ₂ e	carbon dioxide equivalent (global warming potential)
EIT	economies in transition
EU	European Union
EUR	Euros (<i>for this study estimated as 1.2 USD = 0.8 GBP</i>)
FTE	full-time (job) equivalent
GBP	British Pounds (<i>for this study estimated as 1.5 USD = 1.25 EUR</i>)
ha	hectares = .01 square kilometers
km ²	square kilometers
LNG	liquefied natural gas
m ³ /t	cubic meters (methane) per tonne (coal)
mbbl	million barrels (water) = 163 million liters
Mcm	million cubic meters (methane)
mscfd	thousand cubic feet (methane) per day = 28 cubic meters per day
mscft	thousand cubic feet (methane) per US ton (coal) = 31.1 cubic meters per tonne
MMBtu	million British Thermal Units = 0.29 MWh
MtCO ₂ e	million tonnes of carbon dioxide equivalent (global warming potential)
MWh	megawatt hours
tcm	trillion cubic meters (methane)
USD	US Dollars (<i>for this study estimated as 0.66 GBP = 0.83 EUR</i>)
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

EXECUTIVE SUMMARY

The overall goal of this study is to support the Joint Research Centre (JRC) of the European Commission in assessing the environmental impacts and sustainability of energy sources in the EU. In particular, it provides an analysis of the coalbed methane (CBM) status and prospects (up to 2030) from the sustainability point of view, i.e. economic, environmental, and social implications.

Top Policy Relevant Findings

- ❖ *Publically available data on CBM resources is very limited.*
- ❖ *Under economically feasible scenarios, CBM could reduce EU gas imports by up to 4.4% and lower gas prices by up to 2.4%.*
- ❖ *EU-wide direct job (i.e. temporary and permanent) job creation could potentially lower unemployment rates in coal mining regions.*
- ❖ *Climate policies consistent with the IEA-450 emissions pathway may coexist with the development of indigenous coalbed methane resources in the short and mid-term (i.e., through 2030) provided that such resources substitute more carbon intensive fossil fuels or gas imports and do not replace renewable energies.*
- ❖ *However, even with control technologies in place, fugitive emissions of CBM could be significant, although the extent to which net emissions are higher or lower than supplanted gas is unclear. If incentives to encourage methane control are insufficient, other tools, such as encouraging implementation of carbon capture and storage (CCS) might be required.*
- ❖ *Land use and water impacts are considerable and abatement practices are limited.*
- ❖ *Policies to encourage the development of CBM resources have been successful in many non-EU countries.*

Coalbed methane is, simply put, methane gas liberated from unmined coal seams. Hence this study focuses on methane within undisturbed coal strata that is liberated deliberately for commercial purposes. Coal mine methane – or methane liberated as a by-product of the coal mining process – is examined in a previous report¹.

Since the 1980s, when production of coalbed methane not related to mining began in the United States, the CBM industry has grown in North America and elsewhere. Although the overall European CBM resource is in the multiple trillions of cubic meters, to date commercialisation of the resource in the EU has failed to take off, possibly owing to a combination of contrary physical qualities within the coal fields and various commercial, legal, and social factors and circumstances.

In order to better understand the CBM potential in the EU, this study estimates the producible reserves and potential production of CBM in the EU countries with the largest CBM potential – the United Kingdom, Germany, and Poland – at the coal basin level. To estimate gas in place, an estimation methodology in which gas density readings from boreholes and mines are extrapolated to the basin as a whole,

¹ Schultz, K. and Adler, L. (2015). "Environmental and Sustainability Assessment of Current and Prospective Status of Coal Mine Methane Production and Use in the European Union," eds. Kavalov, B. and Cristobal Garcia, J., European Commission, Joint Research Centre, Institute for Environment and Sustainability, EUR 27402 EN.

which is then subdivided into regions of similar gas density. Based on a streamlined well production model, we use net present value analysis to remove regions for which the natural characteristics (e.g., gas density and permeability) would be unsuitable for producing net positive value over a fifteen-year well lifetime.

To explore the range of sensitivities for the economic and social implications of CBM production, three scenarios that attempt to span the spectrum of potential uptake of CBM production in the EU are applied:

- *Reference Scenario:* In the Reference case, CBM production is driven under the constraints of the Reference EU Energy & Climate Policy Scenario. Gas production is assumed to take place if the net present value of a well is positive based on the 2016-2030 import gas prices under the EU Reference case.
- *Climate Strong Scenario:* This Scenario obeys the same type of market-clearing conditions as the Reference Scenario, except that the CBM Production is further constrained by a lower series of 2016-2030 gas prices commensurate with additional climate policy consistent with the International Energy Agency's climate-rigorous 450 pathway (which is similar to the EU's proposed Carbon Action Plan).
- In the *Technically Feasible Scenario*, production is assumed to proceed in all regions with a "feasible" CBM content (defined for the purposes of the study as a CBM resource with a gas density of greater than or equal to 1.5 m³/tonne coal). This is not in any real sense a possible future scenario, as the market price would have to be extremely high for all technically possible gas to be produced. Instead it is a way of understanding the greatest extent that CBM could be produced, and understand the correlated (potentially much more significant) impacts.

The current and potential CBM picture for each of the three principal countries is discussed in detail. The socioeconomic implications of each scenario are summarized based upon stated assumptions of market pricing structure, with outlooks for 2020 and 2030 by scenario given for:

- natural gas production;
- income generation to projects;
- tax revenues, and;
- job creation

The economic and environmental figures developed for the United Kingdom, Poland, and Germany are roughly scaled up in order to develop a set of potential three-scenario outlooks for the European Union as a whole. Given the large potential for additional natural gas under these scenarios (with projected CBM production adding 3-5 percent to the anticipated EU gas volume in 2030), the potential for market-wide price disruption is high (with calculations suggesting an EU-wide natural gas price reduction of up to 5 percent in 2030).

Table 1 - Economic Impacts Summarised

Country or Unit	Projected Economic Impact Ranges (figures rounded), 2030			
	CBM Production (BCM)	Income (M EUR)	Tax Revenues (M EUR)	Job Creation (FTEs)
United Kingdom	7.0 – 10.8	1,500-2,200	370-560	15,500 – 16,100
Germany	0.6 – 2.4	140-280	38 -77	770 – 1,740
Poland	8.6 – 8.9	2,200-2,900	600 - 820	13,700 – 14,800
Total European Union	25.8 – 33.3	10,100 – 12,300	2,500 – 3,500	58,000 – 60,400

From Table 1 above, the largest single country impacts are in the UK, followed by Poland and Germany. Overall, the gas production scales up by a factor of about 50 percent by including other EU countries known to have CBM resources, although the EU-wide revenues are proportionally higher based on generally higher gas price assumptions than in the three primary countries.

The analysis shows up to 60,000 jobs could be created by 2030 throughout the EU. These include short-term positions in drilling, along with up to 11,000 longer-term jobs in gas production.

In a section examining environmental impacts, each country is assessed in terms of local and climate change implications by scenario, with outlooks given for:

- land use;
- water use and groundwater production;
- local air quality effects, and;
- fugitive greenhouse gas emissions.

Table 2 - Environmental Impacts Summarised

Country	Projected Environmental Impact Ranges (figures rounded), 2030		
	Direct land use (km ²)	Water stress (including fracking use and groundwater production) mbbl	Fugitive Greenhouse Emissions (MtCO ₂ e)
United Kingdom	140 - 300	3,200 – 7,600	24.5 – 37.8
Germany	6 - 135	240 – 1,740	2.1 – 7.0
Poland	130 -150	3,600 – 3,800	30.2 – 31.3
Total EU	520 - 940	21,300 – 46,000	56.7 – 116.6

As is seen, the water stress, which is broken into groundwater produced and water that must be imported for hydro-fracturing, is considerable. Water use and production are major environmental impacts in the production of unconventional gas; in particular, the proper treatment of produced groundwater contaminated by intra-seam chemicals and salts makes up a significant proportion of ongoing production costs.

The overall fugitive greenhouse gas emissions in Table 2 above represent unabated figures; for the EU as a whole, these figures would represent an approximately 2 – 4 percent increase above the 2012 EU-wide greenhouse emissions inventory levels. However, it is possible to reduce fugitive emissions from the gas production cycle by a factor of 67% – while saving saleable gas – through the systematic use of monitoring and maintenance technologies.

Although economic factors have the potential to drive the growth of CBM in the EU, production of the resource can face a set of barriers that can be characterized as informational, resource, legal/property rights, and market uncertainty-related. The experience of other countries in which CBM has been commercially produced is examined in order to better understand how these barriers could be overcome, should it be decided to develop such resources.

Finally, the study concludes with some remarks on how the analyses could be useful in policy formulation, without making any suggestions as to what specific policies would be appropriate.

Some of the major findings include the following:

- The viable potential for coalbed methane production in 2030 might reduce EU gas imports by up to 4.4 percent at current import ratios, and lower gas prices by up to 2.4 percent.
- Direct job creation potential could lower unemployment rates in coal mining/former mining regions already facing higher than average unemployment.
- Reference and Climate Strong Scenarios have fairly similar production and impact outcomes, with the implication that more aggressive climate policies may coexist with policies to encourage indigenous coalbed methane resources in the short and mid-terms.
- However, strong climate policies will most likely eventually rule out unabated natural gas production and use by around mid-century. This studies scenario analysis does not go out far enough to see this in play, however.
- As with any natural gas production, CBM will result in some fugitive emissions. However, the net greenhouse gas emissions are uncertain, as it is possible that any domestic CBM production could displace other gas production that may have higher or lower fugitive emissions.
- Even with fugitive methane control technologies in place, climate policies implementation might be more difficult in the 2030 timeframe in light of such emissions. If incentives to encourage methane control are insufficient, other tools such as encouraging implementation of carbon capture and storage (CCS) might be required.
- Land use and water impacts are considerable; abatement practices are limited for land use and water demand impacts; they are available however for produced water impacts at nominal costs.

Experiences in the EU and elsewhere demonstrate that more than just technical and/or economic feasibility is required to realize uptake of CBM resources. Examples of incentives directed at resource uptake are available.

A. INTRODUCTION

For many years, methane in coal seams and surrounding strata, also known as coalbed methane or coal seam gas, was viewed in an unfavourable light. The mining industry considered it a nuisance and safety hazard that threatened lives, equipment and operations while inhibiting mine productivity. For natural gas exploration and production, coalbed methane represented a gas resource that was difficult and expensive to produce. In a number of countries, the gas resource base is high, but the low permeability and unique gas reservoir characteristics typical of many coal seams add a level of complexity that has not been cost-effective to overcome.

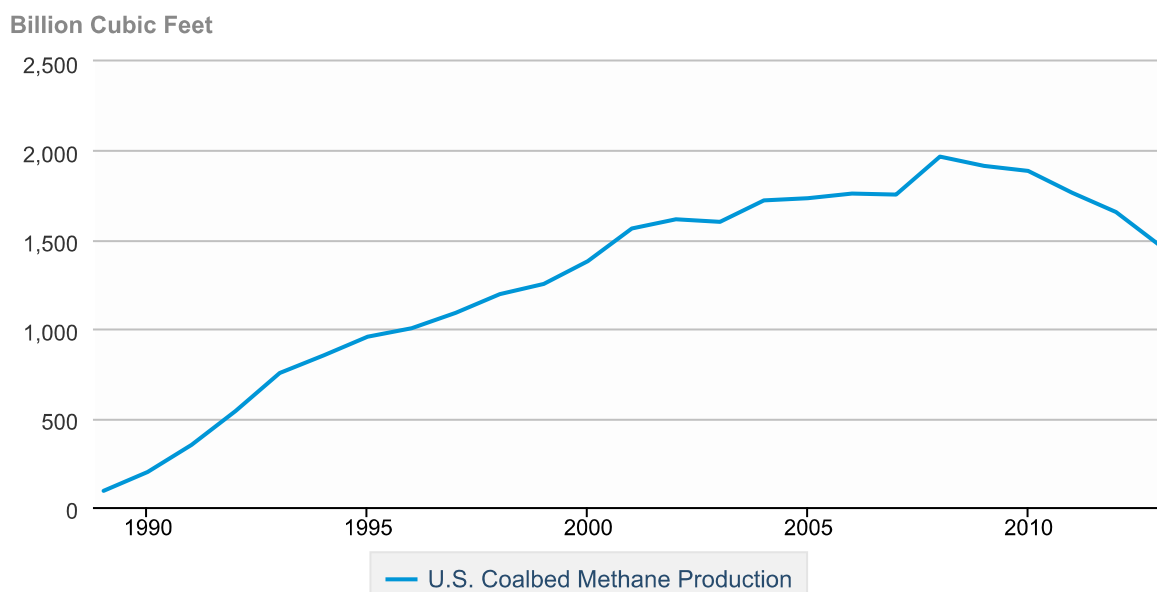
Even with these inherent difficulties, efforts to capture methane from coal seams began as early as the late 1700s when a British scientist drove a metal pipe into a coal seam and produced methane for use in his laboratory. This "well" is considered by some to be the birth of the modern industry. By the early 1900s several European countries were beginning to capture methane from coal mines. By the 1950s and 1960s coal mine methane recovery had begun in other countries.

Drainage of methane in advance of mining was introduced in the 1970s, and natural gas producers became interested in the resource potential of coalbed methane. With a combination of mine safety, energy security, and energy market restructuring motivations, the U.S. government supported research on improved drilling technologies, and in 1980 put in place a Federal tax credit for the production of unconventional gas resources including coalbed methane. The first coalbed methane well not associated with mine degasification was spudded in 1981 in the Black Warrior Basin².

The U.S. CBM industry grew rapidly in the 1980s and 1990s, and by 2000 CBM production was 1.38 trillion cubic feet (tcf) or 39 billion cubic meters (BCM), with 13,973 wells in production accounting for seven percent of U.S. gas production. In the early 2000s CBM production continued to increase, peaking at 1.966 tcf (55.7 bcm) in 2008, followed by a gradual decline in production as reserves in major basins started to become depleted³.

² Elder and Deul, 1974, and EPA, 2004.

³ See figure below, from U.S. Energy Information Agency, downloaded at http://www.eia.gov/dnav/ng/hist/rngr52nus_1a.htm on 9 September 2015.



eia Source: U.S. Energy Information Administration

Figure 1 - Historical CBM Production in the U.S.

DEFINING CBM AND COMPARISON WITH OTHER GAS RESOURCES

Simply put, coalbed methane is methane that resides within the pore system of coal seams. In effect, it is natural gas from coal seams. As discussed above, however, there are some differences in the resource, and in the extraction technologies required to produce the gas commercially.

Coalification, the geologic process that progressively converts plant material to coal, generates large quantities of methane. Increased pressure from water in the coal seams forces this methane to adsorb into the coal.

CBM extraction requires the removal of groundwater to reduce the pressure in the coal seam, which allows gas to flow to the surface through the well. This water may include contaminants, including elevated levels of salinity, sodicity, and trace elements (e.g., barium and iron). As a consequence, production of CBM can cause adverse environmental impacts and also affect the potential for beneficial use of produced water.

CBM wells can be open hole or cased. In open-hole completions, the well is drilled but no lining material is installed, so any gas can seep out all along the well into the wellbore for removal to the surface. In cased completions, a lining is installed through all or most of the wellbore. These casings need to be perforated or slotted to allow gas to enter the wellbore for removal to the surface. Open-hole completions are less expensive than cased completions, and are used more often in CBM production than in conventional oil and gas production.

