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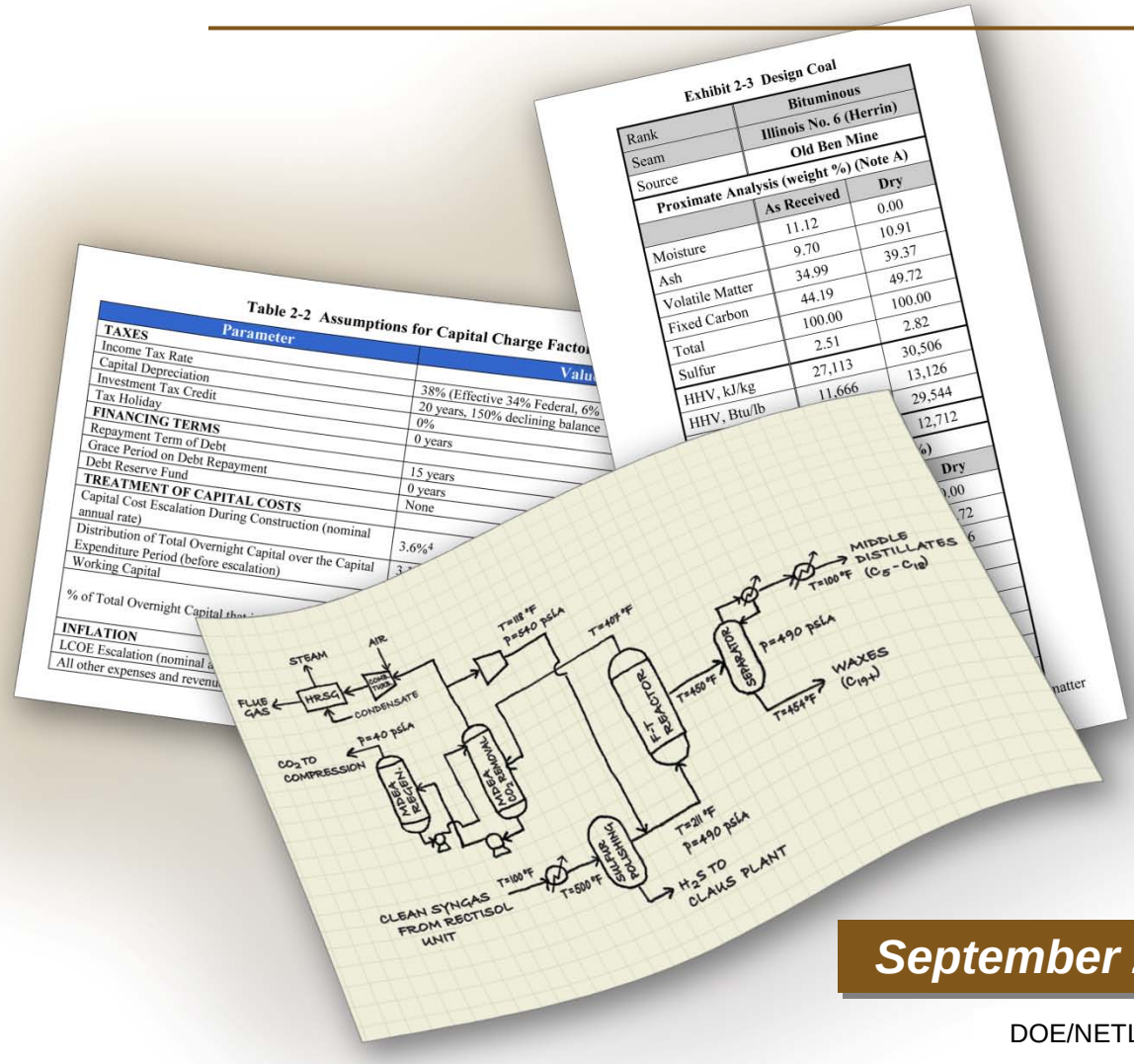
QUALITY GUIDELINES FOR ENERGY SYSTEM STUDIES

Methane Emissions from Mining Powder River Basin Coals



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NATIONAL ENERGY TECHNOLOGY LABORATORY

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Quality Guidelines for Energy Systems Studies
Methane Emissions from Mining Powder River Basin Coals

Topic

Evaluate methane emissions associated with the mining of Powder River Basin (PRB) coal, via surface or underground mining, and the potential for recovery of this methane.

