RUBY CANYON ENVIRONMENTAL

For the Colorado Department of Regulatory Agencies, Public Utilities Commission

Assessment of Eligibility for the Renewable Energy Standard of Electricity Generated by 3 MW LLC From the Combustion of the Short-Lived Climate Pollutant, Methane, Emitting from the Elk Creek Mine Area of the Somerset Coal Field, Colorado.

October 19, 2020

By Ruby Canyon Environmental, Inc.

On Behalf of:
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Introduction

This report serves as support documentation for 3 MW LLC's application for the eligibility of their electricity generation project combusting methane located at the Elk Creek Mine Area in Somerset, CO to the Colorado Renewable Energy Standard.

Elk Creek Mine Area Background

There have been six mines dating from around 1910 mining four main coal seams. These seams are (from bottom to top) are the B, C, D, and E seams. Other less thick and discontinuous seams are interbedded within these coal measures. The mine workings together cover over 15,000 acres.

The Elk Creek Mine Area is exceptionally gas prone. It is estimated that 130 billion cubic feet (BCF) of methane has emitted over the last 120 years from the area. That is enough methane (natural gas) to supply 1.8 million residential customers based on 2009 usage of 74 Mcf per customer in 2009 (Energy Information Agency). Historically this gas could not be utilized, however, there remains approximately 194 BCF of methane within the lease area. A portion of this gas could be captured and utilized from the abandoned mines left in the area, which are currently emitting fugitive methane from faults and fractures above the mines and through other pathways such as leaking boreholes or shafts.
The Elk Creek mining permit area is shown in **Figure 1**.

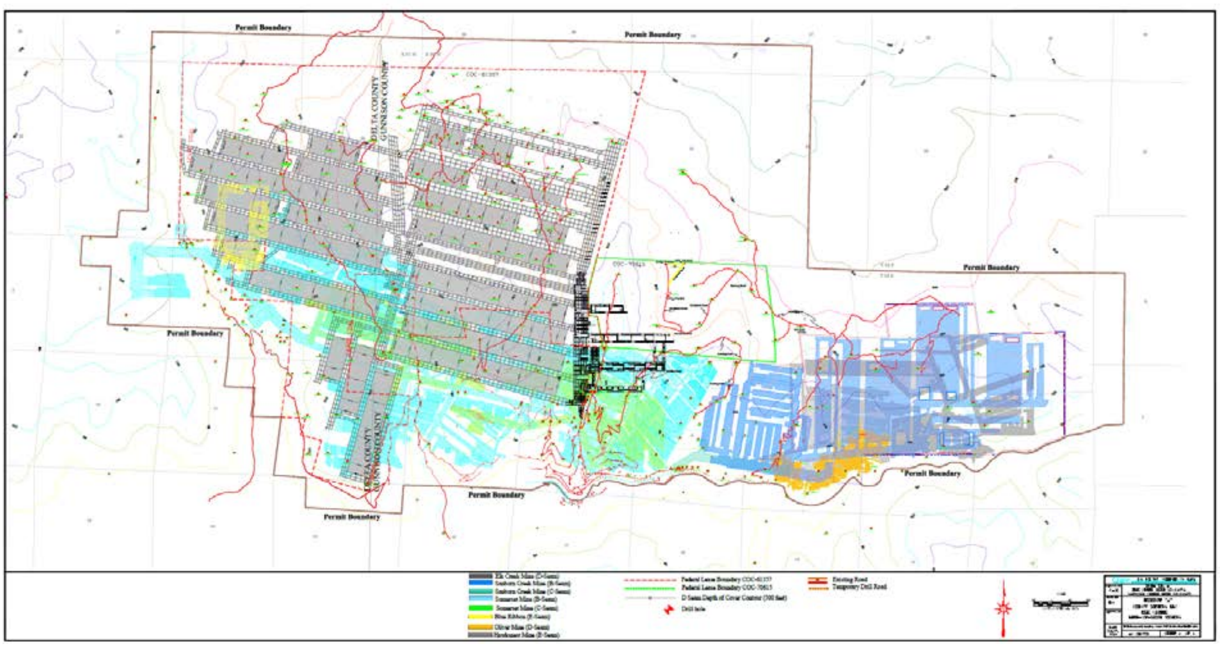

Figure 1: The Elk Creek Mine permit boundary including the abandoned mines within it

Methane as a Greenhouse Gas

Recent studies found that just under half of global warming is caused by Short Lived Climate Pollutants (SLCPs) that are potent greenhouse gases (GHGs). The largest near-term GHG emission reductions can come from SLCP mitigation. Methane is considered the most important

SLCP because its life expectancy in the atmosphere is only about a decade (National Research Council, 2010).