CBM wells are often considerably (up to an order of magnitude) shallower than conventional hydrocarbon wells. CBM wells can often be drilled using water well

drilling equipment, rather than rigs designed for conventional hydrocarbon extraction, which are used to drill several thousands of feet into typical conventional reservoirs.

A CBM well's typical lifespan is between 5 and 20 years, with maximum methane production often achieved after one to six months of water removal. CBM wells go through the following production stages:

- Early stage, when groundwater is removed from the seam to reduce the underground pressure and encourage the gas to release from the coal seam (years 0-1);
- Middle stage, when groundwater production decreases, gas production increases, and there can be many years of stable production (years 1-8); and
- A late stage, in which the amount of gas produced declines to a low but, in many cases, economic levels (years 9-30).

In general, CBM wells tend to maintain significant production levels longer than either shale or conventional natural gas wells. For instance, a CBM well might still be producing at 10-20% of its maximum production level even in year 10, with production slowly tapering thereafter, whereas a comparable shale well could, for all intents and purposes, be played out in 3-5 years.

When the coals are low in permeability, as is typically the case for European coals, it becomes important to stimulate production. Unlike shale gas production, hydrofracturing ("fracking"), or stimulation of well production through the introduction of cracks within the matrix using liquid overpressure is not always absolutely necessary in the production of CBM, as natural cleats and fissures in the coal matrix can often leave the resource "pre-fracked." Nevertheless, the use of hydrofracturing has become common in the CBM field, and fracking may be the only way to sufficiently speed up production where there are extremely low permeabilities.

Methane is also produced from coal mines (CMM), but the techniques for producing methane from virgin coal seams are considerably different as is the quality of much coal mine methane. While in the U.S., it is an established practice to use CBM wells to produce gas from virgin seams in advance of mining, thus lowering the methane releases when mining occurs and permitting safe mining of coal, all other techniques more directly associated with coal mining (in mine and from the surface of mined out spaces) may produce considerable quantities of gas, but the methane concentration is considerably lower.

CBM IN THE EU

Following the boom in U.S. coalbed methane production, a number of producers began exploration throughout the world starting in the early 1990's, including in several European countries. Exploration in Poland, Bulgaria, France, and Germany has yet to result in any commercial production. In the UK, commercial production into the grid started in 2009 and approximately 60 CBM licenses were granted for exploratory drilling around the country in the 13th Onshore Licensing Round in 2008⁴. As of 2015, limited production was ongoing at the Doe Green site in Staffordshire, England and exploratory wells were being drilled near Airth, Scotland.

⁴ UK Department of Energy and Climate change, "The Unconventional Hydrocarbon Resources of Britain's Onshore Basins – Coalbed Methane" (2013).

Elsewhere in the EU, progress in exploration has been slow. In Germany, first exploration efforts on CBM were made by a consortium of Ruhrgas AG and Conoco-Phillips Inc. in the 1990s. Because of low production rates, relatively high exploration and production costs, and the low gas prices at that time this project was stopped. Similarly, Amoco and then Texaco drilled test wells in Poland's Upper Silesian Basin starting in 1993. Low production rates from these wells led to Texaco abandoning its production plans in Poland by 1998.

One reason for the slow adoption of CBM in Europe is that, with some exceptions, the coal is generally less permeable; producing CBM from low-permeability coal requires additional costs and technology, as such coals must often be artificially stimulated through a process called hydro-fracturing ("fracking") in order to produce appreciable levels of gas.

Yet CBM has developed as a viable gas resource beyond the U.S. in the past decade. Commercial production is significant in Australia, Canada and China, and there are other viable exploration and production activities elsewhere. Some of these developments have come by adapting the technologies, successful in the U.S. coal basins, to different conditions. Additionally, production technologies have generally advanced, driving down the potential costs of production and increasing the potential resource that may be commercially viable. In recent years, production in UK has been looking more viable. Overall, the question of the feasible scale of potential CBM production in the EU is not yet settled.

Energy security is another concern throughout the world, and certainly in the EU. While the rapid uptake of renewable energy developments is widely supported, natural gas remains important and is a flexible source of fuel for electricity production among other demands on the resource. Yet domestic EU gas production is declining, requiring greater dependence on foreign sources, which may have geopolitical implications. CBM gas-in-place in the EU is considerable, and if it may be commercially produced it could play a significant role in enhancing EU energy security should Member States decide to extract such resources taking into account decarbonisation commitments.

But in light of heightened awareness of the environmental impacts of fossil fuel production, both locally and on the global climate, it is important to consider how CBM fits into the environmental policy agenda and public perceptions of its environmental suitability. Exploration of shale gas in the EU is facing considerable controversy because of the real or perceived impacts of fracking. CBM in the EU also is likely to require fracking. There are potential impacts on water quality, and produced water may contain contaminants.

Climate policies are perhaps the most important factor determining the suitability of different energy resources. CBM (and all natural gas) is a fossil fuel, and without carbon capture and storage, gas consumption results in considerable emissions of carbon dioxide, along with fugitive methane emissions. Compared with coal, life cycle emissions from CBM per unit energy may be as little as half. However, the EU is on a pathway to significantly reduce its greenhouse gas emissions. Depending on how steep this pathway is, and how much carbon capture and storage plays a role in EU's future energy economy, the market for natural gas, including CBM, may transition from being positive (if substituting coal or imported gas and not replacing renewable energy sources), into a climate liability. Especially if climate policies follow a similar pathway outside the EU, at some point these policies will mean

demand will fall and prices for natural gas will decline (at least relative to business as usual), dampening the commercial potential to develop EU's CBM resource.

Hence, the future of CBM in the EU is uncertain, and CBM's potential must be considered in light of possible climate policy scenarios in order to understand the realistic alternatives scenarios under which this resource can be produced. These policy scenarios impact CBM production potential, but furthermore, the environmental, social, and economic impacts of CBM production need to also be analysed in order to inform decision making at all levels.

PAPER GOALS AND OUTLINE

The overall goal of this study is to support the Joint Research Centre (JRC) of the European Commission in assessing the environmental impacts and sustainability of energy sources in the EU. In particular, it provides an analysis of the CBM status and prospects (up to 2030) from the sustainability point of view, i.e. economic, environmental, and social implications.

Following this scene setting chapter, the study begins its analysis by outlining the set of methodologies developed to obtain, manage and calibrate quantitative data and also the approach to a qualitative analysis of these data and overall trends in the technical, economic, and environmental situation of CBM resource development and its economic, social, and environmental impact. The study uses separate analysis of three different production scenarios for CBM resource development as the basis for understanding how the resource could be treated, and the impacts, going forward. It also looks at how some of these impacts (water and land use) are mitigated by integrating particular environmental control technologies.

The study then considers the socioeconomic implications of each scenario based upon stated assumptions regarding technology choice and market pricing structure. These then form the basis for an understanding of potential revenues, job creation, and energy supply implications of each scenario. Macroeconomic energy price impacts are considered in a short section.

The following section details the environmental implications of the alternative scenarios, including greenhouse gas emissions (fugitive emissions) and local environmental impacts (particularly local water requirements, produced water impacts, and land use).

The paper also explores using the findings for the three study countries as a proxy, the potential for CBM production throughout the EU, and its associated environmental and socio-economic impacts.

The study considers commercial uptake: namely, why experience in different countries indicates that purely economic drivers of CBM resource development often are insufficient for all viable potential to be undertaken. The study then summarises some of the means of overcoming these barriers to resource development, should Member States decide to develop such resources.

B. ECONOMIC AND SOCIAL IMPACTS

This section discusses the comprehensive process used to develop the study and outlines the methodology employed to obtain, manage, and calibrate quantitative data. The section summarises three scenarios for future CMM development and discusses the manner in which their outputs are used to assess impacts in Poland, Germany, and the UK. It also introduces the methodologies used to consider impacts in other EU countries and the EU as a whole.

DISCUSSION OF METHODOLOGIES

In order to better understand the range of sensitivities for the economic and social implications of CBM production, we developed three scenarios that attempt to span the spectrum of potential uptake of CBM production in the EU.

- *Reference Scenario:* In the Reference case, CBM production is driven under the constraints of the Reference EU Climate Policy (i.e., 2013 Reference Case for now, to be updated with CPI in early 2016). Based on the 2016-2030 import gas prices under the EU Reference case (see Table 3) gas production is undertaken if the net present value at a project at a discount rate of 10% is greater than zero. The gas price and cost factors under this scenario are discussed below.
- *Climate Strong Scenario:* This Scenario obeys the same type of market-clearing conditions as the Reference Scenario, except that the CBM Production is further constrained by a lower series of 2016-2030 gas prices (Table 3) commensurate with additional climate policy consistent with the International Energy Agency's climate-rigorous 450 pathway⁵ (which is similar to the EU's proposed Carbon Action Plan).
- In the *Technically Feasible Scenario*, production is assumed to proceed in all regions with a "feasible" CBM content (defined for the purposes of the study as a CBM resource with a gas density of greater than or equal to 1.5 m³/tonne coal). The third scenario is not in any real sense a possible future scenario, as the market price would have to be extremely high for all technically possible gas to be produced. Instead it is rather a way of understanding the greatest extent that CBM could be produced, and understand the correlated (potentially much more significant) impacts.

To model gas prices in our two economic scenarios, we used projections for the price of gas imported into the EU for 2016 onward (see Table 3), adjusted by country to reflect market price differentials in different regions of the EU. For the reference scenario, we adopted figures used in the PRIMES Reference scenario for 2020-2050, linearly interpolating the decadal figures to get year-by-year series. To develop the Climate Strong scenario, we similarly adopted projections for EU import gas prices used by the International Energy Agency in developing its 450 Scenario.

The price evolutions of the respective Scenarios represent competition between the effects of dwindling gas supplies and consumer competition, which will tend to raise prices, with the effects of implementing carbon prices and emissions strictures. In

⁵ Data adapted from IEA Energy Data Services web Portal:
<http://wds.iea.org/WDS/Common/Login/login.aspx>.

both Scenarios, overall prices are seen to generally rise through 2022 as gas fired power is expected to start replacing older, higher emitting coal power plants. Post 2022, with more significant carbon prices coming into effect and increased renewable infrastructure build, both series begin to rise more slowly, particularly in the Climate Strong Scenario, which stops rising in 2027. While both Scenarios are consistent with a declining emissions reduction pathway, that in the Climate Strong Scenario is much steeper as it is in line with attempts under the proposed Carbon Action Plan to reduce total emissions to 80 percent below the 1990 baseline by 2050.

As will be discussed in Chapter C., CBM production would increase gas supply in the EU and deflate pricing. These lower prices are incorporated into the modeling, which in turn slightly reduces gas production in the various Scenarios.

Table 3 - European Gas Price by Scenario (including effects of additional CBM)

Gas Price in EUR/MWh		
Year	Reference	Climate Strong
2016	21.4	20.6
2017	22.7	21.5
2018	24.1	22.4
2019	25.4	23.4
2020	26.7	24.4
2021	27.2	24.4
2022	27.7	24.5
2023	28.2	24.6
2024	28.8	24.6
2025	29.3	24.7
2026	29.9	24.7
2027	30.4	24.8
2028	31.0	24.8
2029	31.5	24.8
2030	32.1	24.8

All price and cost figures used in this study are real and represent 2015 values adjusted for inflation.

In addition to net profits for gas producers and/or project developers, the successful implementation of a project can have significant impacts on local and regional economies in terms of businesses served and employment stimulation as well as transfer income implications for the owners of the gas (in the case of the three countries studied here, this is the national government) in terms of royalties. The modeling approaches and assumptions are described below and outputs detailed and in the section on economic and social impacts.

A discussion of the environmental and climate change aspects (both positive and negative) of CBM production and utilization is deferred to the chapter on environmental impacts.

SCOPE OF STUDY

In this study, we estimate the CBM resources of the United Kingdom, Germany, and Poland using an estimation methodology in which gas density readings from boreholes and mines are extrapolated to the basin as a whole, which is then subdivided into regions of similar gas density (“isopycnics”). Based on a streamlined well production model, we use net present value analysis to remove regions for which the natural characteristics (e.g., gas density and permeability) would be unsuitable for producing net positive value over a fifteen year well lifetime. This exercise is performed under two future gas price series associated with the Reference and Climate Strong scenarios, respectively. For the Technically feasible scenario, we assume that all CBM resources with an average gas density of above 1.5 m³/tonne of coal are developed.

ESTIMATING RESOURCE BY BASIN AND REGION

Generally speaking, the total resource of a gas deposit must be estimated through interpolation of numerous point data sources; in the case of CBM, such points can be most directly characterized using well-bore measurements to determine the gas density in m³/tonne of coal within the drilled coal seam. If direct borehole measurements are not available, data on specific emissions (m³/tonne mined coal) from underground coal mines can be used as “proxy” well data⁶, although the specific emissions will tend to be higher than actual gas density because the mine excavation process results in draw of gas from surrounding strata. In order to compensate for this, we divide mine specific emissions figures by two in this study to derive estimated gas density figures.

Once well and mine data have been gathered, the total estimated gas resource and distribution of gas densities must be estimated. To estimate gas resource, we use a formula derived by Caldwell and Heather:⁷

$\text{Total Gas Resource} = \text{coal region area} \times \text{coal thickness} \times \text{gas density} \times \text{coal density}$

The formula is actually applied based on estimates of its constituent factors provided by individual samples and estimates of, e.g., the basin area and thickness and respective densities. For CBM resources, Caldwell assumed that each parameter could be represented as having a lognormal distribution (i.e., a normal distribution bordered by zero and infinity that is skewed or biased toward zero) that could be reconstructed by deriving minimum, maximum, and modal sampled data points.

Of course, this method works best with large numbers of data points; therefore, in basins or regions where we could find approximately five or more well or mine data points, we assumed that these represented a lognormal distribution and calculated the total gas resource using Monte Carlo simulations of the constituent factors (using the @RISK Microsoft Excel add-in). Where only a few or one data point had to be

⁶ This methodology was suggested to the authors by Raymond J. Pilcher and James S. Marshall of Raven Ridge Resources, A U.S.-based CMM and CBM resource development company founded in 1988. A modified version of the coal mine kriging methodology was also used by the USEPA in *Assessment for the potential for economic development and utilization of coalbed methane in Poland*, (1991).

⁷ Caldwell, R.H. and Heather, D.I. (1991), “How To Evaluate Hard-To-Evaluate Reserves,” *J Pet Technol* 43 (8): 998-1003. SPE-22025-PA.

used to represent a region or basin, we used either mean values or just the point value alone as proxies to derive gas resource.

ESTIMATING DISTRIBUTION OF GAS

Using the overall basin gas resource estimates and point source data, we applied Gaussian process regressing (“kriging”) software to estimate distributions of roughly constant gas density within each region (the kriging calculations were carried out using 3DField shareware). Based on well/mine point data, we used isopycnic mapping (kriging software) to divide basins into near-constant density regions to help validate this methodology, we compare two figures below. Figure 2 shows a density map of the Upper Silesian Coal Basin in Poland produced by 3DField using mine-based data. Figure 3 shows isopycns produced for the same region by a previous study (USEPA 1991). Note the overall similarities in the distributions and contours.

