Production of Coal Bed Methane in Germany

Oliver Langefeld and Amit Agasty

Department of Underground Mining Methods and Machinery, Institute of Mining, Clausthal University of Technology, 38678 Clausthal-Zellerfeld, Germany

Abstract. The political situation in Germany and the EU in general, has provided an opportunity for energy sources like CBM. The Decision of the Federal Government to move from the traditional Nuclear Power to renewable and sustainable sources has led to the implementation of various energy sources including Geothermal and Power generation from mine gas. This does not only ensure energy security for the country but also mitigates climate change by keeping the greenhouse emissions within the EU norms and standards. Methane, the major component of mine gas, is a 20 times more potent greenhouse gas than CO_2. Extraction of gas from coal seams for power generation and heat supply thus reduces the emissions significantly. Abandoned Mine Methane (AMM) and Coal Mine Methane (CMM) projects are now prevalent in several sites in North Rhine-Westphalia and Saarland. As mining companies start to wind-up their activities in the country more AMM projects will start up. Along with this there is a need to invest in the development of virgin Coal Bed Methane projects to secure an abundant energy supply for the future. The Münsterland Basin has good potential for this. This paper discusses the state-of-the-art of degasification technology and the present production scenario for coal seam methane.

Keywords: Coal Mine Methane (CMM), Abandoned Mine Methane (AMM), Coal Bed Methane (CBM), Germany, Block Heat and Power Plants (Blockheizkraftwerke BHKW).

1 Introduction

According to phase III of the European Union Emission Trading Scheme (EU ETS) the annual allowable CO_2-Emmisions in the entire EU should be reduced by 21% of the present 2.1 billion tons by 2020 [1]. In addition, the decision made by the Federal Government of Germany in 2011 to accelerate the phasing out of the Nuclear Power on one hand necessitates securing the Energy supply in Germany and on the other hand gives a competitive advantage to the development of renewable energy sources. This leads to the “Renewable Energy Act”

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(Erneuerbare-Energien-Gesetz, EEG), established in April 2000. The 2004 version of the EEG regulates compensation for power generation from mine gas, in cases where mine gas is produced from active or abandoned mines [2, 3].

The German mining laws (Bundesberggesetz) permit the extraction/production of mine gas from coal seams, a mineral resource. Methane, the major component of mine gas, is a 20 times more potent greenhouse gas than CO_2, and so its use for power production can contribute tremendously to the protection of the climate, while at the same time providing a sustainable source of energy. In the German state of North Rhine-Westphalia, where most of the coal seams are located, the government supports and recognizes the importance of mine gas as a future energy resource ("Landesinitiative Zukunftsenergien" 2001).

Different technologies are available to recover Coal Seam Methane, depending on the stage of recovery. This paper discusses the aspects related to these recovery stages, a state-of-the-art coal seam methane drainage technology and the current situation in Germany with regard to the production of mine gas.

2 Coal Seam Methane and Coal Seams in Germany

Mine gas consists mainly of methane, with its content varying from about 20% to over 90 % during production, depending on the drainage stage and method used. Methane found in coal seams was formed at the same time as coal. The methane content of a virgin seam depends on the depth of the seam, age and rank of the coal. Figure 1 shows an idealized concept of gas content increasing with coal rank [4]. Additionally Table 1 gives the mean methane content as a function of depth [5].

The German coal seams are concentrated in three main geographical regions. The largest of which is the Ruhr-Region in western Germany. Second is the state of Saarland and third is the Ibbenbüren-Region. In the east Ruhr region the seams are at a depth of about 1000 m with a vitrinite reflection of 1.7 %, accounting for about 88 % of the carbon. However, the west Ruhr region also contains Anthracite with a vitrinite reflection of 2.3% at same stratigraphic level, but different geothermal gradient and variable overburden. In principle, all types of coal can be found in the Ruhr region. Generally, coal seams are flat, with a slight dip towards the north-east. In the south of the Ruhr-region the seam is exposed to the surface. The overburden thickness increases towards the north, as depicted in Figure 3.