Methane is a potent GHG with a global warming potential (GWP) many times that of CO_2 and represents approximately 10 percent of global GHG emissions. As with other SLCPs such as N_2O, CFCs, and HFCs, the GWP of methane has changed over the past 25 years. As climate change models continue to evolve, Intergovernmental Panel on Climate Change (IPCC) studies now show the GWP of methane rising from what was accepted in 1995. The GWP of methane over a 100-year time frame rose from 21 to 28. GWPs represented a measure used to adjust GHGs to the equivalency of CO_2 over a 100-year time frame, which was standard practice used for GHG emissions accounting at that time. However, when viewing the impact of methane on 10- and 20-year time frames, the GWP increases dramatically to around 104 and 84, respectively based on the Fifth Assessment Report of the IPCC in 2013 (AR5 (see Figure 2, black line).

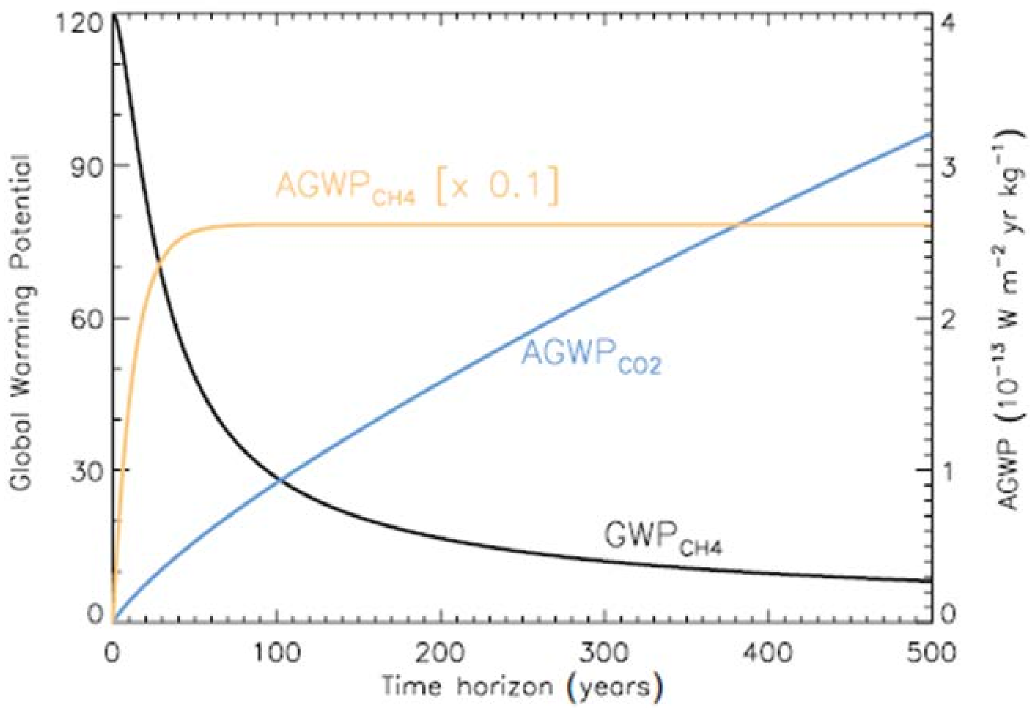

Figure 8.29 | Development of AGWP-CO_2, AGWP-CH_4 and GWP-CH_4 with time horizon. The yellow and blue curves show how the AGWPs changes with increasing time horizon. Because of the integrative nature the AGWP for CH_4 (yellow curve) reaches a constant level after about five decades. The AGWP for CO_2 continues to increase for centuries. Thus the ratio which is the GWP (black curve) falls with increasing time horizon.