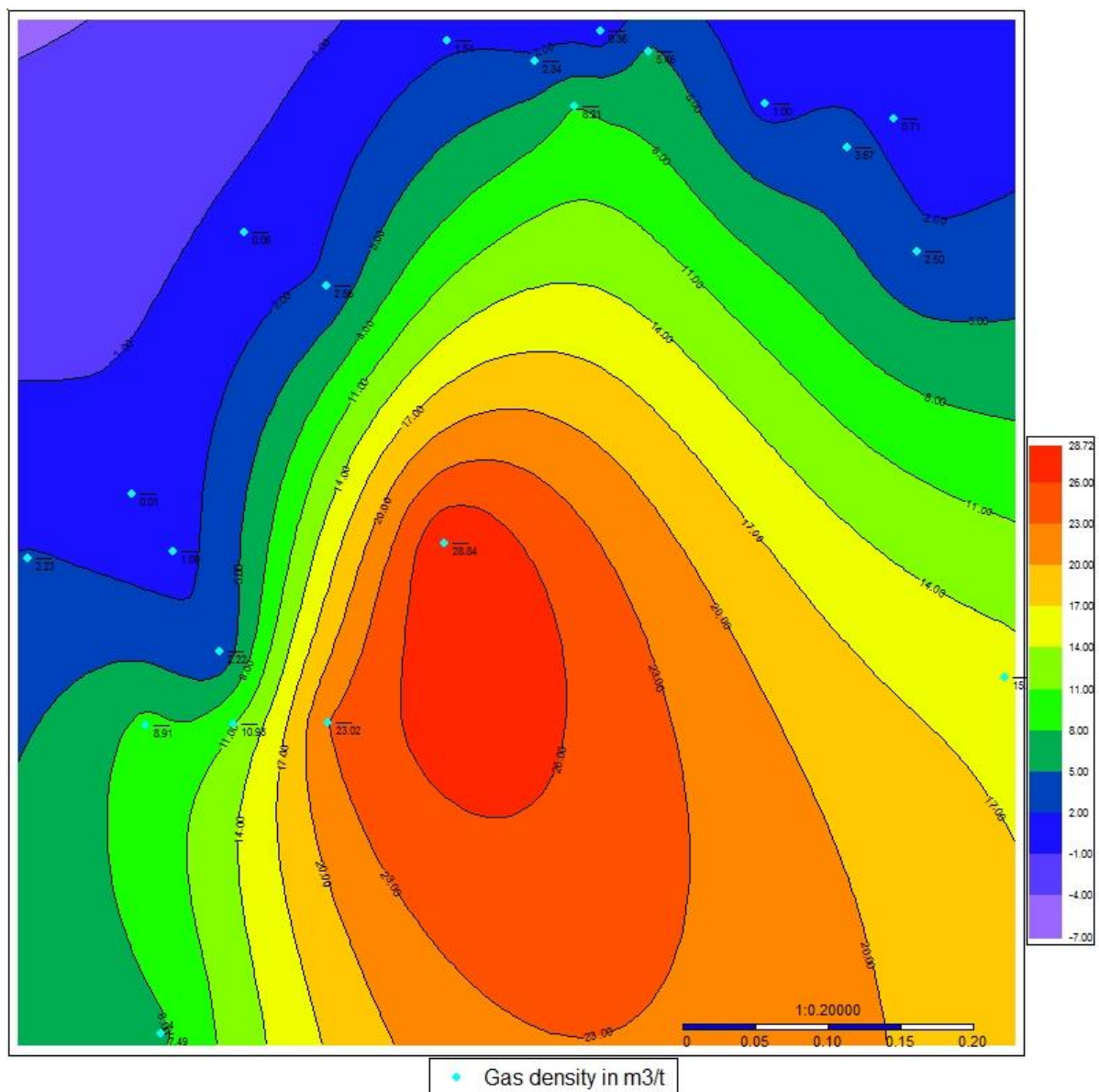


Figure 2 - Upper Silesian Coal Basin modeled by authors, 2015

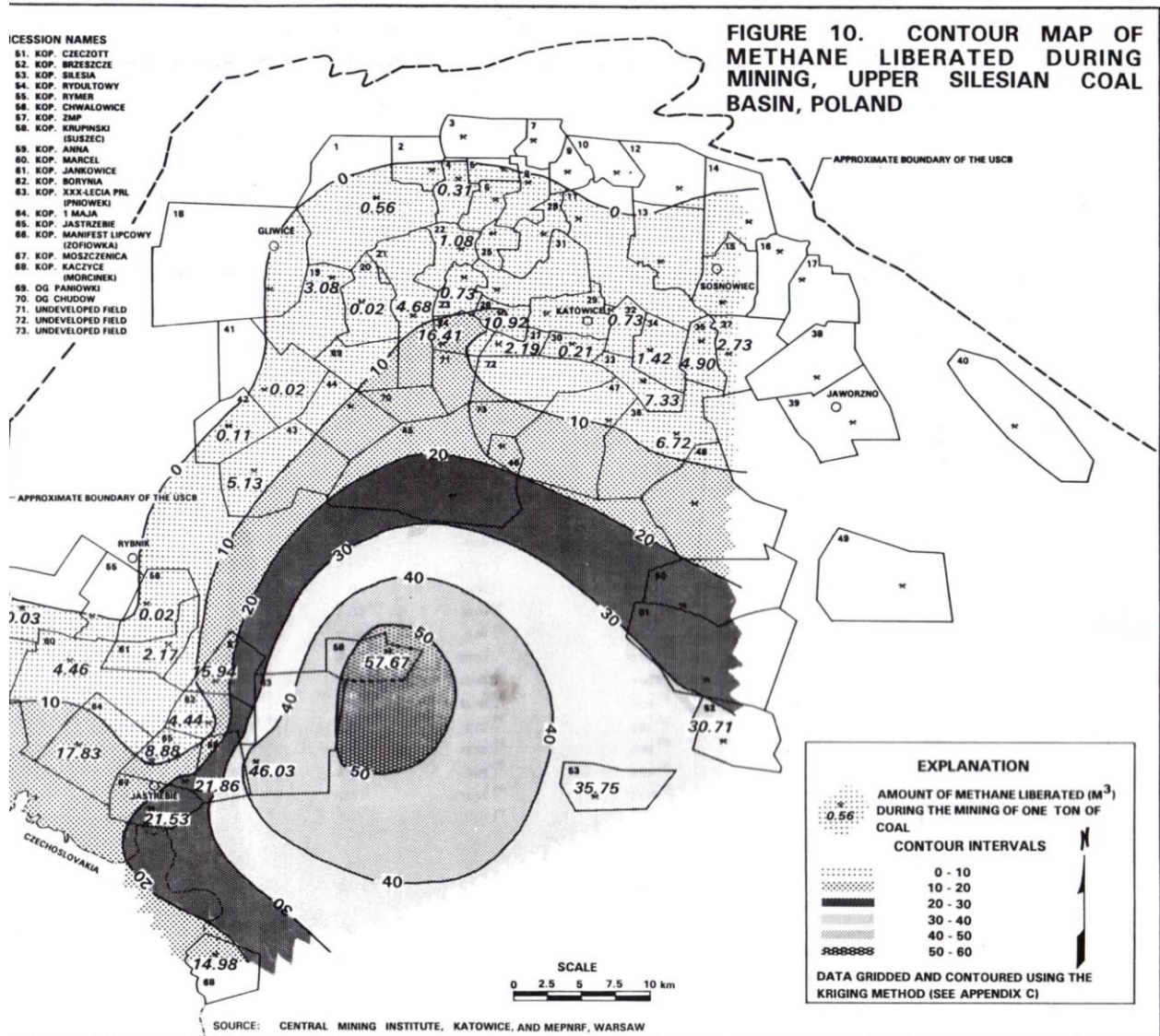


Figure 3 - Upper Silesian Coal Basin modeled by USEPA, 1991

CBM PRODUCTION

The profitability of a well is driven by its maximum production value (in m^3 per day), how quickly it reaches maximum, and by the relative shallowness of its decline curve after maximum. While the gas production curve is driven by many geological and production factors, it has been shown⁸ that higher gas density and permeability will tend to move the production curve upward (see Figure 4). In order to model gas production over time, we used a curve fit of the evolution of the production curves shown in Figure 4 in order to determine maximum production and decline rates as a function of gas density.

⁸ Halliburton, "Coalbed Methane: Principles and Practices," Chapter 10 (2007).

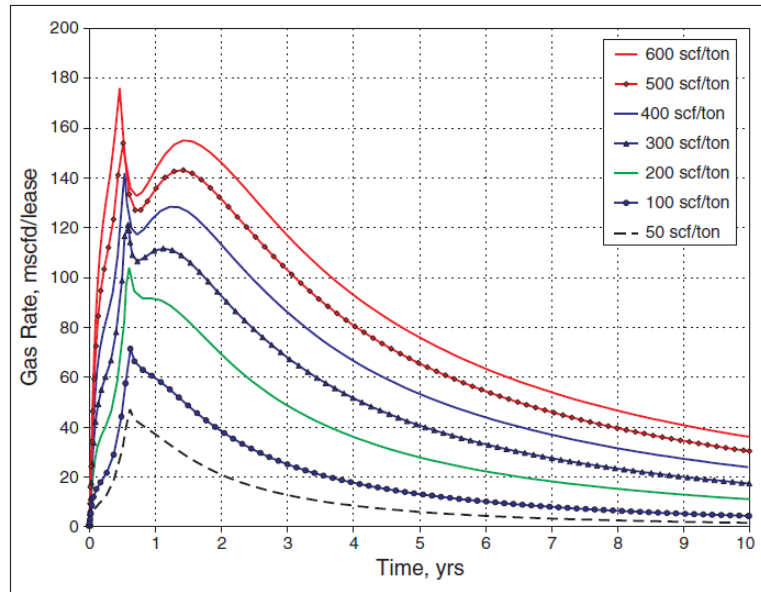


Figure 4 - CBM production profiles⁹

Source: Halliburton

WATER PRODUCTION AND QUALITY

The production of coalbed methane is almost always accompanied by a significant production of water, which must be pumped from the coal while degassing proceeds. As can be seen in Figure 5, the water production profile is front-loaded toward the beginning of the CBM recovery process; during the first stages of the process, the flow rate of water is higher than that of gas, but is declining while gas production increases toward its peak. Until gas production peaks, water use declines rapidly; thereafter and until the end of the well's lifetime it reduces to a low, nearly-constant rate.

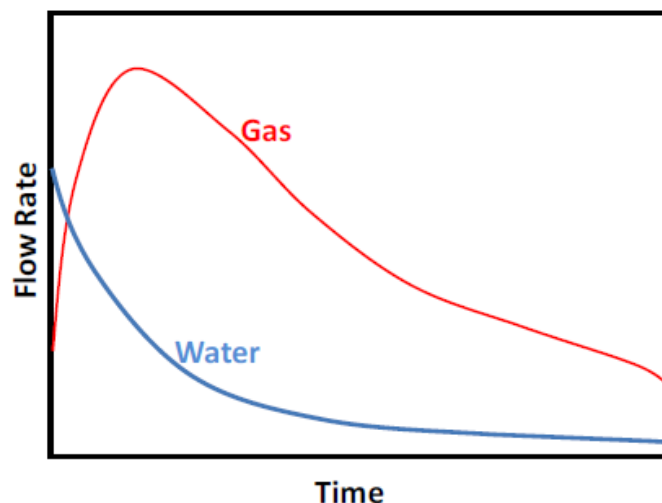


Figure 5 - Schematic Water and Gas Production Profiles of CBM

Source: USEPA

⁹ Note that US units are used in original figure: "mscfd" is "thousand standard cubic feet per day" and "scf" is "standard cubic feet."

Although the water production rate varies over the lifetime of the well, Lawrence (1993)¹⁰ levelises the overall production rate to 0.31 barrels per 1,000 cubic-feet of methane; this figure is used in this study as the basis for calculating the impacts and costs of water disposal from CBM projects. This is a considerable amount of water over the course of a well; for a well producing 12 million cubic meters of gas over its lifetime, this means that more than 200,000 barrels of groundwater are removed; in areas with limited water resources this may be a significant concern.

The quality of produced water can vary to a great extent from resource to resource or even well to well. In a very few cases documented in the U.S., wells produced water deemed clean enough by applicable regulations to be discharged directly to the surface with no treatment whatsoever. Of course, the amount of treatment will depend upon local regulations and acceptability as well as inherent quality. In general, CBM-associated water will contain chlorides, fluorides, and trace metallic elements such as calcium, magnesium, and iron. The concentrations of dissolved salts and metals will vary by geological conditions and coal characteristics, with measured contaminant levels in US CBM basins ranging from less than 100 to greater than 14,000 mg/L.¹¹ The ecological impact of such contaminants varies with concentration level and by contaminant, with environmentally and health safety acceptable concentrations, as cited by the USEPA, for various biological consumers given in the Table 4 below¹²:

Table 4 - Tolerance levels for water contamination

Consumer or purpose	Maximum safe concentration of solid contaminants, mg/L
Irrigation and stock watering	3,000
Cattle or sheep	2,500-5,000
Human consumption	500

Produced water can be discharged directly to the local watershed (“discharge treatment”) or not (“zero discharge”), with zero discharge options ranging from deep geological reinjection to use as agricultural or livestock feed to evaporative or membrane distillation treatment. Halliburton estimates costs of various treatments,¹³ varying from about 0.5 US cents per barrel for untreated discharge to about 5 USD/barrel for ion exchange or reverse osmosis. If local untreated discharge is impossible owing to concentrations of contaminants that are above healthy and/or regulatory limits and treatment is determined to be too expensive, producers must remove produced water through the use of, for instance, brine shipments via truck at a cost of about 2 USD/barrel or via pipeline.

In estimating the costs of water disposal within the scope of this study we will assume that untreated discharge treatment is impossible owing to either low water quality, local regulation, or some combination of the two. Instead, we will consider

¹⁰ Lawrence, A.W.: "Coalbed Methane Produced-Water Treatment And Disposal Options," Quarterly Review Of Methane From Coal Seams Technology (December 1993) 11, No. 2, 6-17.

¹¹ USEPA, "Technical Development Document for the Coalbed Methane (CBM) Extraction Industry" (2013).

¹² Data derived in Zimpfer, G.L., Harmon, E.J., and Boyce, B.C.: "Disposal of Production Waters from Oil and Gas Wells in the Northern San Juan Basin, Colorado," Rocky Mountain Association of Geologists Guidebook, Denver, Colorado (1988) 183-198, as reported in Halliburton, "Coalbed Methane: Principles and Practices," Chapter 9 (2007).

¹³ Halliburton, "Coalbed Methane: Principles and Practices," Chapter 10 (2007).

two environmental sensitivity scenarios for water use: under the Reference and Technically Feasible Scenarios, produced water is trucked from site, costing the developer 1.3 EUR per barrel; under the Climate Strong scenario, produced water is given a thorough reverse ion discharge or distillation treatment at 3.3 EUR/barrel¹⁴.

HYDROFRACTURING AND WATER DEMAND

Unlike shale gas production, hydrofracturing (“fracking”), or stimulation of well production through the introduction of cracks within the matrix using liquid overpressure is not always absolutely necessary in the production of CBM, as natural cleats and fissures in the coal matrix can often leave the resource “pre-fracked.” Nevertheless, the use of hydrofracturing has become common in the CBM field, and in the interests of obtaining a threshold net present value, fracking may be the only way to sufficiently speed up production, particularly where there are extremely low permeabilities of 5 mD or below.