Background

Methane emissions resulting from the release of methane trapped in coal beds can have a significant impact on the life cycle greenhouse gas (GHG) emissions associated with coal production. These emissions vary dramatically by coal rank, specific seam, and seam depth and thickness. Various methods can be utilized to mitigate methane emissions, although these are only applied in certain situations.

Typically, shallower coal seams have lower methane contents, as do lower rank coals. PRB coal is a sub-bituminous coal, and has been found to have a lower methane content than other, higher rank coals, by a factor of ten or more. [1] However, the wide range in seam depth and thickness for PRB coals – ranging from 450 feet to over 6,500 feet underground – also has dramatic impacts on both the methane content and the emissions resulting from mining. [1]

Source Data from the Literature

Table 1 describes the wide range of methane contents and mining emissions associated with PRB coals. "Coal/Description" describes which coal is evaluated, and includes: (1) unspecified PRB or Western coals, (2) average values taken from multiple mines, and (3) projections for seams at different depths. The latter data point (3) is based on a combination of samples taken and detailed modeling of coal seam geology and only evaluated seams located below 250' in depth (in Montana) or below 300' in depth (Wyoming).

The "Mining Method" column details whether a certain type of mining – either surface or underground – is assumed in the calculations, as the mining method can impact how methane is released from the coal. It is unclear what the economic cut-off depth for surface mining is, however, it seems reasonable to assume that the seams located below 250' evaluated in *Powder River Basin Coalbed Methane Development and Produced Water Management* are below this level. [3]

Table 1: PRB Coal Mine Methane Content and Emissions Levels

Coal/Description	Mining Method	Methane Content (scf CH_4/ton coal)	Specific Emissions[1] (scf CH_4/ton coal)
Generic PRB Coal [1]	Not Reported (n/r)	30 – 40	n/a
Generic Western Coal [2]	Underground	n/r	77
PRB Coal, Up to 200' Deep [2]	Surface	n/r	9.1
Generic Western Coal [2]	Surface	n/r	12.5
Average of 4 PRB Mines [2]	Surface	n/r	4 (3.5 – 4.6)
PRB Coal, 250' to 700' Deep [3][2]	n/a	39 – 60	n/r
PRB Coal, Deeper than 700' [3][2]	n/a	62 – 191	n/r
10 Gassiest PRB Mines [4]	Surface	n/r	40

[1] Specific Emissions provide an estimated emission rate per ton of coal mined. The estimate is an extrapolation based on an estimate of annual methane emissions divided by annual coal production figures.
[2] These values are based on the extrapolation of sampled data, which then assumes a given saturation and free gas content for each coal seam based on seam characteristics, thickness, and depth. Regionalized degassing is not accounted for (which would reduce emissions rates), and seams less than 20 feet thick are excluded from the assessment. [3]

The "Methane Content" describes the in situ methane content of the coal. This is the actual methane content of the coal, a portion or all of which may desorb from the coal after it is removed from the mine and prior to use. This methane content does not account for methane which may have desorbed into the surrounding rock strata over time. Methane content of PRB coals appear to typically fall within the range of 30 to 191 standard cubic feet of methane per short ton of coal (scf CH_4/ton coal), with evidence pointing to shallower seams (depths greater than 250 feet) containing less methane (39 to 60 scf CH_4/ton coal) and mines over 700 feet in depth having significantly more, ranging up to 191 scf CH_4/ton coal. [1, 3]

Figures 1 and 2, reproduced from the *Coalbed Methane Development* study, detail the relationship between coal seam depth and methane content. As shown in Figure 1, reservoir pressure (or coal seam) is approximately 100 psia at a seam depth of 200 feet. [3] The methane content at this pressure is roughly 32 scf CH_4/ton coal, as described in Figure 2. [3] The relationship of methane content to reservoir pressure is nearly

Figure 1: Reservoir Methane Pressure as a Function of Coal Seam Depth [3]