Figure 2: Methane GWP

The climate change mitigation benefits of reducing methane emissions may be three to four times that of the traditional 100-year time frame. Given the importance of immediate actions to combat climate change, methane stands out as a GHG that needs to be reduced as quickly as possible.

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Change in GWPs over time

Every six years the Intergovernmental Panel on Climate Change (IPCC) working groups publish a climate change assessment report. Included in the physical science basis report are calculated GWP values for GHGs. **Table 1** summarizes the difference GWP values for methane from the first assessment report in 1990 through the last report, AR5 in 2013. Over the years, the methane GWP tends to increase with each assessment report. The Sixth Assessment Report Synthesis is due to be published in 2022.

Table 1: Methane GWP change through time

IPCC Reports	**GWP of Methane**	
	20 year	**100 year**
IPCC First Assessment Report (1990)	63	21
IPCC Second Assessment Report (1995)	56	21
IPCC Third Assessment Report (2001)	62	23
IPCC Fourth Assessment Report (2007)	72	25
IPCC Fifth Assessment Report (2013)	84	28

Updated GWPs have been attributed to updated scientific estimates on methane's life expectancy, energy absorption, or atmospheric concentrations (EPA FAQ). Increased atmospheric concentrations of methane result in an increase in life expectancy and that results in a larger GWP. The calculation of carbon offset credits has followed the early convention of using the 100-year interval for methane while the 20-year interval is about 4 times higher. The typical crediting period of an offset project is 10 years. The atmospheric lifetime of methane is about 12 years which would mean that during the entire crediting period of the project, the methane that would have been released to the atmosphere would likely have a GWP of about 104.

Methane as an ozone precursor

Tropospheric ozone is a major air and climate pollutant which also causes warming, is harmful to human health and crop production. Breathing ozone is particularly dangerous to children, older adults and people with lung diseases, and can cause bronchitis, emphysema, asthma, and may permanently scar lung tissue. Its impacts on plants include not only lower crop yields but also a reduced ability to absorb CO_2.

Tropospheric ozone is not emitted directly but instead forms from reactions between precursor gases, both human-produced and natural. These precursor gases include methane. Globally increased methane emissions are responsible for approximately two-thirds of the rise in tropospheric ozone. Reducing emissions of methane will lead to significant reductions in tropospheric ozone and its damaging effects.

North Fork coal geologic setting – contribution to methane emissions

The geologic setting, both stratigraphic and structural, produced both high quality coal as well as very gassy coal mines. The Somerset coal field is located at the southern end of the of the Piceance basin of western Colorado as shown in **Figure 3. Figure 4** shows the location of the mines in this area of the basin.