For the purposes of this study, we will assume that all resources developed have default permeabilities of 5 mD (except in a few cases in which the permeabilities are higher than this value, as will be noted in the data tables). This assumption is based on the generally low values found in data scoping and bears out the conclusion of many exploratory efforts that coals within the three countries studied are generally tight (low permeability); as a practical effect of this assertion, we will assume that fracking occurs in all wells¹⁵.

The amount of water used to frack an individual well varies by coal quality and production needs. In some cases, wells are stimulated a number of times by the producer. Sample figures from North America show that anywhere from 50,000-350,000 US gallons per well¹⁶ (189,000 – 1,323,000 liters/well) may be used; for the purposes of this study, we will assume a constant figure at the upper end of this range of 1.3 million liters per well.

Hydrofracturing represents a second type of water stress that can be introduced in the CBM production process; whereas the water produced in well pumping can represent an ecological or soil hazard and must be disposed of somehow, the considerable use of water in fracking can be a source of water resource stress. For a fairly typical gas production field of 100 wells, this implies that a considerable quantity of water (1.05 million barrels) must be supplied over the following drilling and prior to production. Furthermore, additional gels or proppants (such as sand) that may be used in the fracking process can, when back-pumped to the surface, require further disposal efforts.

LAND USE AND IMPACTS

Like any type of gas recovery process, CBM extraction and gathering requires the use of land. In addition to the footprint of a well and the associated equipment,

¹⁴ Costs in dollars based on Halliburton estimates for the U.S., converted into Euros.

¹⁵ There has been limited experience of drilling for coalbed methane without fracking in the Lorraine region of France. In 2013, a test well (“Folschviller 2”) drilled by European Gas Limited using very advanced multilateral drilling techniques produced without fracking.

¹⁶ USEPA Figures quoted by
https://www.earthworksaction.org/issues/detail/hydraulic_fracturing_101#.VfqSdpdBnVI.

extensive easements may be required for pipeline interconnection and road use may have to be scheduled for additional traffic. Furthermore, dynamics particular to the coalbed methane resource often dictate closer spacing of wells and, as a result, denser usage of land. While land use is always a strong consideration, lower population densities and clearer ownership of land and resources has perhaps given North American CBM developers a structural advantage over those in Europe. The shale gas exploration performed so far in Europe has led to some particularly vocal and passionate opposition in which objections on the grounds of climate impact and local water effects are often joined to concerns as to construction noise and congestion, and the aesthetic impacts of drilling.

Of course, there are some types of terrain that are simply unsuitable to exploration and drilling: developed areas, for instance, or rivers and other bodies of water and fens (unless the latter are drained), as well as regions of sufficient topographical relief or brokenness. Limitations on allowable activity within national parks vary by country, but attempts to develop CBM resources within the boundaries of such districts would be sure to face additional permitting requirements and to draw enhanced scrutiny. In addition to overarching EU frameworks, any activity planned within habitats protected by EU-wide designations such as Natura 2000 likewise faces enhanced scrutiny under, e.g., the Habitats Directive.

MODELING THE LAND USE FOOTPRINT

Unlike shale or conventional gas wells, which are individually most productive when maximally spaced, the extensive networking of cleats and fractures that is often found in the coal matrix leads to a phenomenon in which closely spaced wells stimulate overall production. Although in theory gas flow can accordingly be maximized by placing well pads arbitrarily close together, assessments of the infrastructure and maintenance costs of production leases in the United States led Halliburton¹⁷ to conclude that a well spacing of 40 acres (16 hectares) was optimal in terms of net present value.

To increase economies of scale, operators will often develop in units of “leases” consisting of at least ten individual wells. To understand the potential use of land for the purposes of this study, therefore, we will assume a 400 acre (162 hectare) lease of ten wells as the minimum unit of land development. Note that the 400 acre unit is driven by well spacing considerations and does not reflect footprint of the well pad and associated infrastructure, which is much smaller; for the purposes of calculating land use in Section D. below, we will assume a per-well footprint of 100 meters squared (.01 hectare)¹⁸.

ECONOMICS

To determine the conditions under which a CBM resource would be exploited, we developed a simple, spreadsheet-based net present value (NPV) model of a single well. The drivers of cost in this model are initial and capital expenses - namely well completion infrastructure, pumping lines and tubing, rig leasing, and overhead and

¹⁷ Halliburton, “Coalbed Methane: Principles and Practices,” Chapter 10 (2007).

¹⁸ For instance, see Trident Exploration FAQ site at <http://www.tridentexploration.ca/what-is-the-environmental-footprint-of-cbm/details>.

intangibles – and recurring and operating expenses, such as monitoring, upkeep, and water disposal. The cost of hydrofracturing was entered as a separate initial expense. Wells produce income in the form of gas sales, which in turn are driven by the price obtainable per unit of gas and the temporal gas production curves, which are largely driven by gas content within the coal seams, as shown in Figure 4¹⁹.

Given a region with a characteristic gas density, therefore, we are able to estimate whether a typical well with known production costs would break even over a fifteen-year lifetime for a series of gas prices correlating with the three scenarios.

WELL COSTS

Well lifecycles fall into two fundamental chronological phases: drilling and completion, which is more heavily capital and labour intensive, and production. Initial phase costs include drilling equipment leasing, lines and tubing costs, and hydrofracturing, if it is done.

Other initial costs would typically include payroll, leasing, and supporting infrastructure (roads, etc.).

Production costs are also driven by operating expenditures, particularly water disposal and maintenance. Such costs are large in CBM production – on the order of one tenth of initial CAPEX every year²⁰.

All indications are that the break-even cost for gas produced by unconventional drilling in Europe will be larger than in North America owing to relative scarcity of equipment and skilled personnel and higher land access and material costs²¹. Net present value modeling conducted by the authors indicated that doubling the break-even price in Euros is consistent with an overall increase in cost by a multiplicative factor of approximately 1.6 (i.e., increasing the input costs by sixty percent doubles the break-even wellhead gas price). These figures were calibrated by using them to model the NPV over 15 years at annual discount rate of 10% for a well with peak production of about 3,500 m³ per day, resulting in a breakeven NPV at a gas price of about EUR18/Mwh (\$8/MMBtu), or about twice that of a comparable project in the United States. Scaling US EIA well-drilling expense averages²² by this factor produces the following cost assumptions by line item:

Table 5 - CBM Well Cost Elements

Item	Cost (EUR)/Well
Drilling and completion CAPEX	163,000
Other initial costs	10,000
Hydrofracturing	250,000
Annual recurring costs, including water disposal	16,300

¹⁹ Halliburton

²⁰ Energy Information Agency (2010), "Oil and Gas Lease Equipment and Operating Costs 1994 through 2009."

²¹ For example, see International Energy Agency (2012), "Golden Rules for a Golden Age of Gas," p.

72.

²² Energy Information Agency (2010).

GENERAL ECONOMIC AND SOCIAL EFFECTS

It is important to assess the economic and social effects accruing at local, regional, and national/international levels that are associated with CBM production. These can be divided into two primary effects – specific local and regional economic impacts and correlating social impacts (e.g. employment), and wider impacts e.g. on national and European gas markets and energy security.

Environmental, including climate, implications of CBM production are addressed in further detail in Chapter D.

The study looks at coal fields sited in a wide number of locales associated with varying economic and social settings. In several cases these coal fields have or are being mined, and coal mining communities in the EU generally face common challenges and advantages. These include:

- Economic and social stress owing to mine closure;
- Air, water, and land degradation owing to generally long-standing mine and associated industrial activities;
- Mining activities, however, have typically endowed such sites with an infrastructural legacy and a populace with applicable skillsets. Where mines are collocated with specific communities, such locales can be especially hard hit when production is cut or the mine is closed, but can also benefit from the presence of cheap proximate energy resources;

The production of coalbed methane requires significant input of capital and infrastructure, the provision of which can provide local and regional income in the form of jobs and capital/equipment rentals as well as income to gas resource owners (in Europe, this is generally the central governments) from royalties. Although the magnitude of specific employment stimulus is difficult to ascertain, we estimate direct “temporary” employment in terms of production (i.e., drilling and completion) and “long-term” employment for distribution and maintenance.

In order to normalize the estimation of employment activities, we follow Jacquet (2011)²³ in assuming a figure of 13 full-time equivalent (FTE)²⁴ positions to drill a well and 0.18 FTEs to maintain production of each well. While the direct employment involved in drilling a well is much larger, drilling FTEs only “last” as long as the well is being drilled (a process that might take in the order of months to about a year), while each maintenance FTE is ongoing for the assumed 15 year lifetime of the well. Although drilling employment related to a single well only lasts for the relatively short duration of active drilling and completion, in the course of building up a CBM sector it is unlikely that an experienced crew would be dismissed after the drilling of a single well. Instead (and particularly during a “boom” in activity) it is more realistic to assume that individuals and crews would be able to move from job to job. For simplicity, the well drilling and production model used in this study assumes that drilling activity remains constant over the fifteen year scenario window.

²³ Jacquet, Jeffrey (2011), “Workforce Development Challenges in the Natural Gas Industry”.

²⁴ Following Jacquet and standard human capital terminology, a full-time equivalent represents one person performing salaried work full-time for a year. Thus, the thirteen FTEs Jacquet quotes per drilling job could involve 26 personnel working full-time over six months, 13 personnel working full-time over a year, or any number of combinations in-between.

These figures are used in the economic analysis tables in the following section to estimate the maximum number of jobs within each country for each Scenario for 2020 and 2030. The additional economic activity generated in this manner could have direct and significant positive impacts on localities and regions that, as a rule, continue to be adversely affected by the effects of mine closure.

As the range of salaries associated with gas production is wide, with top-line managers and highly skilled engineers potentially earning about twice what a roughneck or field earner would, no attempt will be made to quantify additional CBM-based income in this study; however, existing figures suggest that the mean salary in gas production can be as much as twice the provincial or national salary average²⁵. Furthermore, studies of induced indirect employment effects suggest that each job directly created would leverage one service or support position²⁶. Considering the relatively high unemployment rates in mining regions, these jobs could contribute towards mitigating the social impacts of further mine closures. The net local income effects of CBM production and distribution can generally be positive in communities transiting away from coal production, as CBM activities can leverage highly paid employment based on many of the skillsets available in a well-trained mining workforce.

However, although some of the organizational and technological skill sets needed for CBM production are similar to those needed to run a mining operation and thus be commensurate to the skills of the labour force in coal mining regions, it is possible that a good percentage of drilling and completion jobs would be sourced from either the gas sector or from other parts of the fossil fuel sector, at least initially. Although the UK already has a robust gas production workforce connected to its North Sea industry, the question remains whether workers within the coalfield regions would be at a relative disadvantage, as well to what extent countries with less-developed indigenous gas production sectors – such as Poland and Germany (although Germany does have a well-developed transmission and distribution sector) – would have to outsource.

²⁵ See, for example ShaleNet (2013). “A Guide To Careers in the Oil and Natural Gas Industry.”

²⁶ Jacquet (2011).

C. ECONOMIC AND SOCIAL IMPACTS

Each cubic meter of gas produced comes with investment and operating costs that decline from about 6 to 9 Euro-cents per cubic meter in 2020 to 4 to 6 Euro-cents per cubic meter in 2030. These costs are developed in terms of overall capital and operating expenditures by Scenario. Based on the net profit, tax revenues accruing to the licensing authority (the national government) are shown by Scenario.

In this section, the socioeconomic implications of each scenario will be summarized based upon stated assumptions of market pricing structure. These include:

- natural gas production;
- income generation to projects;
- tax revenues, and;
- job creation.

These overall impacts are important for the variety of energy security, economic development, government fiscal benefits, and social benefits they can deliver, both at the regional and the national levels. In general, EU coal mining regions have in recent years faced high unemployment levels owing to steep declines in coal production.

The experience with shale and CBM gas in North America has been accompanied by dramatic employment and social effects, both documented and anecdotal; in this study, we will attempt to quantify potential impacts in the EU in terms of employment and revenues. Overall, our results show that the socio-economic impacts – at least the direct impacts – would be positive.²⁷

ECONOMIC AND SOCIAL IMPACTS BY COUNTRY AND SCENARIO

UNITED KINGDOM

UK SCOPE IN SUMMARY

UK coal production has decreased significantly since the 1980s. Based in part on the scale of UK mine closures, the long-term employment outlook in UK coal mining regions is generally unfavorable. As of 2015, unemployment for those aged 16-64 within the regions assessed in this study varied from 5.7% in both Wales and Scotland to 6.3% in the West Midlands.

Declines in North Sea natural gas production in recent years are making the UK increasingly reliant on imports, with 62% of its gas imported in 2014. However, owing to geography and well-developed liquefied natural gas (LNG) import infrastructure, the country is much less reliant on than many other European countries on relatively expensive pipeline gas from the East. It is anticipated that large quantities of shale gas anticipated to be imported from North America will help further stabilize UK gas prices.

²⁷ Potential negative impacts, on the other hand, might include housing and land stresses and price inflation.

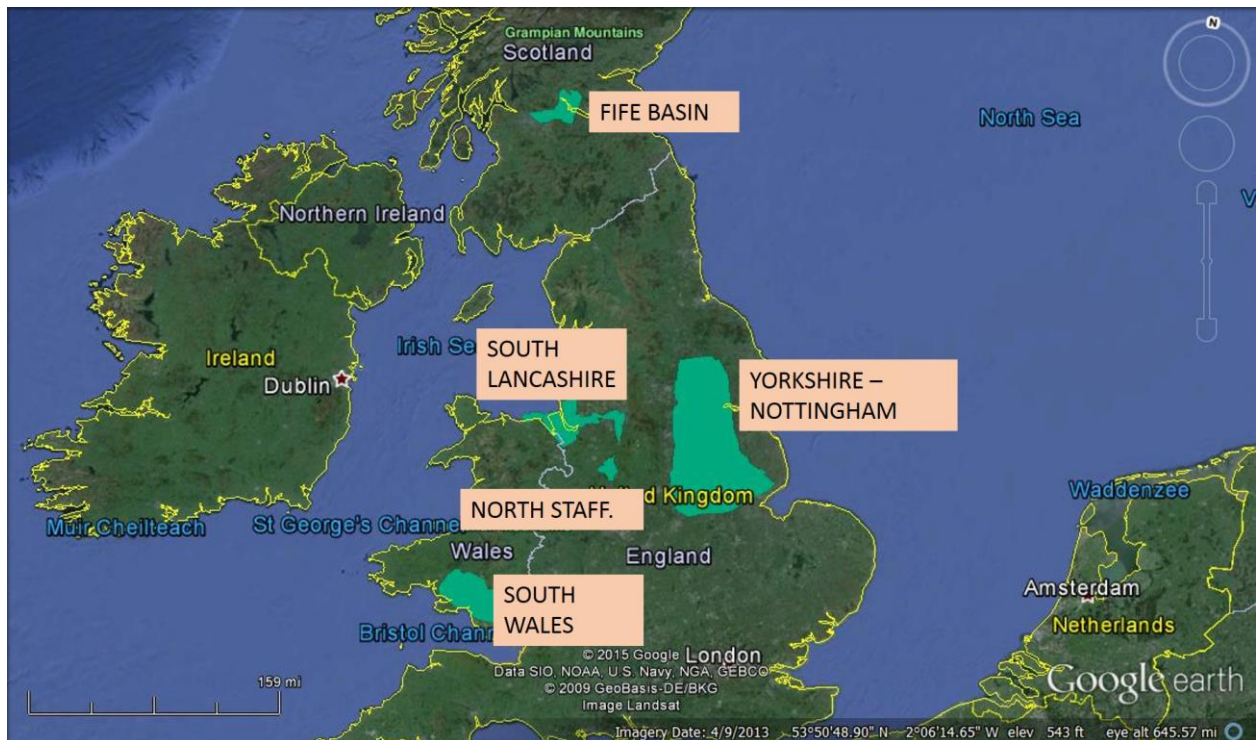


Figure 6 - Potential CBM Fields in the UK

Source: Google Earth with fields provided by authors

UK CBM RESOURCE

The UK has an estimated coal reserve of 3,200 Mt, 2,340 Mt (73%) of which are underground reserves.²⁸ Starting in the late 20th Century, the former UK Coal Board took several hundred borehole measurements around the country in order to determine gas contents of the resource; in 2004, the UK Department of Energy and Climate Change estimated the overall resource to be about 2.9 trillion cubic meters (tcm).