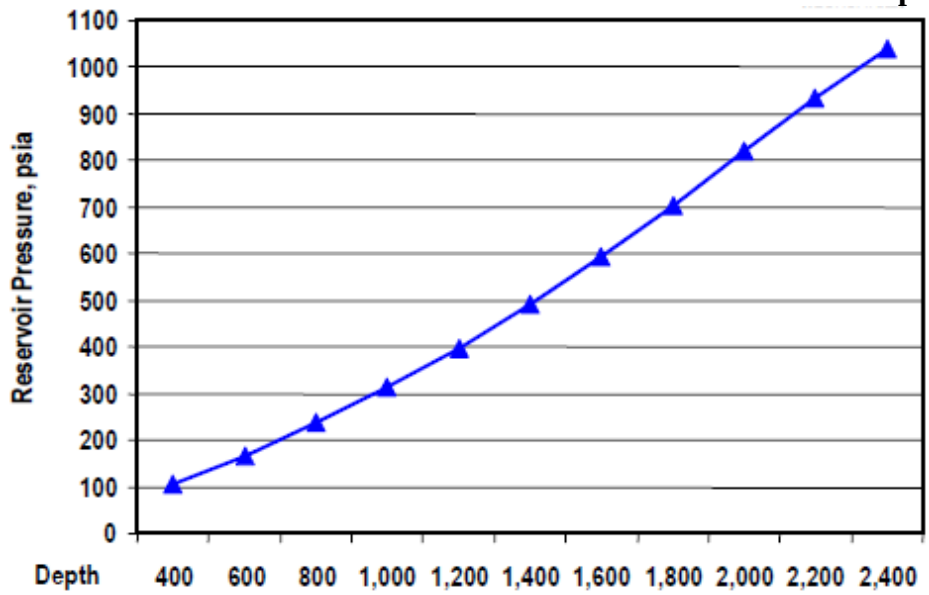
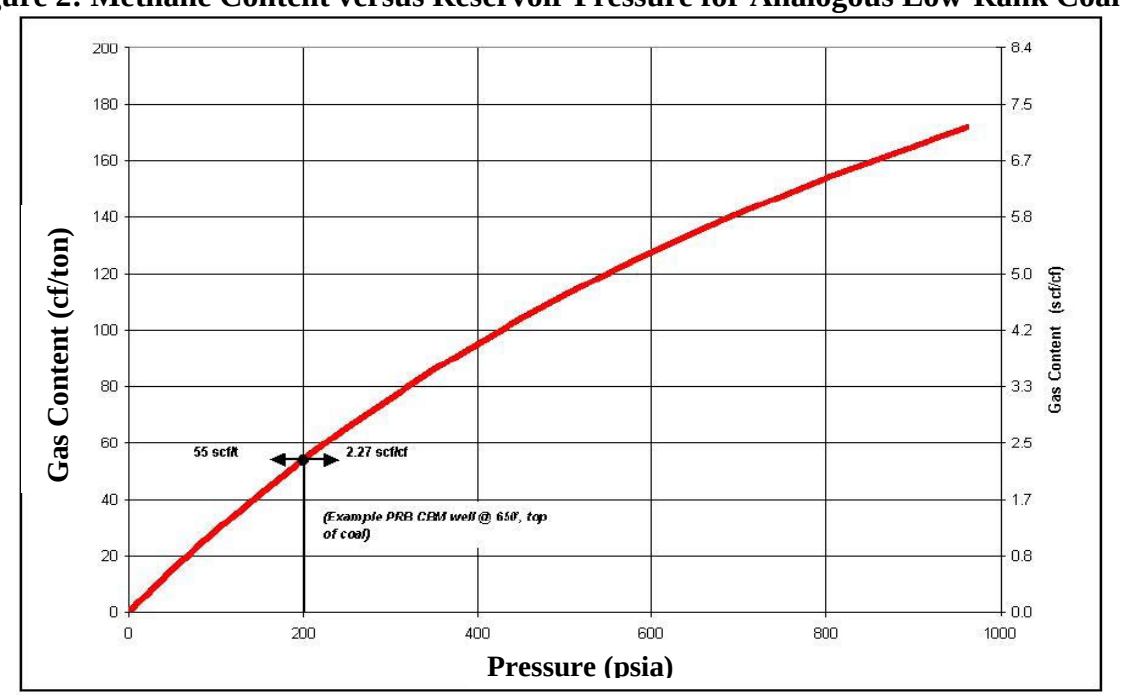


Figure 2: Methane Content versus Reservoir Pressure for Analogous Low-Rank Coal [3]



linear below this depth, with methane content dropping to the pressure drops to zero (methane desorbs into the atmosphere). However, the relationship of reservoir pressure to seam depth is not reported below a depth of 250 feet, and therefore no estimate direct estimate can be made for shallower beds. This may be due to the uncertainty of reservoir pressures of shallower beds associated with an increased likelihood of fractures above the formations, and consequent partial desorption of methane into the atmosphere through non-anthropogenic means. Figure 3 provides data similar to Figure 2, but specific to PRB coals (rather than an analogous coal) and is from a separate data source. [5]