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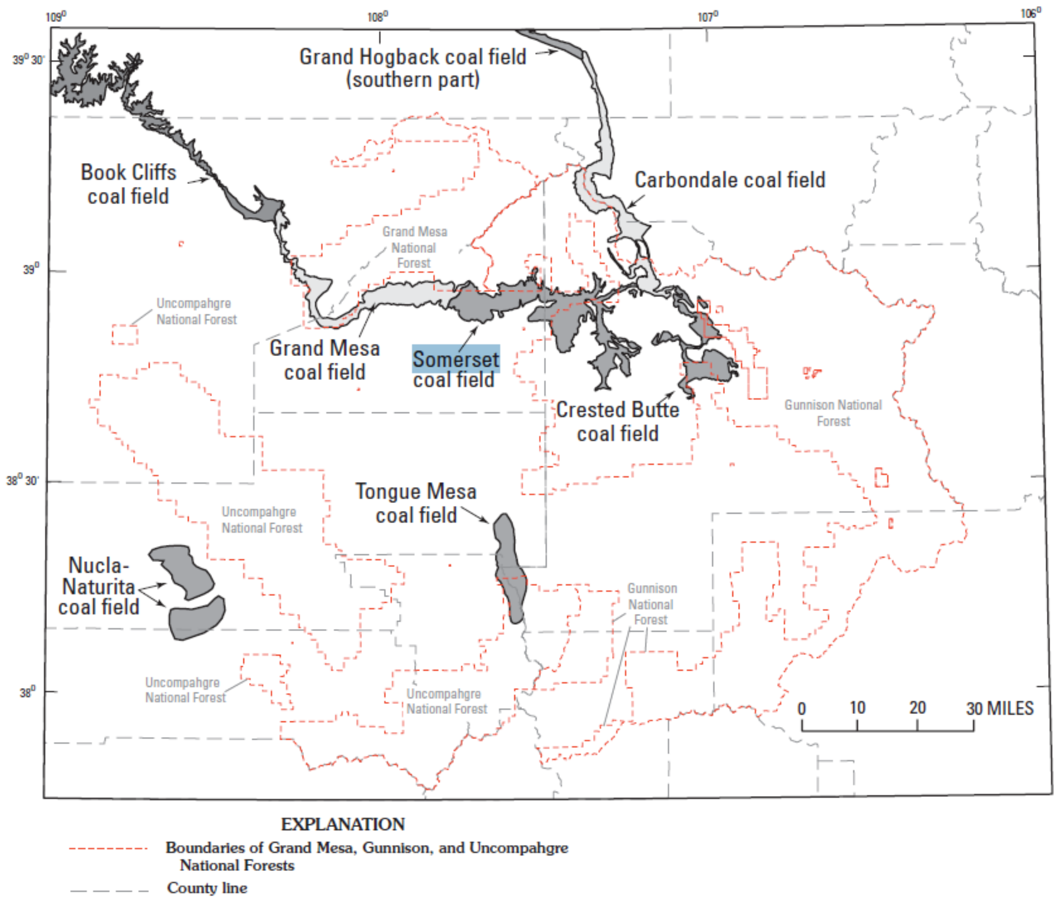

Figure 3: Location of coal fields of Western Colorado

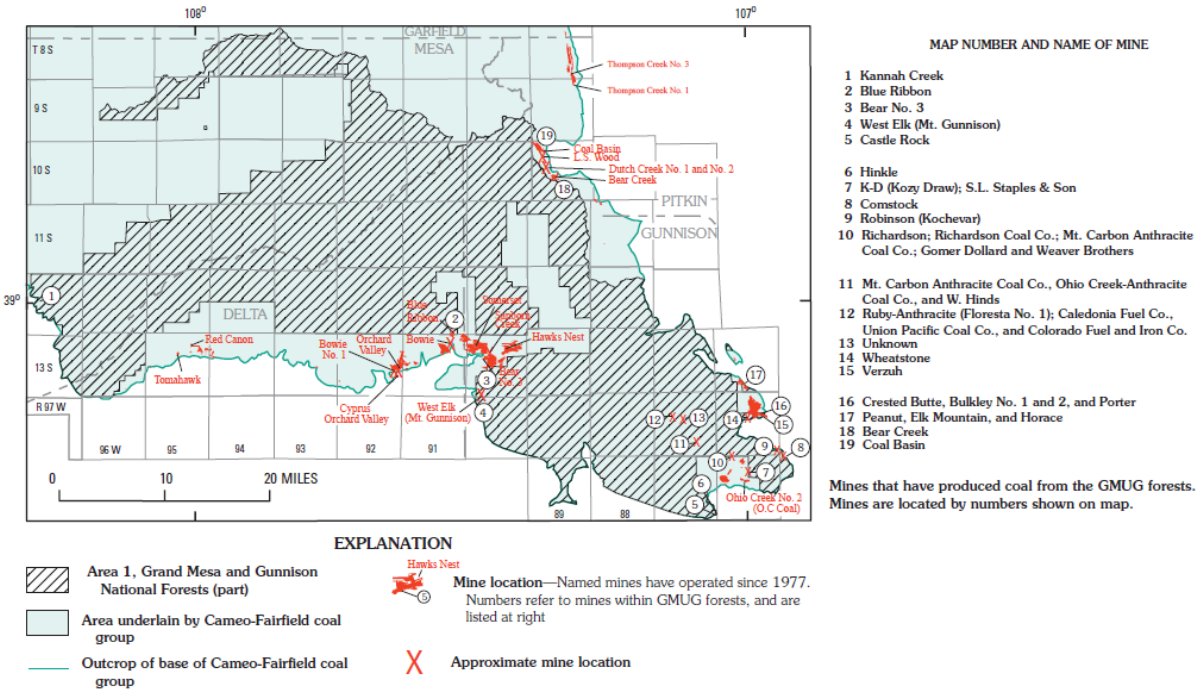

Figure 4: Location of coal mines that have produced from the Cameo-Fairfield coal group