Table 6 - UK CBM Resource Evaluated in this Study

BASIN	AREA (KM ²)	CBM RESOURCE ESTIMATE (MILLION M ³)
South Wales	2,400	617,650
North Staffordshire	200	572,200
South Lancashire	1,400	1,120,900
Fife (Scotland)	790	335,730
East Yorkshire-Nottingham	9,530	784,870
Total Gas (Mcm)		2,881,350

Although measured gas density figures in range up to about 20 m³/tonne, UK coals are generally tight, a factor that has perhaps stymied production of the resource to date. Nevertheless, as of 2015 the UK remains the only nation within the EU to have experienced commercial success with CBM production. Exploratory boreholes have been drilled in South Wales, Kent, East Yorkshire, North Staffordshire, South Lancashire, and in Scotland in the region of the Firth of Forth; however, gas contents

²⁸ Figures quoted by the UK Energy Minister, 2011.

in Kent have proven to be low, and this region is not covered in this study. Estimates of potential CBM resource in these regions, which were developed as discussed in Section B. above, are shown in Table 6.

UNITED KINGDOM ECONOMIC AND SOCIAL IMPACT OUTLOOKS – DATA

Table 7 below shows projected key gas production and economic indicators for the UK for 2020 and 2030 based on the Scenario modeling described in Section B.

Table 7 - UK Economic Impacts by Scenario

Economic Impacts UK by Scenario	2020			2030		
	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE
Projected ANNUAL PRODUCTION (BILLION M ³)	3.0	2.9	4.5	7.2	7.0	10.8
Estimated ANNUAL REVENUES (based on gas sales) in MILLION EUR	769	680	NA	2226	1634	NA
Estimated CAPEX costs for annual build (based on per well costs) MILLION EUR	165	157	NA	165	157	NA
Estimated OPEX (based on annual per well costs) MILLION EUR	123	116	NA	288	273	NA
Total Costs MILLION EUR	288	273	NA	454	430	NA
Other income: government royalties (32% of net profit) MILLION EUR	252	217	NA	852	594	NA
Direct Employment - Drilling Activities (in Full Time Equivalents - FTEs)	13,493	12,843	NA	13,493	12,843	NA
Direct Employment - Production Activities (FTEs)	934	889	NA	2,802	2,667	NA
Total Direct Employment (FTEs)	14,427	13,732	NA	16,295	15,510	NA

The difference in gas production between the Technically Feasible and the other two economic Scenarios, which reaches 3.8 Bcm in 2030, is the result of the development of the technically significant but lower quality gas resource in East Yorkshire and Nottinghamshire under the former Scenario.

The potential for direct job creation is significant in each Scenario, growing from 13.7 to 15.5 thousand full time equivalents from 2020-2030. Projected gas production taxes to the UK Treasury range by Scenario from 217-252 million Euros in 2020 to 594-852 million in 2030.

PRICE AND TAX RATE ASSUMPTIONS AND PARAMETERS

For the UK scenarios, gas prices (Table 8) are based on the Reference and Climate Strong Scenario import prices, as revised in light of overall CBM market effects in Table 2 above, discounted by a factor of 20% to account for the downward pressure on UK hub prices resulting from North Sea production and a greater disconnect from higher import price regimes further east in Europe.

Table 8 - UK Gas Prices by Scenario

UK Gas Prices by year and Scenario (GBP/MWh)		
Year	Reference	Climate Strong
2016	11.4	11.0
2017	12.1	11.5
2018	12.9	12.0
2019	13.5	12.5
2020	14.2	13.0
2021	14.5	13.0
2022	14.8	13.0
2023	15.0	13.1
2024	15.4	13.1
2025	15.6	13.2
2026	15.9	13.2
2027	16.3	13.2
2028	16.5	13.2
2029	16.9	13.2
2030	17.1	13.3

In the UK, coal bed methane production is licensed by the Crown, which is the legal owner of all gas resources. The assumed tax rate is based on depreciated production value at a standard rate of 32 percent and is levied by the UK Government at the point of primary production.

GERMANY

GERMAN CBM RESOURCE

Germany has an estimated total coal reserve of about 6,700 Mt, although more than 95% of this (6,500 Mt) is lignite and subbituminous coals²⁹. Significant underground coal reserves lie in the Ruhr, Saar, and Ibbenburen regions; owing to economic non-competitiveness and removal of production subsidies, the few remaining operating underground mines in Germany are slated to shut down by 2018.

²⁹ Global Methane Initiative Germany Fact Sheet (2015).

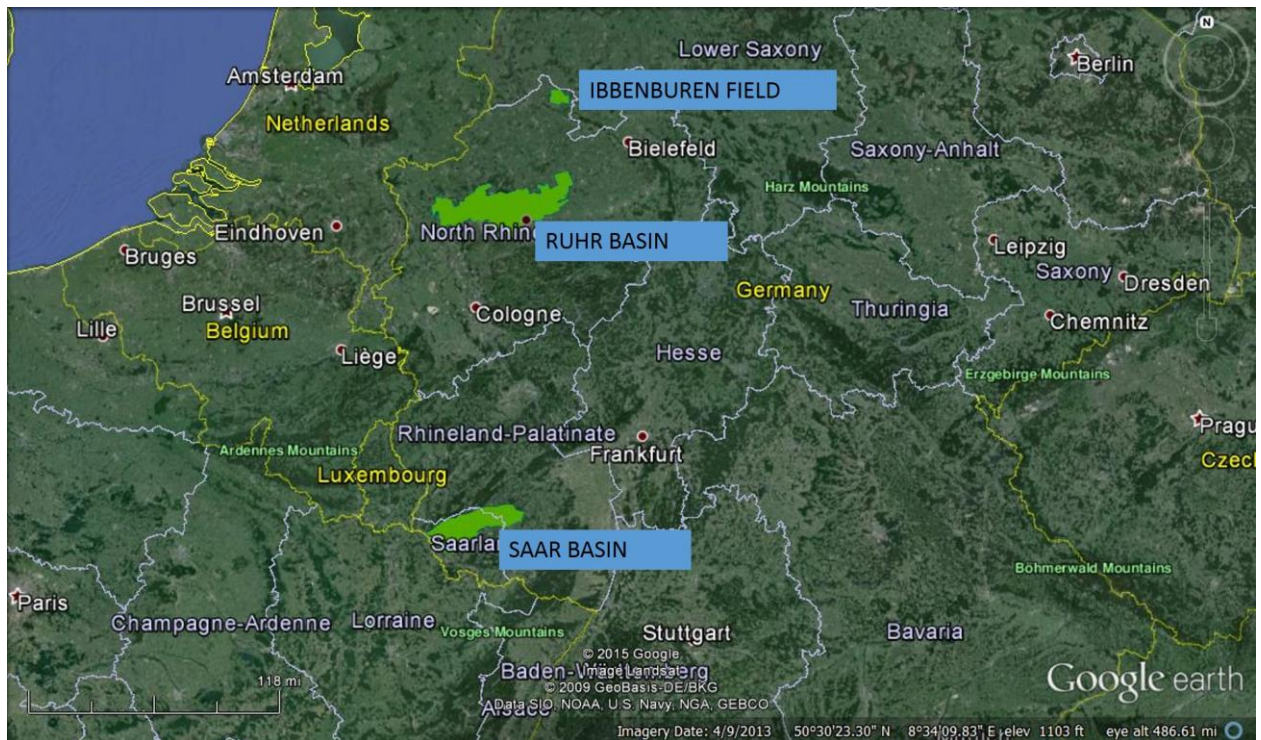


Figure 7 - Potential German CBM Fields

Source: Google Earth with fields provided by authors

Although the potential gas in place is large, CBM production attempts in Germany have been unsuccessful to date, with companies drilling wells before finally upping sticks in the 1990s owing to poor production and high costs. Simplified analysis in this study in which modified mine degassing figures were interpolated to derive areal gas density estimates showed a widely varying resource, with densities ranging from much higher than 20 m³/tonne of coal in the Ibbenburen region down to less than 5 m³/tonne of coal in the Saar. Based on these figures, rough estimates of the CBM resource in Germany that could potentially be developed are shown in Table 9 below.

Table 9 - German CBM Resource Evaluated in this Study

BASIN	AREA (KM ²)	CBM RESOURCE ESTIMATE (MILLION M ³)
Ruhr	4,600	230,577
Saar	1,318	66,230
Ibbenburen	92	97,349
Total Gas (Mcm)		394,156

GERMANY SCOPE IN SUMMARY

As in the UK, the employment outlook in the German Saar and Ruhr regions is troubled owing both to deindustrialization and mine closure. Unemployment in the Ruhr in 2013 was above 6%, and the German Hard Coal Association has predicted

that closure of the remaining German underground mines by 2018 will add another 2 percentage points to this figure.³⁰

Table 10 shows projected key gas production and economic indicators for Germany for 2020 and 2030 based on the Scenario modeling described in Section B.

Table 10 - German Economic Impacts by Scenario

Economic Impacts Germany by Scenario	2020			2030		
	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE
Projected ANNUAL PRODUCTION (BILLION M ³)	0.4	0.3	1.0	0.9	0.6	2.4
Estimated ANNUAL REVENUES (based on gas sales) in MILLION EUR	104	71	NA	288	145	NA
Estimated CAPEX costs for annual build (based on per well costs) MILLION EUR	18	11	NA	18	11	NA
Estimated OPEX (based on annual per well costs) MILLION EUR	13	8	NA	31	14	NA
Total Costs MILLION EUR	31	19	NA	49	25	NA
Other income: government royalties (32% of net profit) MILLION EUR	23	17	NA	77	38	NA
Direct Employment - Drilling Activities (in Full Time Equivalents - FTEs)	1,443	644	NA	1,443	644	NA
Direct Employment - Production Activities (FTEs)	100	45	NA	300	134	NA
Total Direct Employment (FTEs)	1,543	689	NA	1,743	778	NA

By Scenario, the overall production levels are lower than in the UK, reflecting both the much lower level of overall estimated resource (300 billion versus 2.8 trillion cubic meters – a difference by factor of 9) as well as lower levels of average gas content in the Ruhr and Saar coal basins. Correspondingly, the revenue and employment leveraging effects are much lower. In 2015, North Rhine Westphalia and the Saarland (which respectively contain the Ruhr and Saar regions) had a combined unemployment rate of 8.3%, or 806,040 unemployed workers³¹.

³⁰ German Hard Coal Association (2007). "Coal: Options for the Future."

³¹ Found online at EURES, the European Job Mobility Portal.

PRICE ASSUMPTIONS AND PARAMETERS

For the German scenarios, gas prices (Table 11) are based on Reference and Climate Strong Scenario import prices, as revised in light of overall CBM market effects in Table 3 above, discounted by a factor of 10%. Although German prices are suppressed somewhat by higher contracting liquidity in Northwestern European trading hubs, a continued reliance on more expensive contract-driven gas supplies from east of the EU should help keep price levels above those of the UK. All price and cost figures are real representing 2015 values adjusted for inflation.

Table 11 - German Gas Prices by Scenario

German Gas Prices by year and Scenario (EUR/MWh)		
Year	Reference	Climate Strong
2016	19.3	18.5
2017	20.5	19.3
2018	21.7	20.2
2019	22.8	21.0
2020	24.0	22.0
2021	24.5	22.0
2022	24.9	22.0
2023	25.4	22.1
2024	25.9	22.1
2025	26.5	22.2
2026	26.9	22.2
2027	27.4	22.3
2028	27.9	22.3
2029	28.3	22.4
2030	28.9	22.4

POLAND

POLISH CBM RESOURCE

Poland has by far the largest coal resource in the EU, with 19,000 Mt of proven hard coal reserves alone³². Based on specific emissions data from major underground mines within the Upper and Lower Silesian basins, we estimated gas content within specific regions of these data. Our estimates of the CBM resource in the primary underground coal mining regions of Poland are shown in Table 12.

Table 12 - Polish CBM Resource Estimates

BASIN	AREA (KM ²)	ESTIMATED CBM RESOURCE (MILLION M ³)
Upper Silesian	2,700	942,691
Lower Silesian	1,150	419,606
Total Gas (Mcm)		1,362,297

³² EURACOAL (2013) Country Profile for Poland.



Figure 8 - Potential Poland CBM Fields

Source: Google Earth with Fields Provided by Authors

CBM test wells were drilled in the Upper Silesian Basin starting in 1993, but low production rates caused foreign investors to abandon production plans by 1998.

POLAND SCOPE IN SUMMARY

Likely mine closures in Upper Silesia after 2018 would prove economically painful to the region, which has already suffered a profound and long-lasting economic downturn following the collapse of Communist rule in 1989, and although unemployment in Silesia hit a high of 20% in 2003, more recently this figure has dropped to a registered unemployment rate of 9.5% in 2015.³³ According to EURACOAL, the Polish hard coal industry employed 113,000 people in 2012.³⁴

POLAND ECONOMIC AND SOCIAL IMPACT OUTLOOKS – DATA

Compared to the respective UK and German Scenarios, it is seen from Table 13 that there is relatively little marginal gain in total Polish CBM production under the Technically Feasible Scenario. Although previous production attempts had been abandoned, as mentioned above, the relatively high concentrations of resource potentially available in the Upper and Lower Silesian Basins suggest that economic production might be viable under the relatively elevated gas prices obtained in Poland, especially if production costs can be controlled and economies based on experience elsewhere can be successfully adopted.

³³ EURES.

³⁴ EURACOAL.

The large gas production potential in Polish Silesia could equate to a comparably large employment stimulus, as is seen in Table 13. Given the 9.5% 2015 unemployment rate in the voivodship, the approximately 14,000 potential FTEs created in 2030 under the “Reference” scenario could have a large impact.

Table 13 - Poland Economic Impacts by Scenario

Economic Impacts Poland by Scenario	2020			2030		
	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE
Projected ANNUAL PRODUCTION (BILLION M ³)	3.7	3.6	3.7	8.8	8.6	8.9
Estimated ANNUAL REVENUES (based on gas sales) in MILLION EUR	1,046	929	NA	2,986	2,261	NA
Estimated CAPEX costs for annual build (based on per well costs) MILLION EUR	153	141	NA	153	141	NA
Estimated OPEX (based on annual per well costs) MILLION EUR	109	101	NA	263	243	NA
Total Costs MILLION EUR	262	242	NA	416	384	NA
Other income: government royalties (32% of net profit) MILLION EUR	251	219	NA	822	601	NA
Direct Employment - Drilling Activities (in Full Time Equivalents - FTEs)	12,251	11,327	NA	12,251	11,327	NA
Direct Employment - Production Activities (FTEs)	848	784	NA	2,544	2,352	NA
Total Direct Employment (FTEs)	13,099	12,111	NA	14,795	13,679	NA

PRICE AND TAX RATE ASSUMPTIONS AND PARAMETERS

For the Reference and Climate Strong Scenarios in Poland, we applied no discount to the overall CBM-revised EU gas price series in Table 3. Poland has very little indigenous production and is highly dependent on pipeline gas from the east, particularly Russia, although the country’s first LNG terminal is expected to reach full capacity by 2018. Nevertheless, prices will remain driven to a large degree by oil-indexed long-term contracts and are projected to remain among the highest in the EU.