The "Specific Emissions" column of Table 1 describes both the average methane emissions over multiple years (obtained by dividing the estimated methane emissions by the rate of coal production) as well as the minimum and maximum annual emissions over the data collection period. These emissions are the actual methane emissions associated with coal mining and account for methane degassing from the coal itself, as well as the surrounding rock strata. As shown, the specific emissions associated with coal production can vary widely, with surface mining tending to result in emissions ranging from 3.5 to 40 scf CH_4/ton coal mined for surface mining compared to 77 scf CH_4/ton coal mined for underground mines. [2, 4] It is expected that the range between surface and underground mining is related more to the increasing methane content of the coal as a function of seam depth, tied to the prevalent use of underground mining for deeper seams. It should be noted that while one study estimates methane emissions for surfacing mining of PRB coals to be under 10 scf CH_4/ton coal mined, the gassiest of active PRB surface mines have a much higher emissions rate of 40 scf CH_4/ton coal mined, and this value should be considered a upper bound. [2, 4]

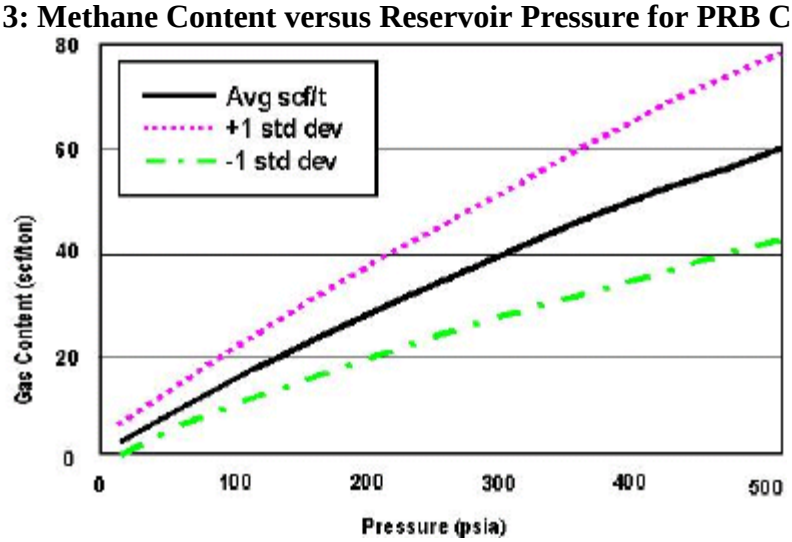
Coal Mine Methane Recovery

As detailed in the *Coalbed Methane Development* study, there is an opportunity to recover upwards of 64% of the methane in place in deep (greater than 250 feet) PRB coal seams. [3] Economic recovery of said methane will depend on issues such as (1) water usage and cleanup requirements, (2) resolution of mineral rights ownership, (3) royalty levels, and (4) natural gas prices and demand. It is anticipated that in the event a national carbon policy was enacted, that methane recovery efforts would be implemented in order to reduce greenhouse gas (GHG) emissions associated with mining deep PRB coal seams although a commensurate rise in coal prices could be expected.

Discussion

Based on the data outlined above, it is anticipated that the majority of surface mined PRB coal lies in shallow enough beds that the coal methane content is limited. This results in relatively low average methane emissions for surface mined coal, in the range of 4 to 9 scf CH_4/ton coal mined. [2] A value of 40 scf CH_4/ton coal mined can be considered an upper bound for surface mining, consistent with the most gassy, active PRB mines. [4] If a carbon policy were put into place, it seems likely that a low cost method of methane emissions

Figure 3: Methane Content versus Reservoir Pressure for PRB Coal [5]



reduction would be put into place for these mines, such as the drilling of gob or vertical pre-mining holes, and the flaring of recovered methane. These methods could reduce emissions by up to 70%, resulting in methane emissions of 12 scf CH_4/ton coal mined. [6]

Methane emissions from deeper PRB seams are likely to be much higher, ranging from 80 to 380 scf CH_4/ton mined. These figures are based on the assumption that 50% of the methane emissions associated with coal mining is due to gas in the rock strata surrounding the coal. [6] In the event that a carbon policy is in place, it seems likely that coalbed methane recovery methods would be implemented in order to limit these emissions, although the issues such as mineral rights, water consumption and clean-up, and natural gas prices will undoubtedly impact the feasibility of such a course of action.

References

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