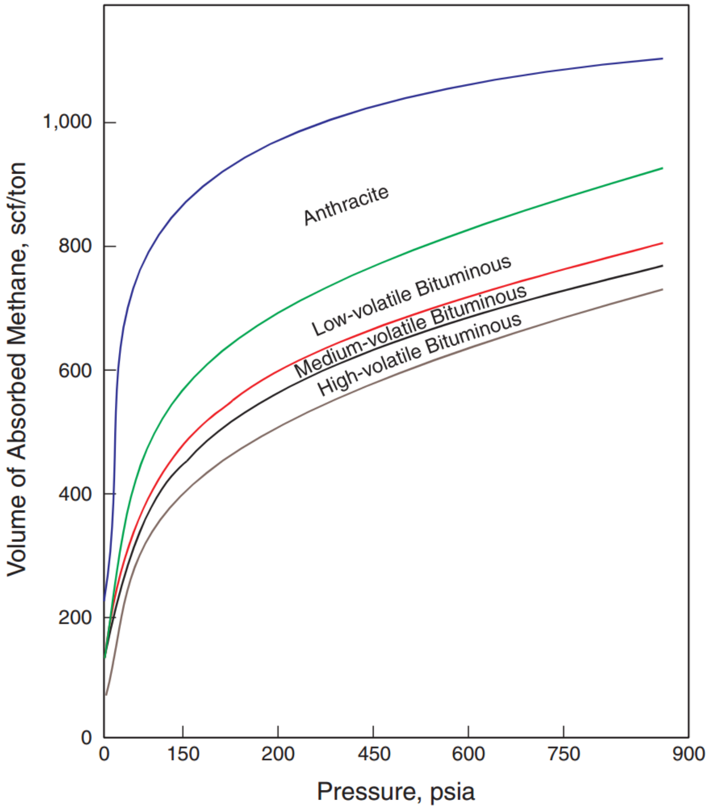

Fig. 1 Gas content of a maturing coal seam [4]

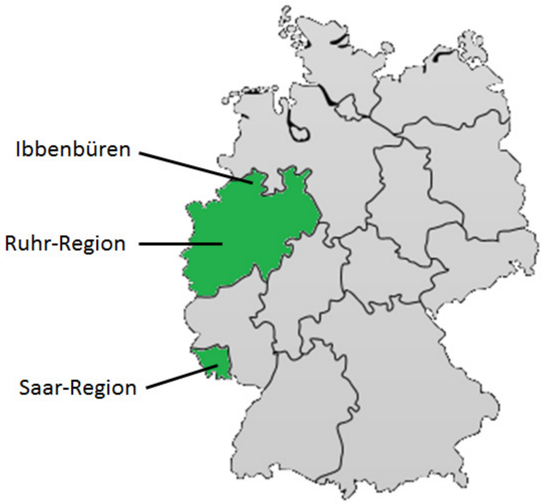

Fig. 2 Coal Mining Regions in Germany

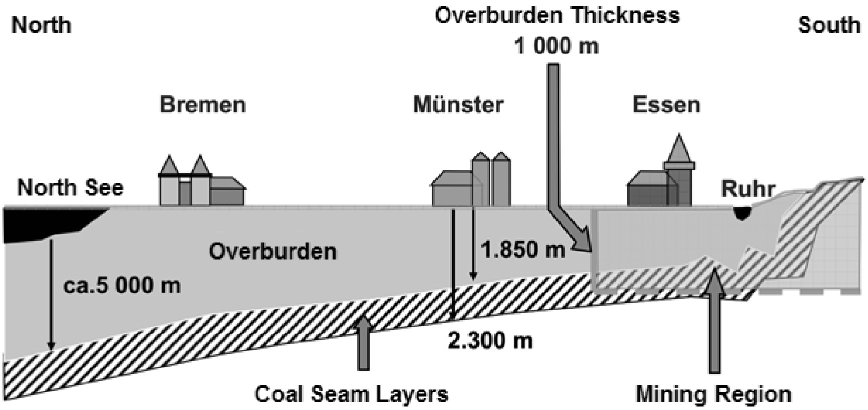

Fig. 3 Dipping of the coal seam from the Ruhr-region to the North [2]

The total German coal bed methane reserve is about 3 trillion cubic meters, but the recoverable portion is restricted by geo-technical constraints, mostly the low permeability.