Table 14 - Polish Gas Prices by Scenario

Polish Gas Prices by year and Scenario (EUR/MWh)		
Year	Reference	Climate Strong
2016	21.4	20.6
2017	22.7	21.5
2018	24.1	22.4
2019	25.4	23.4
2020	26.7	24.4
2021	27.2	24.4
2022	27.7	24.5
2023	28.2	24.6
2024	28.8	24.6
2025	29.3	24.7
2026	29.9	24.7
2027	30.4	24.8
2028	31.0	24.8
2029	31.5	24.8
2030	32.1	24.8

EUROPEAN UNION

By extrapolating the resource and economic figures developed above for the United Kingdom, Poland and Germany, the economic and social impacts of coalbed methane can be roughly scaled up to cover potential three-scenario outlooks for the European Union as a whole. While the amount of available gas in the three primary countries assessed in this study constitute the bulk of potential EU CBM production, an initial assessment of potential CBM resources within other EU member states³⁵ allowed us to identify also other countries with significant CBM potential (Table 15).

Table 15 - Additional EU CBM Resource Estimates

Country	Country CBM Resource Estimate (Bcm)	Resource Share for EU
Germany	394	7%
Poland	1,363	25%
United Kingdom	2,881	53%
Bulgaria	196	4%
Czech Republic	400	7%
France	28	<1%
Italy	30	<1%
Hungary	150	3%
Total	5,442	

The production figures in Table 16 are extrapolated in a manner similar to that in which resource estimates for Germany, Poland, and the UK were used to develop

³⁵ Sources for these estimates were provided primarily by examination of US EPA Coalbed Methane Outreach Program (CMOP) country profiles.

production scenarios in those countries. To characterize gas content, we applied like-for-like comparison with known figures; e.g., we assumed that CBM gas in the Lorraine in France was similar to that in the contiguous Saar basin in Germany and we assumed that Czech coals bordering Upper Silesia matched the profile of comparable Polish coals. As can be seen, over half of all CBM resources are found in the UK, with Poland responsible for another 25%.

The scenario analysis found between 25.8 and 27.0 bcm of CBM production in 2030. Production scenarios by country found in Table 16 show that while UK production is significant, it is proportionately less than CBM resources, while Poland's production is roughly proportionate to its resource levels for the EU as a whole.

Table 16 - EU Economic Impacts by Scenario

Economic Impacts EU by Scenario	2020			2030		
	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE	REFERENCE	CLIMATE STRONG	TECHNICALLY FEASIBLE
Projected ANNUAL PRODUCTION (BILLION M ³)	11.4	10.9	14.0	27.0	25.8	33.3
Estimated ANNUAL REVENUES (based on gas sales) in MILLION EUR	4,920	4,263	NA	12,290	10,113	NA
Estimated CAPEX costs for annual build (based on per well costs) MILLION EUR	575	529	NA	575	529	NA
Estimated OPEX (based on annual per well costs) MILLION EUR	517	477	NA	1,422	1,718	NA
Total Costs MILLION EUR	1,092	1,006	NA	1,997	2,247	NA
Other income: government royalties (32% of net profit) MILLION EUR	1,257	1,068	NA	3,479	2,516	NA
Direct Employment - Drilling Activities (in Full Time Equivalents - FTEs)	50,023	46,021	NA	50,023	46,021	NA
Direct Employment - Production Activities (FTEs)	3,463	3,186	NA	10,389	11,668	NA
Total Direct Employment (FTEs)	53,486	49,207	NA	60,412	57,689	NA

To put this in perspective and consider the impact on gas supplies, 2013 natural gas imports into the EU were 314 bcm³⁶, so if CBM production were to meet these levels, they could represent about 8.5% of imports. Looking at gas consumption

³⁶ From BP Statistical Review 2014.

projections, The Oxford Institute for Energy Studies estimates these to be 610 bcm in 2030, so CBM could contribute about 4% to total demand.³⁷

Depending on Scenario, a projected 49,000 – 53,000 and 58,000 – 60,000 FTEs directly related to drilling and production could be in place in 2020 and 2030, respectively. These include positions in drilling, along with up to 11,000 longer-term FTEs in gas production.

The revenues for gas sales in the economic Scenarios are based on the respective overall EU import price series.

Country / region	Projected Economic Impact Ranges (figures rounded), 2030			
	CBM Production (BCM)	Income (M EUR)	Tax Revenues (M EUR)	Job Creation (FTEs)
United Kingdom	7.0 – 10.8	1,500-2,200	370-560	15,500 – 16,100
Germany	0.6 – 2.4	140-280	38 -77	770 – 1,740
Poland	8.6 – 8.9	2,200-2,900	600 - 820	13,700 – 14,800
EU total	25.8 – 33.3	10,100 – 12,300	2,500 – 3,500	58,000 – 60,400

MACROECONOMIC PRICE EFFECTS

As noted above, the input into the European gas market of the volumes of CBM shown in Table 16 is significant. For instance, under the 2030 Reference Scenario, CBM production equals 27.0 Bcm. Assuming a projected 610 Bcm of consumption EU-wide in 2030³⁸ this would represent a 4.4 percent increase in gas supply. One assessment of the price elasticity relative to gas supply suggests that each additional percent increase in supply in such markets would result in a decrease in price of between 1.3 – 2.4 percent³⁹.

To account for this, we have used an average elasticity of 2.2 percent per percentage increase in EU-wide gas volume to reduce the market price used in our various scenarios based on the following schedule (Table 17). The resulting reduced prices are used in the calculations in this study to determine income to producers and tax income to licensing authorities and to develop net present value models in each of the production scenarios. A potential complexity introduced into the marketplace by such price-shifting effects is that, given significant enough production-driven price adjustments, the underlying economics of production can tend to oscillate; i.e., increased production will tend to lower the market price, reducing the profitability of production and thus the volume, which, in turn, will raise the price. However, examination of the dynamics of the model used in this study under the amended price series in the table above showed no measurable production effects at the granularity of the model; therefore, this effect is disregarded here.

³⁷ The Oxford Institute for Energy Studies (2014), “The Outlook for Natural Gas Demand in Europe.”

³⁸ *ibid.*

³⁹ See, for example, Johnson, Erik (2011). “The Price Elasticity of Supply of Renewable Electricity Generation: Evidence from State Renewable Portfolio Standards.”

Table 17 - Price Effects of Additional CBM in Market

Year	Baseline Gas Demand EU (bcm) ⁴⁰	Additional CBM into market – Reference Scenario (bcm)	Additional CBM into market – Climate Strong Scenario (bcm)	Price Reduction Reference Scenario	Price Reduction Climate Strong Scenario	Reference Reduced Price (EUR/MWh)	Climate Strong Reduced Price (EUR/MWh)
2017	555	3.8	5.9	-0.7%	-1.1%	22.7	21.5
2018	560	6.3	8.8	-1.1%	-1.6%	24.1	22.4
2019	565	8.9	10.3	-1.6%	-1.8%	25.4	23.4
2020	570	11.4	10.9	-2.0%	-1.9%	26.7	24.4
2021	576	13.7	11.4	-2.4%	-2.0%	27.2	24.4
2022	582	15.7	11.9	-2.7%	-2.0%	27.7	24.5
2023	588	17.6	12.3	-3.0%	-2.1%	28.2	24.6
2024	594	19.2	12.7	-3.2%	-2.1%	28.8	24.6
2025	600	20.6	13.0	-3.4%	-2.2%	29.3	24.7
2026	602	21.9	13.3	-3.6%	-2.2%	29.9	24.7
2027	604	23.2	13.6	-3.8%	-2.3%	30.4	24.8
2028	606	24.5	13.9	-4.0%	-2.3%	31.0	24.8
2029	608	25.9	14.2	-4.3%	-2.3%	31.5	24.8
2030	610	27.0	25.8	-4.5%	-2.4%	32.1	24.8

⁴⁰ Oxford Institute for Energy Studies (2014).

D. ENVIRONMENTAL IMPACTS

INTRODUCTION

This section will outline environmental impacts by country studied and scenario. A subsection outlining likely impacts for other countries and the EU as a whole is also included. The primary focus of the analysis is on determining the net environmental (i.e., regional and global) benefits and/or damages resulting from Scenario-indicated changes in water demand, produced water impacts, and land use. Other impacts include potential for soil degradation from water disposal, methane emissions and other greenhouse gas emissions from CBM production and transmission, and construction and operations linked noise and induced traffic.

LAND AND WATER USE

The land use impacts of coalbed methane production can be somewhat significant in cases where new seams or deposits need to be explored and drilled, although the actual final per-well footprint, assumed in this study to be 100 × 100 meters (1 hectare), is not necessarily a large fraction of the roadway and working space needed to complete a well. As discussed earlier, another driving factor is the inter-well spacing used to increase gas production. The synergistic production effects of multi-well fields and economies of scale in investment suggest that CBM resource would be developed in fairly substantial 10-well leases of 1.6 square kilometers per lease.

Thus, while the physical well footprint could be small, the land required to site such leases would be constrained particularly in Western and Central Europe, which are much more densely populated than North America. Based on assessment of the typically dense land use characteristics in such countries, this study assumes that any significantly large CBM region would have an urban or suburban coverage of about 38-40 percent of its total land area; assuming that it would be impossible to drill on such developed areas, potential production would therefore be limited to 60-62 percent (i.e., 100 minus 38-40 percent) of the overall land area. However, the fact that many leases would be developed on existing or former coal mine sites suggest that available land would be well-mapped and relatively easy to develop on. Furthermore, voluntary or legal strictures on drilling on protected or heritage sites, such as national parks or EU Natura 2000 sites cannot be ignored. For the purposes of this study, all protected areas over potential well sites have been identified and removed from the available land under the Climate Strong Scenario.

METHANE EMISSIONS

Production of coal bed methane involves significant leakage of methane and to a lesser extent - carbon dioxide, nitrous oxides, and volatile organic compounds - to the atmosphere, a phenomenon called fugitive emissions, which occur during production, processing, transport, and distribution phases. Overall, mean fugitive emissions from CBM are about 36% higher than from conventional gas production,⁴¹

⁴¹ Glancy, R.P. "Quantifying Fugitive Emission Factors from Unconventional Natural Gas Production Using IPCC Methodologies" (2013).

with the differential occurring during the production phase. Although there is no consensus on the exact figures, generally speaking fugitive emissions can total one to nine percent of methane produced by volume; for the purposes of this study, the following figures from an IPCC study are used (Table 18).

Table 18 - Fugitive Emissions from CBM Production

Pollutant	Intensity of fugitive emissions (tonnes of CO ₂ e per Mm ³ produced)
methane	3,000
carbon dioxide	500
non-methane volatile organic compounds (VOCs)	0.5
nitrous oxides	<<0.01

Source: Glancy, R.P.

The primary impacts of fugitive emissions are climate related. As discussed previously, methane has a 100-year global warming potential⁴² of 34; from the Table 18 above, it is seen that each million cubic meters of coalbed methane produced can create greenhouse emissions equivalent to about 3,500 tonnes of CO₂ equivalent. For each country and Scenario, an estimate of methane emissions in CO₂ equivalent units is shown in the subsection *Environmental Impacts by Country and Scenario* below.

In addition to its climate effects, methane is a volatile organic compound (VOC); together with slight emissions of non-methane VOCs (Table 18), methane fugitive emissions can interact with oxygen to create ground-level ozone, which has detrimental effects on human and animal health in the form of breathing impairment and can contribute to soil and vegetation toxicity as well as visible haze. In the high troposphere, methane-induced ozone can act as a greenhouse gas.

CONSTRUCTION AND OPERATIONS NOISE AND TRAFFIC

In addition to water impacts and air quality, some of the more direct concerns affecting local populations as a result of CBM activities include the potential for noise and visual pollution generated by drilling and additional road traffic induced by construction. These concerns are exacerbated by the generally high population densities and often narrower roads of Europe.

In the UK, the council in which drilling is to take place has the penultimate vote granting or denying approval of drilling (with denials reversible upon appeal to Parliament). In addition, the noise and traffic effects of production activity on motorways, local communities must be vetted by the environment ministry, making the overall approval process a potentially long and involved one. Similar rules and restrictions apply in Germany at the state level.

⁴² The global warming potential (GWP) of a gas is a dimensionless number that is a function of how well and over which portions of spectrum the gas absorbs infrared radiation as well as the amount of time a molecule of the gas typically persists in the atmosphere. The GWP carbon dioxide is set at a baseline of 1. As new measurements and research refine the understanding of the radiative forcing and atmospheric qualities of individual gases over time, their assigned GWPs can be amended; in the case of methane, the GWP has recently been increased to its current (2014) level of 34.

ENVIRONMENTAL IMPACTS BY COUNTRY AND SCENARIO

UNITED KINGDOM

The major environmental impacts for the UK by Scenario are outlined for 2020 and 2030 in Table 19 below.

Table 19 - UK Environmental Impacts by Scenario

UK Environmental Impacts	2020			2030		
	Reference	Climate Strong	Technically Feasible	Reference	Climate Strong	Technically Feasible
Total Land Use (km ²)	52	49	103	156	146	309
Annual Ground-water Production (million barrels)	930	899	1,395	2,232	2,170	3,348
Annual Water Use for Hydrofracturing (million barrels)	1,244	1,186	4,302	1,244	1,186	4,302
Annual Fugitive Greenhouse Gas Emissions (MtCO ₂ e) ⁴³	10.5	10.2	15.6	25.2	24.5	37.8

In 2012, the latest year for which figures are available, estimated UK GHG emissions were 570 Mt CO₂e.⁴⁴ Based on the scenario analysis in Table 19 above, by 2030 the direct emissions effect of fugitive methane emissions from CBM production under the Reference Scenario represent about five percent of this figure.

GERMANY

Table 20 - Germany Environmental Impacts by Scenario

Germany Environmental Impacts	2020			2030		
	Reference	Climate Strong	Technically Feasible	Reference	Climate Strong	Technically Feasible
Total Land Use (km ²)	2	2	45	6	6	135
Annual Groundwater Production (million barrels)	124	93	310	279	186	744
Annual Water Use for Hydrofracturing (million barrels)	133	60	1,069	133	60	1,069
Annual Fugitive Greenhouse Gas Emissions (MtCO ₂ e)	1.4	1.1	3.5	3.2	2.1	7.0

⁴³ Note that the fugitive emissions figures in this Table and in Tables 20, 21, and 22 are *gross* figures. As is discussed in this report's section on minimizing and characterizing fugitive emissions, it is plausible if not likely that domestic CBM production would supplant gas that would have been produced or imported anyway; thus, additional emissions should net out the fugitive emissions that would have been produced anyway. As will be shown in the relevant section, fugitive emissions from some imported gas production could actually be higher than from domestic CBM production, making the displacement of such sources by EU CBM production a net environmental gain.

⁴⁴ UNFCCC Greenhouse Gas Inventory for Germany (April, 2014).

In 2012 the self-reported GHG emissions for Germany were 818 Mt CO₂e.⁴⁵ In the Reference fugitive emissions case, 3.2 Mt CO₂e is emitted, i.e. about 0.4 percent of the 2012 emissions.

POLAND

Table 21 - Poland Environmental Effects by Scenario

Poland Environmental Impacts	2020			2030		
	Reference	Climate Strong	Technically Feasible	Reference	Climate Strong	Technically Feasible
Total Land Use (km ²)	47	44	50	141	132	150
Annual Groundwater Production (million barrels)	1,147	1,116	1,147	2,728	2,666	2,759
Annual Water Use for Hydrofracturing (million barrels)	1,130	1,045	1,198	1,130	1,045	1,198
Annual Fugitive Greenhouse Gas Emissions (MtCO ₂ e)	13.0	12.7	37.0	30.9	30.2	31.3

The 2012 Poland GHG Inventory submission to the UNFCCC estimated total emissions for that year of about 399 Mt CO₂e.⁴⁶ Based on the scenario analysis in Table 21 above, fugitive methane emissions from CBM production in 2030 under the Reference Scenario would be 309 Mt CO₂e, or about 7.7 percent of the 2012 total.

EUROPEAN UNION

An extrapolation of the land use and emissions reduction figures from the environmental assessments of the three countries developed above produces a rough EU outlook, as shown in Table 22 below. While the impacts in terms of direct land use for drilling and production are small on a by-country basis, these accumulate at the EU level and result in about 560 km² needed for the direct CBM production footprint in 2030 under our Reference Scenario.

Table 22 - EU Environmental Effects by Scenario

EU Environmental Impacts	2020			2030		
	Reference	Climate Strong	Tech. Feasible	Reference	Climate Strong	Tech. Feasible
Total Land Use (km ²)	189	177	316	567	529	947
Annual Groundwater Production (million barrels)	3,534	3,379	4,340	8,370	7,998	10,323
Annual Water Use for Hydrofracturing (million barrels)	14,650	13,411	35,737	14,650	13,411	35,737
Annual Fugitive Greenhouse Gas Emissions (MtCO ₂ e)	39.9	38.2	49.0	94.5	56.7	116.6

⁴⁵ DECC (2013). 2013 "UK Greenhouse Gas Emissions, Provisional Figures and 2012 UK Greenhouse Gas Emissions, Final Figures by Fuel Type and End User."

⁴⁶ UNFCCC Greenhouse Gas Inventory for Poland (April, 2014).

According to the UNFCCC aggregated EU 2012 Emissions Inventory, a net 3,401 Mt CO₂e were emitted in that year. The fugitive emissions in 2030 under the Reference Scenario of 94.5 Mt would represent about 2.77 percent of total 2012 emissions.

CHARACTERIZING AND MINIMIZING FUGITIVE EMISSIONS

Although fugitive emissions represent a serious downside from a climate policy (and purely climate) standpoint, the gross emissions from CBM gas production referenced above must be taken in context. Any gas production involves the release of fugitive emissions, which in turn are only a portion of emissions produced over the entire production/transport/storage cycle (Figure 9). To the extent that produced CBM displaces the use of conventionally produced gas, the fugitive emissions from equivalent conventional gas production should be subtracted from CBM emissions in order to accurately characterize net increases fugitive emissions.

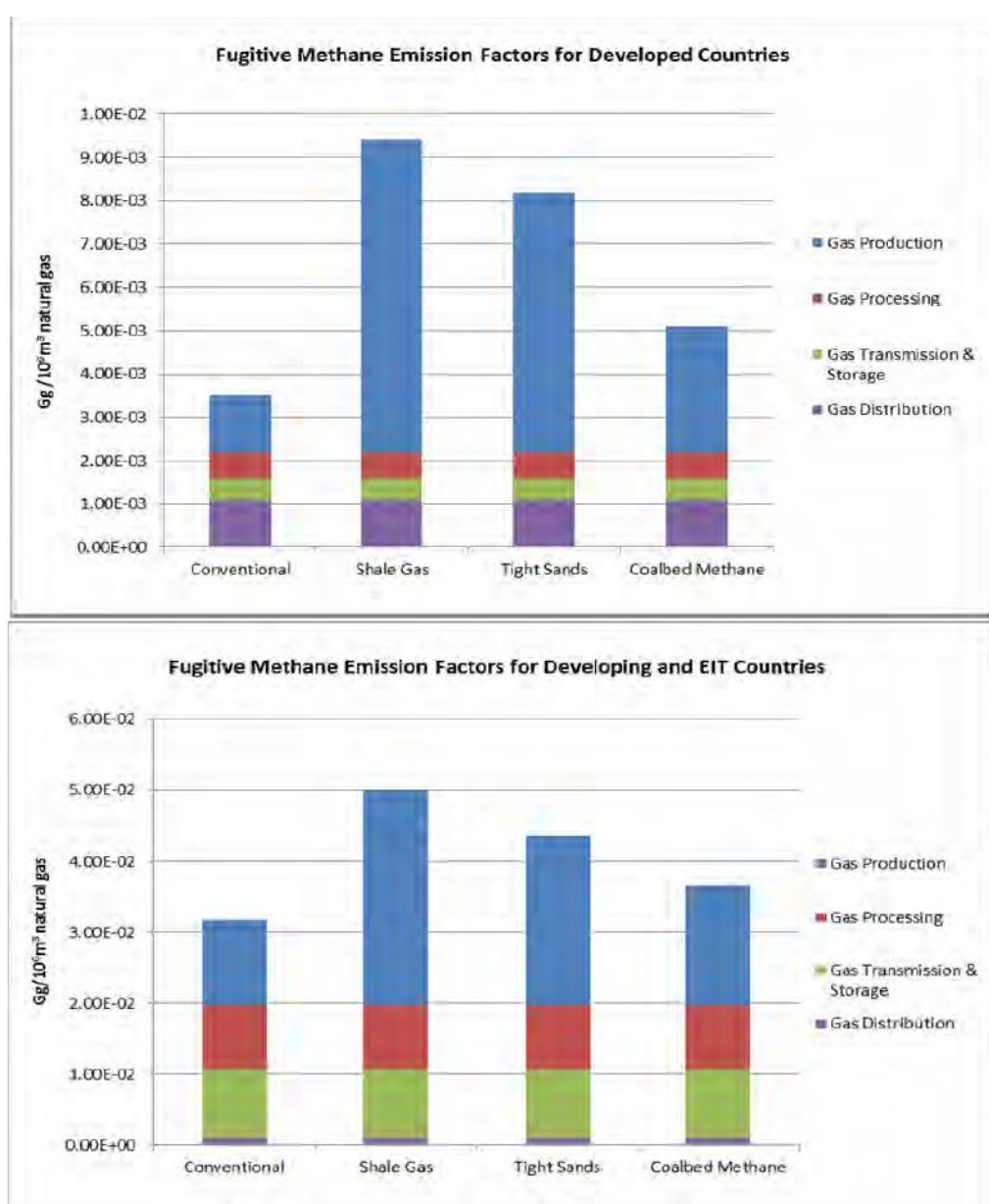


Figure 9 - Fugitive Methane Emissions Factors

Source: Glancy, R.P.

Furthermore, the traditional gas consumption profiles of Germany, the UK, and Poland – as well as of the EU as a whole – are fairly heavily weighted toward imports (as in the respective country profiles previously). Thus, it is likely that CBM produced within the EU would displace some imported gas. Much of the EU's imported gas originates from economies in transition (EIT), in which gas production has been characterized as higher in emissions than facilities in developed economies. In fact, a comparison of panels 1-2 of Figure 9 shows that CBM production within the EU might actually reduce net emissions relative to imported conventional gas. Other factors that would mitigate relative fugitive emissions from domestic CBM production include generally shorter pipeline distances traveled and less leaky transport equipment.

Based on the figures provided in Figure 9, therefore, we can characterize the *net* fugitive emissions increase resulting from EU CBM production per cubic meter of displaced gas to fall within a broad range, from +1.6 (EU-produced gas) to -7 (imported EIT gas) tCO₂e/Mm³.

One other observation of interest from Figure 9 is that CBM production involves lower overall fugitive emissions than either shale gas or tight sands production (3 versus 6 and 5 tCO₂e/Mm³, respectively).

In 2005, the oil and natural gas sectors in the EU were responsible for a total of 67 Mt CO₂e emissions in the EU (64% of fugitive emissions from fuels); of this figure, 44% of emissions were the result of gas production⁴⁷.

The primary sources of methane emissions from the natural gas sector are chronic leaks in production equipment and pipelines, constituting approximately 86% of total fugitive emissions⁴⁸. As Figure 10 demonstrates, the plurality of emissions comes during the transmission and distribution phase (72%) while only 17% of emissions occur during production, from both “chronic leaks” and from production activities.

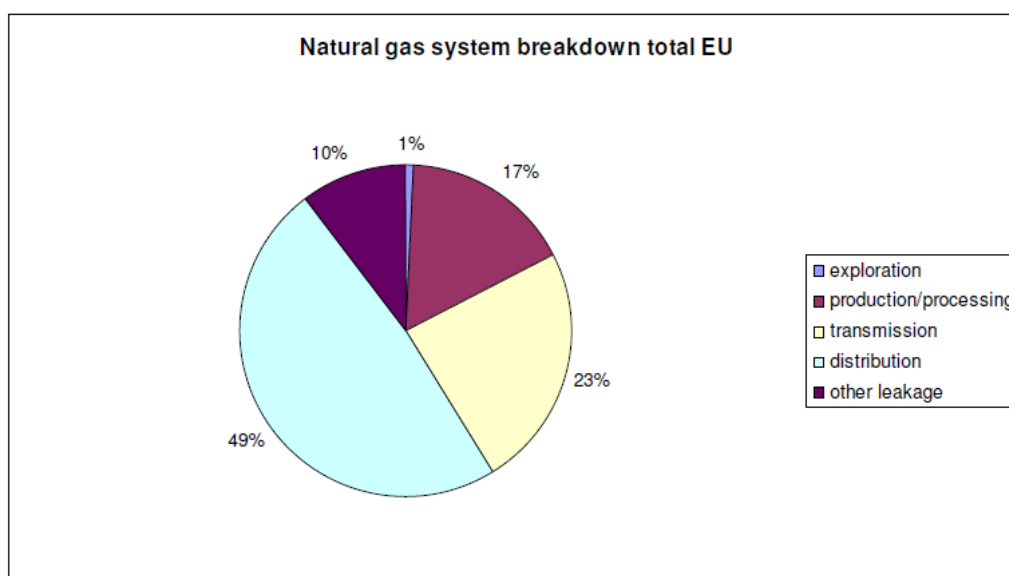


Figure 10 - Breakdown of EU Fugitive Gas Emissions, 2005

Source: ECOFYS

⁴⁷ ECOFYS (2009), “Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC) Methane from fugitive emissions.”

⁴⁸ *ibid.*

To effectively reduce production leakage, advanced monitoring and inspection techniques can be combined with regular maintenance routines. Recently developed automated inspection regimes that rely upon monitoring of gas flows to pinpoint troubles might be able to reduce the overall fugitive emissions of CBM production by 66% at an average discounted (10%) net present cost of 3.0 EUR/tonne of CO₂e reduced⁴⁹. These factors are used to estimate fugitive emissions reductions and costs EU-wide in Table 23.

Table 23 - Fugitive Emissions Reductions and Costs for the EU

Fugitive Emissions Management	2020			2030		
	Reference	Climate Strong	Technically Feasible	Reference	Climate Strong	Technically Feasible
Unabated Annual Fugitive Emissions MtCO ₂ e	39.9	38.2	49.0	94.5	56.7	116.6
Reduced Annual Fugitive Emissions MtCO ₂ e (based on ECOFYS figures)	13.2	12.6	16.2	31.2	18.7	38.5
Total Cost (Million EUR)	80.2	76.8	98.5	189.9	114.0	234.4

Table 23 above shows the effects and costs EU-wide of implementing such leak reduction measures; all told the discounted costs in 2030 could be between EUR 114 and 190 million at a marginal cost of about 6 Euros per tonne of CO₂ equivalent abated. The costs, however, would include considerable capital expenditure upfront, so the investment requirements would be borne earlier in a well project. While it's beyond the scope of this study to integrate these costs in the NPV analysis, it's important to note, however, that although the aggregated costs are considerable, leak reduction in the CBM production and distribution infrastructure would result in increases in saleable gas.

⁴⁹ *ibid.*

E. CBM RESOURCE DEVELOPMENT – BARRIERS AND POLICY OPTIONS

The scenarios presented show what level of CBM production may be possible considering two different levels of climate policy ambition in the EU, and a ceiling scenario on technically viable gas production. Yet the fact that CBM production is minimal in the EU today, in spite of the considerable possible production given gas prices similar to today's, supports the reality that not all coalbed methane project opportunities that seem viable will result in projects. As such, it is important to consider the barriers to practical development of projects and measures that have been successful to overcome these.

The development of any industry requires that broader market and technological conditions exist within which an industry may find a market. Technologies to produce CBM have benefited from a considerable number of research, development, and demonstration projects that have produced several technologies – from improved coal seam stimulation techniques, to horizontal directional drilling – that have become established, commercially proven options. Furthermore, various incentives and legislation to make clear rights/ownership of CBM have stimulated CBM developments.

Commercial use of coal bed methane also requires that project developers have access to markets: these can be rights to use gas on-site as a substitute for other energy sources, or for sale to local users or in a grid as gas or electric power. However, the economic analyses for this study show that deploying technically feasible use technologies at market prices commensurate to the 2014-2015 National Balancing Point range of 18-25 EUR/Mwh would theoretically result in considerably more coalbed methane production than is actually the practice in the three countries studied. In other words, more CBM production could be viable under prevailing market conditions, than actually is produced.

It's important to caveat the above statement: this study is not a geo-technical assessment of production potential, but rather a scenario analysis based on a number of assumptions that cannot yet be validated. Yet, compared to other regions of the world, why for the most part, have projects not been developed in the EU?

BARRIERS TO RESOURCE DEVELOPMENT

Barriers can be characterized as informational, resource, legal/property rights, and market uncertainties. These are outlined below:

- *Lack of Understanding / Information on Resource and Risks by Broader Stakeholders:* A thorough understanding of the market potential and social and environmental risks by all stakeholders (community groups, landowners, coal operators, local and national governments, foreign investors) is critical for better informed investment, planning and decision making.
- *Geo-technological Information:* The publically available data on coalbed methane resources is very limited. Data such as permeability, and gas content are sparse. Testing and dissemination of data on gas properties of coal should be available to potential project developers.

- *Legal Constraints:* Doubt as to the rights to the CBM resource and to energy revenue greatly increase the investment risk of projects and lower the prospects for successfully developing projects. Transparent methane ownership rights, licensing regimes, and energy prices and contracts are necessary.
- *Market and Technological Uncertainties:* EU climate policy will significantly impact gas demand, at least without carbon capture and storage. More stringent climate policies would make CBM unattractive in the long run. Furthermore domestic CBM production needs to compete with gas imports.

Policies and measures, including those that provide or foster unbiased information and analysis services, further research, development, and demonstration (including significant efforts to disseminate the findings) can play an important role in encouraging more and more effective coal bed methane projects. Energy and resource policies can play an important role in clarifying rights and market value in the production of CBM.