Table 1 Methane content in coal [5]

Depth Interval (meters)	Mean methane content (cubic meters per ton of coal)
100	0.02
500	0.99
1000	3.73
1500	4.89
2000	7.09

3 Degasification

3.1 Coal Mine Methane

In mining terminology the methane-air mixture is called "Fire Damp", and is highly explosive within a range of 5 to 15% of methane concentration in the mixture. This is the reason why the mining laws regulate the maximum allowable methane concentration underground, and appropriate dilution measures must be taken by the mine operator. Degasification can be achieved either by supplying enough fresh air ventilation to the working stations or by various possible methane drainage methods.

Ventilation of the underground workings serves two purposes, first to supply enough fresh air to the workforce and the equipment and second to dilute the contaminants, including poisonous or explosive gases, dust, heat etc. Fresh air is drawn into the mine by intake shafts or inclines and channeled through the intake airways to direct the required quantity to the working face. From here the polluted air is taken out of the mine by draining through the exhaust galleries and up the cast shaft. The methane content in the exhaust air is generally very low, usually less than 1 %. This is called Ventilation Air Methane (VAM).

In the case of a very gassy mine, methane drainage, either in the front or behind the working face is necessary for providing a safe environment underground. There are several different systems used in the world for draining methane from a gassy mine. When the seams are not at a great depth, drilling boreholes from the surface is a likely option (Figure 4). In Germany, however, where the coal seams lie at great depths, boreholes from another seam or in-seam are more common. These systems involve drilling boreholes, either from the surface or inside the mine to drain the methane from the coal seam sandwiched between the overlying and underlying strata so that the ventilation is not overloaded. Three different drainage options, however, exist for shallow seams: Surface pre-mining boreholes, horizontal pre-mining boreholes and post-mining (gob) boreholes. The first two options for degasification fall under the stage of methane drainage from active mines. Methane recovered during the mining activities, i.e., when the coal is in the process of being extracted, is known as Coal Mine Methane (CMM). In figure 4 different options of degasification are schematically represented, (1) horizontal pre-mining, (2) surface pre-mining (3) gob well and (4) VAM.

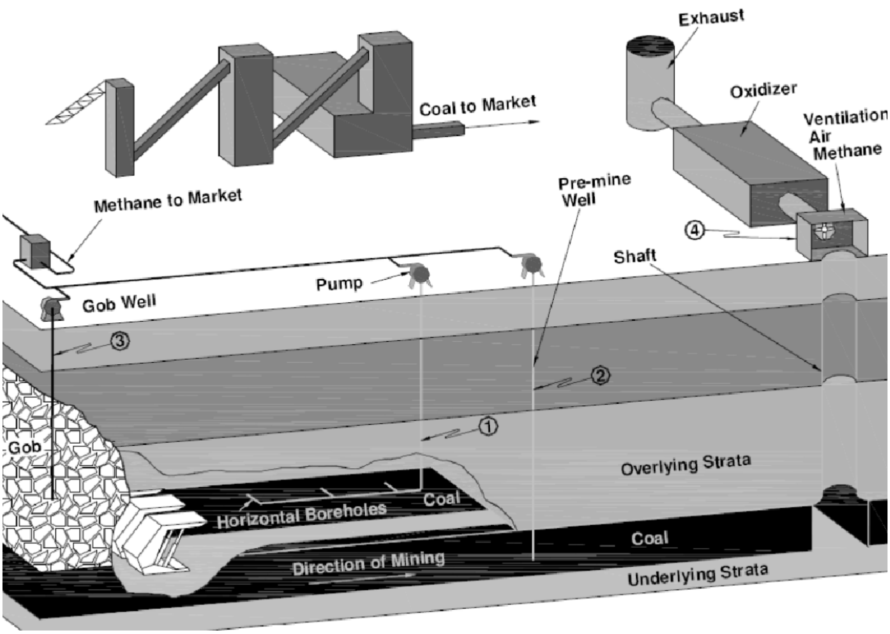

Fig. 4 Types of Methane Degasification from an active mine [5]

In case of longwall mining 50 to 200 m into the coal seam from the longwall face, the over lying beds start to subside as the overburden pressure starts building up [6], this caused by the weight of the strata above that was previously supported by the coal extracted (now gob). The stress at the longwall front can be 4 to 5 times higher than the in situ stress. As a result of the high pressure the elasticity of the coal seam is exceeded and this results in the release of absorbed gases. The density of the mine gas released in this way is about 0.72 kg/m^3. As a consequence this gas tends to settle near the roof of the galleries resulting in the phenomenon of "Methane-Layering".