INTERNATIONAL EXPERIENCE

As the U.S. is the first and by far the largest commercial CBM producer, it is not surprising that a combination of public and private technological innovations have originated there. Research and demonstration projects supported by the U.S. Bureau of Mines in the 1970s included drilling vertical wells into virgin coal seams.⁵⁰ The Gas Research Institute GRI was founded in 1976 in response to the Federal Power Commission (FPC) encouraging increased gas research and development (R&D). GRI administered research funding provided by a surcharge on shipments of natural gas sold by the interstate pipelines, with a considerable program of research in coalbed methane resource characterization and production.

An often-cited major economic stimulus for CBM production in the U.S. was Section 29 of the Federal Windfall Profits Act of 1980 (Non-conventional Fuels Tax Credit) for wells drilled between 1980 and 1992.⁵¹ Legislation was adopted in several U.S. states to clarify ownership rights of CBM, and an EPA analysis clearly shows that, “The passage of CBM legislation in Virginia and Alabama preceded a dramatic increase in CBM resource recovery.”⁵²

Other countries with successful coalbed methane industries, including Canada and Australia, have encouraged production through various royalty incentives, including in Alberta a royalty rate of 5% versus 12-27% for ineligible wells, and in New South Wales in Australia, a five-year royalty holiday.⁵³ The result of these incentives on CBM’s profitability can be striking. As Figure 11 shows, NPVs are uplifted by as much as \$0.10/mcf (EUR .003/m3). While several countries, including China, Russian and Indonesia, have also adopted attractive financial incentives, a recent analysis concludes that these are not always sufficient to spur as dramatic an

⁵⁰ Elder, C.H., and Deul, M., 1974. “Degasification of the Mary Lee Coalbed Near Oak Grove, Jefferson County, Ala., by Vertical Borehole in Advance of Mining, Bureau of Mines Report of Investigations 7968, U.S. Department of the Interior.”

⁵¹ U.S. EPA, 1997. “Coalbed Methane Legislation and Recovery in Alabama, Pennsylvania, Virginia, and West Virginia” November, 1997.

⁵² U.S. EPA, 1997.

⁵³ Straker, R., 2015. “How coalbed methane incentives vary across the global development spectrum”, Energy Global Oilfield Technology, 28/04/2015.

increase in production. Technical obstacles (China), a lack of infrastructure makes it difficult for CBM to go to market.⁵⁴

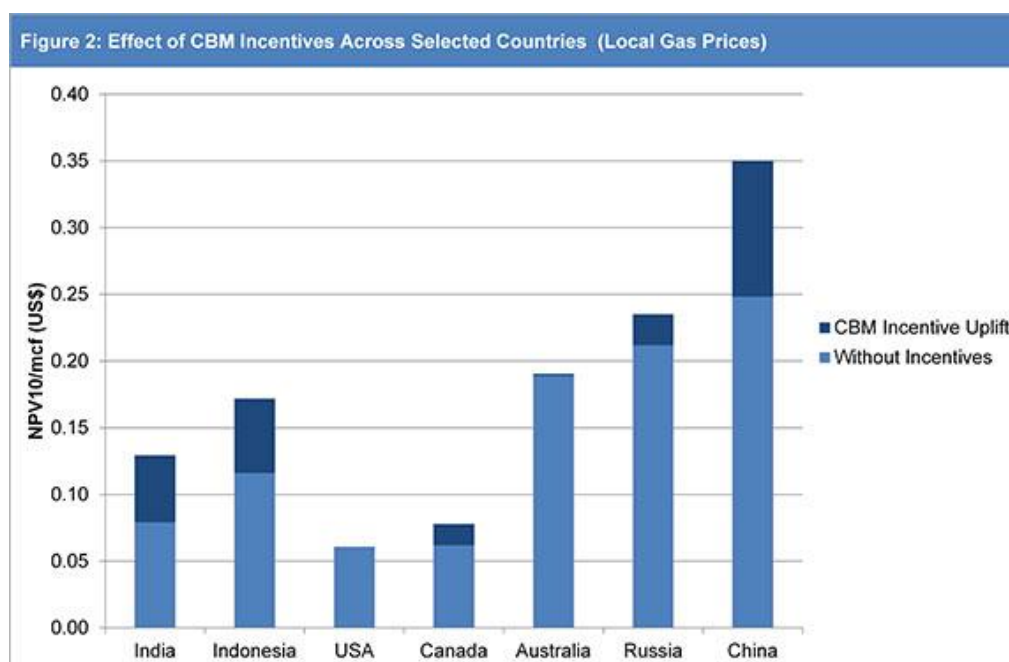


Figure 11 - Profitability Uplift from CBM Incentives

Source: Straker, R.

RELEVANT EU PROGRAMMES

Any State support measures for research into coal-bed methane or for coal-bed methane projects would have been designed in full compliance with State aid rules and must be notified to the Commission under Article 108(3) of the Treaty on the Functioning of the European Union prior to implementation unless they are caught by the Commission Regulation (EU) N°651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty.

In some former mining regions, or regions where the industry is winding down, regional, national, or EU-directed regeneration programmes have been instituted to provide regeneration assistance in the form of knowledge transfer or direct funding. For instance, the EU European Regional Development Fund's ReSource initiative has developed regional profiles for Poland, Germany, and the Czech Republic that gather data such as employment and population dynamics, while the EU's Liaison entre actions de développement de l'économie rural (LEADER) programme has provided grants to regional authorities in Germany and elsewhere to develop tourism activity based on mining heritage.⁵⁵ In the UK, there are a number of government-instituted programmes to monitor and assist the coalfield regeneration process in England, such as the Coalfield Task Force. Although such efforts have generally had moderate success in aiding in the regeneration process, economic indicators in such regions remain poor overall and it is agreed that further work toward recovery will be required.

⁵⁴ *ibid.*

⁵⁵ ReSource (2009). Central European Regional Profile Report.

F. CONCLUSIONS

The purpose of this study was not to project expected CBM production but rather to generate a scenario analysis to quantify the considerable potential social, economic, and environmental impacts of coalbed methane. Such impacts are clear and in many cases considerable across the three Scenarios applied in this analysis to the three subject countries of Germany, Poland, and the United Kingdom.

In terms of overall gas production – which drives all other economic, social, and environmental effects in our analysis – the UK showed, within the confines of our scenario development, the highest potential overall, followed closely by Poland and then Germany. However, the ultimate CBM resource of all three countries is large, and the study's modeling suggests that a combination of increased exploration, technological advance, and sufficient price signal would allow for expanded development of CBM in all three. Particularly in the UK and Germany, the difference between the results of the two Economic Scenarios and the Technically Feasible Scenario underscores the potential to develop considerable national CBM resources as underlying drivers evolve.

Perhaps the most significant potential positive impact of CBM development is the economic one. CBM production results in revenues directly to the producer and less directly as royalty revenues to the government or licensing authority. It is in terms of leveraging community, regional, and ultimately national and trans-European economic stimulus, however, in the form of highly paid and in many cases long-term direct job creation and indirect regional employment that the income effects of CBM production really comes into play. Across Scenarios and in total for the three primary countries of this study, CBM production is projected to generate from 3.4 – 4.7 billion Euros in direct gas sales income in 2030. In the same year, the

Top Conclusions

- ◇ *Based on estimation, the CBM resource in the three countries studied totals about 4.4 Tcm; a rough projection to the EU as a whole increases this to about 5.4 Tcm.*
- ◇ *However, existing (albeit sparse) data suggest that much of the EU CBM resource would require fracking.*
- ◇ *Under modelled scenarios, UK showed the highest CBM development potential overall, followed closely by Poland and then Germany.*
- ◇ *Under economically feasible scenarios, CBM could reduce EU gas imports by up to 4.4% and lower gas prices by up to 2.4%.*
- ◇ *EU-wide full-time equivalent (i.e., temporary and permanent) job creation could potentially lower unemployment rates in coal mining regions.*
- ◇ *Climate policies consistent with the IEA-450 emissions pathway may coexist with policies to the development of encourage indigenous coalbed methane resources in the short and mid-term (i.e., through 2030) provided that such resources substitute more carbon intensive fossil fuels or gas imports and do not replace renewable energies.*
- ◇ *However, even with control technologies in place, fugitive emissions of CBM could be significant, although the extent to which net emissions are higher or lower than supplanted gas is unclear. If policies to encourage methane control are insufficient, other policies, such as encouraging implementation of carbon capture and storage (CCS) might be required.*
- ◇ *Land use and water impacts are considerable and abatement practices are limited.*

Figure 12 - Policy Relevant Top Findings

corresponding direct employment owing to drilling and production ranges by Scenario from about 27,000 to about 32,000 full time equivalent positions.

Turning our eyes to the EU as a whole, we tentatively identified several more countries that have sufficient potential CBM resource and attempted to roughly model corresponding production Scenarios in order to develop an EU-wide aggregate. Although the majority of production still takes place in the UK, Germany, and Poland, adding CBM activities in Bulgaria, the Czech Republic, France, Italy, and Hungary could result in total 2030 gross revenues (under the CBM output-reduced European import price series) of up to 12.3 billion Euros (based on the direct job creation potential of about 60,000 EU-wide under the reference scenario). While from an EU scale these figures are modest, the job-creation potential from a regional development perspective is important, particularly considering the impact of further mine closures on regions already facing high unemployment rates.

The macroeconomic heft of potential gas production in these scenarios is so great that there is the potential for a detectable price-drag within the EU. Based on estimated wholesale gas price elasticity factors, CBM production could suppress EU-wide gas prices by as much as 2.4 percent by 2030. Whenever production of a good is significant enough to have an effect on market price, the market can develop a tendency to oscillate or destabilize in seeking a new equilibrium, e.g., with decreased prices suppressing production, which then again increases prices, leading to more production, etc. Although this effect may occur with marginal production sources, the modeling done within the scope of this report is not sensitive enough to detect it.

The climate implications of large-scale CBM production are, depending on context, potentially both positive and negative. On the positive side, methane is a fossil fuel with CO₂ emissions of about half of coal when combusted for heat or electricity generation. Nevertheless, the extent to which CBM-generated electricity would supplant dirtier fossil fuels or potential zero emissions energy sources is heavily dependent on national policy and economic drivers, as once the coalbed gas goes into the pipeline it is difficult to determine where it would wind up and to what use it would be put. Correspondingly, the greenhouse gas emissions implications of fuel displacement were not analysed in this study.

Furthermore, the relative greenhouse gas emissions benefits of natural gas consumption decline, and reverse, as climate policy ambition strengthens; the Climate Strong Scenario demonstrates that gas is no longer as attractive an investment as prices decline owing to relative decline in demand by 2030. Policymakers can, therefore, consider the promotion of coalbed methane to possibly have climate-positive benefits in the short and medium term, but not in the long term (e.g., 2030 and beyond).

And definitively on the negative side of impacts, methane emitted directly to the atmosphere is a potent greenhouse gas, and a real danger in the production of any kind of natural gas lies in the potential for fugitive emissions. Based on a medium level of potential emissions from wells, equipment, and pipelines, the study found that fugitive emissions from CBM operations could total as much as 95 MtCO₂e EU-wide in 2030, although in the Climate Strong Scenario this is reduced to 56 MtCO₂e. To significantly and systematically reduce fugitive emissions, careful monitoring and suppression technologies could be implemented at a gross cost of 190 – 234 million Euros, depending on the Scenario, in 2030, with corresponding Scenario-dependent fugitive emissions reductions down to 19-38 MtCO₂e per year. Although the above

costs are not insignificant, implementation of leakage control measures will increase volumes of saleable gas, offsetting the costs.

However, the net greenhouse gas emissions resulting from CBM production are uncertain, as it is possible that any domestic CBM production could displace other gas production that may have higher or lower fugitive emissions. Comparison of standard developed economy CBM emissions profiles with comparable profiles from developed countries and/or from economies in transition (EIT) production indicates that complete CBM displacement would alter the amount of net fugitive emissions within a range of +1.6 to (-7) tCO₂e/m³. In other words, EU CBM production might release fewer emissions than gas imported by the EU from countries with economies in transition (EIT).

Similarly, local environmental impacts could be considerable, especially in terms of water stress in the form of groundwater production and fracking water use. The groundwater produced in preparing and maintaining a well can contain various salts and other toxic contaminants that must either be removed to another locale (and then treated) or treated on site at a considerable expense. Our Scenario modeling suggests that EU-wide groundwater production could reach 8.3 -10.3 million barrels a year in 2030. If a well needs to be hydro-fractured (and the study assumes that, in most EU cases, this will be necessary), water use is similarly considerable, with our modeling suggesting an additional water demand of around 14 million barrels for CBM fracking in the EU by 2030.

Furthermore, CBM production may result in a degradation in air quality in regions facing generally moderate to poor air quality, as fugitive emissions contain volatile organic compounds (including methane itself) that can impair breathing and act as a precursor to ozone, which causes haze and can negatively impact human, animal, water, and soil systems.

Well drilling and production come with land and social impacts, both quantifiable and intangible. Although the actual footprint of a CBM well pad is not great, the potential scale of development could amount to a total footprint over the entire EU of up to 1,000 square kilometers under the Technically Feasible Scenario; additional land for pipeline easements, construction, and offsets would certainly increase the overall impact.

Perhaps more problematic are the issues attendant to social acceptance and the more intangible landscape and quality of life impacts of fossil fuel production, whether actual or anticipated. From the village to the national government level, a heated conversation is ongoing in Europe right now as to the net positives and negatives of gas resource development, and the outcome of this conversation may ultimately determine how the resource does or doesn't get developed.

The production of CBM can enhance or at least help stabilise the EU's domestic supply of gas, partially offsetting losses from domestic fields that are expected to play out over the next few decades. Given that the continent is mostly dependent on imported gas (importing a net 65 percent of its 2013 supply⁵⁶) - and acknowledging that it still will be, regardless of its CBM potential – the added liquidity supplied by indigenous coalbed methane can help to suppress gas prices and serve as a hedge against politically problematic international sources.

⁵⁶ Eurostat (2015), "Energy Dependency Rate, EU-28, 2003–13"

The analysis of economic scenarios found between 25.8 and 27 bcm of CBM production in 2030. To put this in perspective and consider the impact on gas supplies, 2013 natural gas imports into the EU were 314 bcm⁵⁷, so if CBM production were to meet these levels, they could represent about 8.5 percent of imports. Looking at gas consumption projections, The Oxford Institute for Energy Studies estimates these to be 610 bcm in 2030, so CBM could contribute about 4% to total EU gas demand.⁵⁸

The choice of three alternative scenarios for the future development of the EU's CBM resource may provide policymakers with a view towards how different energy supply, local and global environmental, and job creation goals could be supported or hindered, and at what opportunity costs. However, the study also notes that experience around the world has shown that not all coalbed methane project opportunities that seem viable will result in projects. As such, it is important to consider the barriers to practical development of coalbed methane resources and measures that have been successful to overcome these.

The study highlights a variety of informational, legal and market barriers and suggests that should it be decided to develop such resources, these barriers may be overcome through policies and measures, that provide unbiased information and analysis services, further research, development, and demonstration (including significant efforts to disseminate the findings), all of which can play an important role in encouraging increasingly effective coal bed methane projects. Energy, resource, and regional development policies can play an important role in clarifying rights and market value in the use of CBM. In any case, however, as already duly noted, any State support measures would have to be designed in compliance with EU State Aid rules.

⁵⁷ From the BP Statistical Review 2014.

⁵⁸ The Oxford Institute for Energy Studies (2014), "The Outlook for Natural Gas Demand in Europe."

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