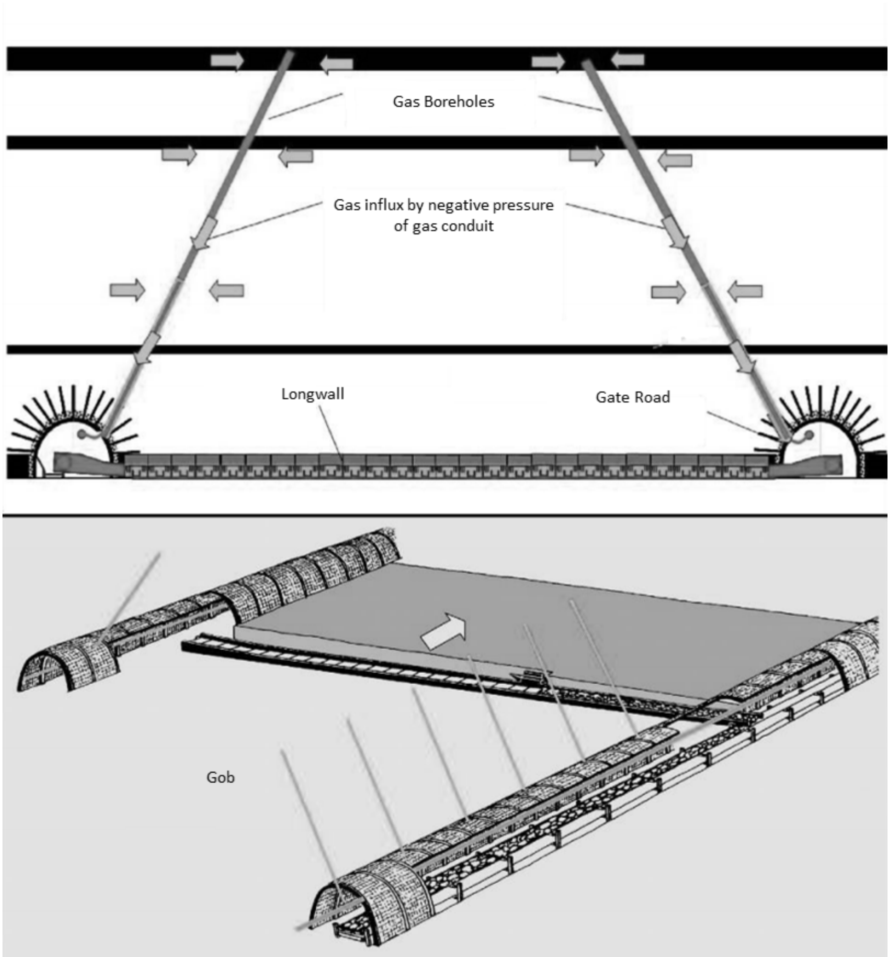

Fig. 5 Horizontal pre-mining Methane Drainage in Ruhr-Region RAG [7]

3.1.1 Block Heat and Power Plants (Blockheizkraftwerk, BHKW)

BHKW is a modular unit used for generating power and heat. It works on the power-heat coupling and vis-à-vis principle. The mine gas recovered is compressed and supplied to a BHKW unit. In the state of North Rhine-Westphalia (NRW) multiple decentralized units are in operation while in Saarland this is achieved with a mine gas network of about 110 km [1]. A BHKW unit with a capacity of 1.35 MW prevents about 50,000 t CO_2-emissions annually. A STEAG Grubengas-Holding NRW GmbH (60 %) and RWE Power AG together own the Mingas-Power GmbH. Mingas-Power GmbH is involved in power generation from the active mine in NRW. It generates a total of 39 BHKW units from 15 sites, and its annual power production in 2012 was 191.1 GWh from 28 BHKW and a heat supply of 40.5 GWh.

3.2 Coal Bed Methane

This is the methane recovered from virgin coal seams. These coal seams may be mined in the future but this is largely dependent upon geological factors such as coal depth and quality. As the coal seam is not yet loose the gas stays adsorbed and thus corresponds to higher methane content. Methane is recovered from unmined seams for two purposes, first when it is necessary to drain the gas before mining as a safety precaution against explosions during future mine operations, and second for energy production regardless of whether the coal is going to be excavated. CBM is recovered by means of surface boreholes and fracking techniques, which aim at increasing the permeability of the strata and hence, gas desorption. The coal seam needs to be dewatered in order to reduce pressure and release the methane from its adsorbed state. The horizontal drilling option is chosen as suitable in several articles, as it can recover higher volumes of methane in comparison to vertical wells. Its efficiency, however, remains low and is dependent on the length of the borehole through the seam.

Coal seams at extreme depths cannot be excavated because of safety, technological and economic reasons and in this case methane extraction is limited to purposes of energy generation. The methane recovery from this method may be over 95 %, as a result of not being exposed to the ventilation air as in case of CMM.

According to the 2006 estimations of CBM, a total global resource of 143 trillion cubic meters exists, of which only a small fraction has so far been recovered. This is as a result of lack of government incentives for its recovery. As mentioned above, compensation by the German government for power generation from mine methane is limited to mine gas recovered from active and abandoned mines. Russia, Canada, China, Australia and USA top the list of estimated resource bases in the world. The deeper coal seam towards the north, as represented in Figure 3, presents an opportunity for Virgin CBM recovery, since coal extraction at such extreme depths is likely to be impossible.

3.3 Abandoned Mine Methane

When considering methane recovery from abandoned mines UK, USA and Germany have taken the lead in technology and project development. The primary aim for such projects is generally energy production but recently their significance in attempts towards greenhouse gas emissions control has been appreciated. The abandoned mines generally get flooded with water. In cases where the shafts are sealed off and the sealing standard is good, the volume of methane will be good. Another option is to leave the mines vented, such that the ventilation shafts are not sealed and fresh air flows through the mine allowing methane to escape into the atmosphere. As expected, abandoned mines that were sealed off present the highest potential for methane recovery, although their economic advantage in recovery lies within the first couple of years post-abandonment. The research in the Ruhr-region pointed out that 10-30 % of gas from the initial pre mining period remains in the abandoned mines. Recovery of the remaining gas is possible either by using the previous methane drainage system or else boreholes need to be drilled to access the gas reserve. The latter option poses a greater risk, as the borehole needs to be drilled in broken, fractured and subsided ground, which may result in the borehole collapsing.

The STEAG Grubengas-Holding NRW GmbH, Essen (74.8 %), the Green Gas Germany GmbH, Meerbusch and the Lambda Gesellschaft für Gastechnik mbH, Herten (12.6 % each) own the Minegas GmbH. Mine gas GmbH has so far produced 58 BHKW units of mine gas from 16 sites as of the end of 2012. The year’s power production was 385.9 GWh from 48 units with a total heat supply of 4.8 GWh. Table 2 presents the cumulative supply of energy from mine gas in Germany, an initiative from the independent mining organizations.

Table 2 Cumulative Mine gas use in Germany up to the year 2012 [8]

Drainage Stage	Power Production (kWh)	Heat Supply (kWh)	Avoided CO_2-Equivalent (t CO_2)
AMM	550,693,681	31,777,692	2,417,821
CMM	257,484,558	76,300,992	1,412,594
Total	808,178,239	108,078,684	3,830,415

4 Conclusion

The BHKW unit’s capacity has increased over the years to 130 MW. As the mining operations in Germany start to wind up the CMM projects will need to be converted into AMM projects. This needs proper planning for mine closures. Moreover, since such reserves are limited it will be necessary to take up CBM projects to recover mine gas from deeper coal seams.

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