Structural setting of the Somerset coal field

The Somerset coal field dips about 3 degrees north-northeast. Numerous steeply dipping normal faults have been observed in the area's coal mines and some exhibit several feet of stratigraphic separation. These normal faults were formed by deep igneous plutons in the Mancos shale shown in blue in **Figure 5** and shown to the right in the cross-section in **Figure 6**. The high geothermal gradients associated with these plutons have increased the coal rank as shown in **Figure 7**. Heat flow maps show that the highest heat flow values are coincident with some of the gassiest mines. Associated with the faulting are numerous fracture systems as well. Both the faults and fractures provide flow pathways from not only between coal seams but from gas generated in the Mancos shale below the coal measures.

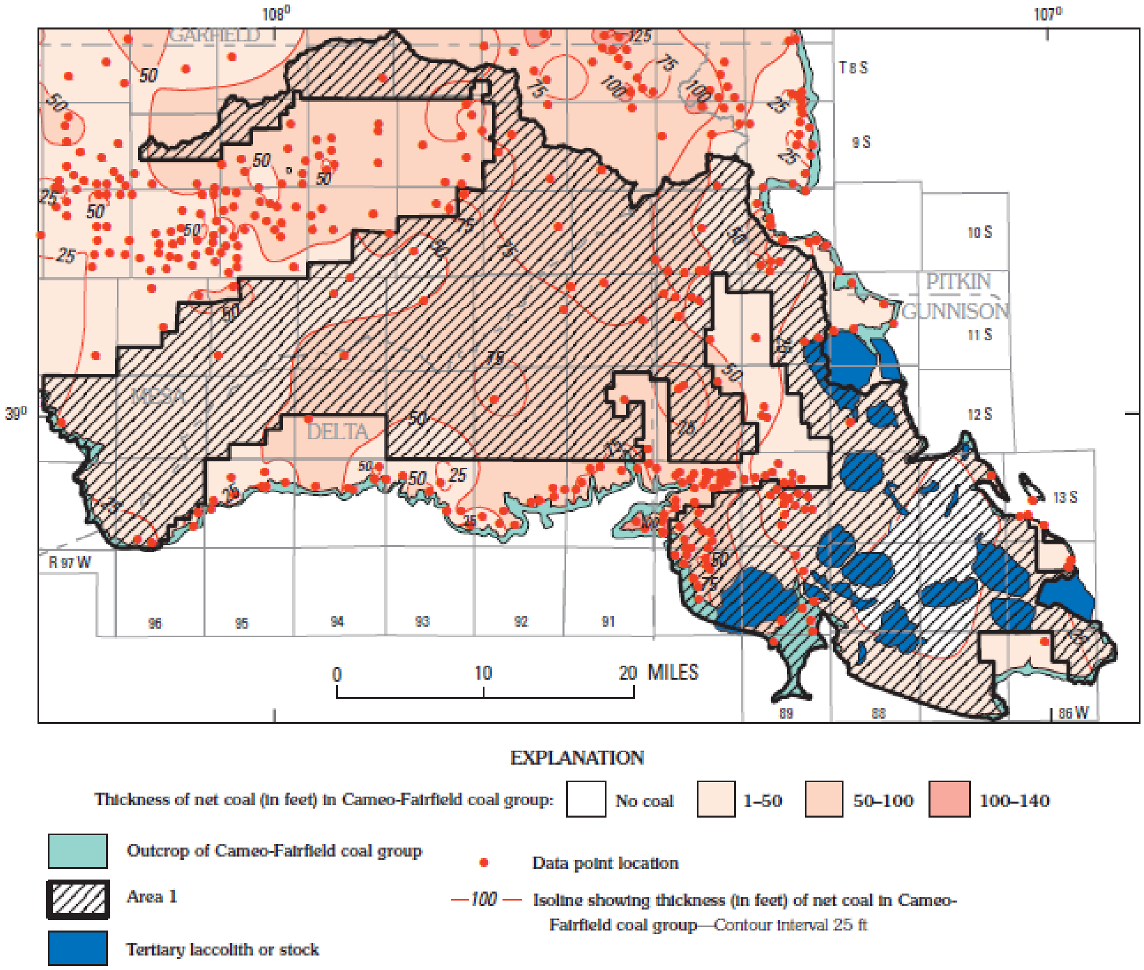

Figure 5: Igneous intrusions formed the West Elk mountains, the isopach lines are net coal thickness

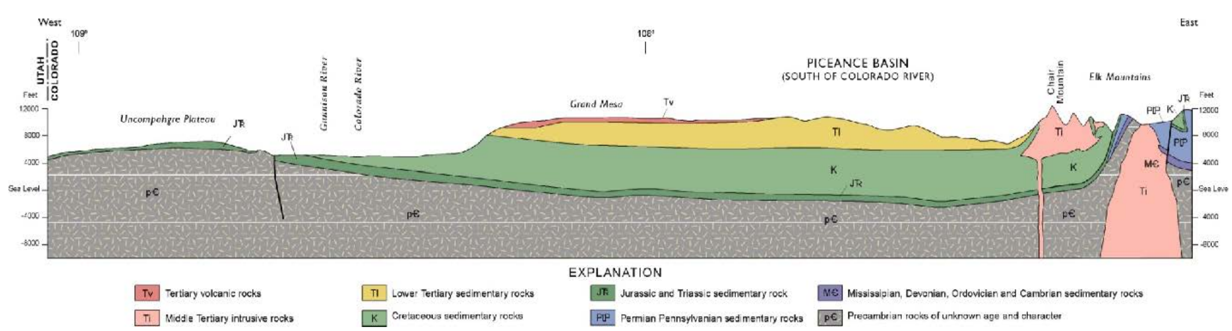

Figure 6: West to East structural cross-section of the Piceance basin

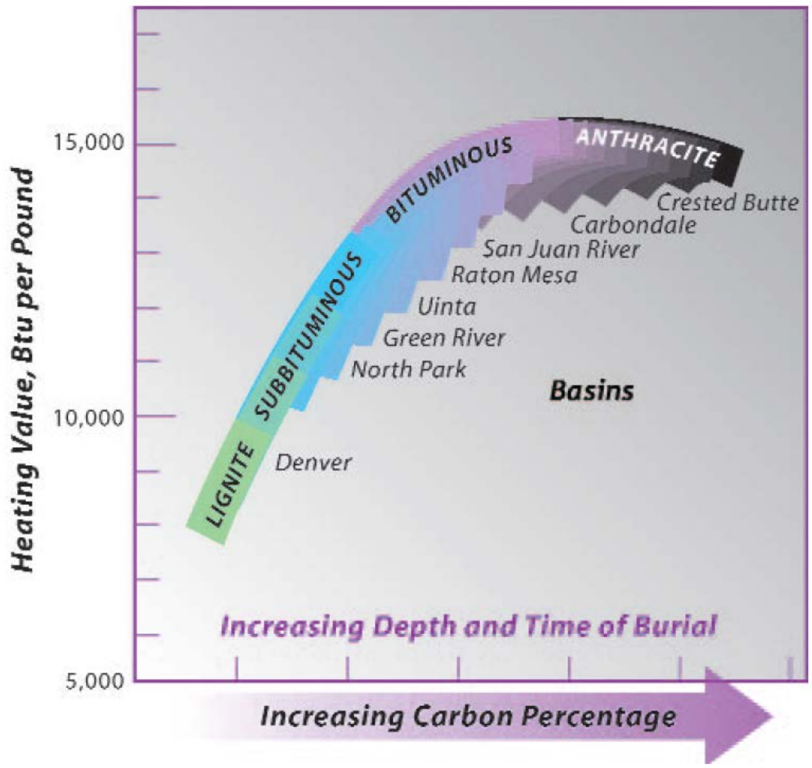

Figure 7: The increased carbon content of coal in the Somerset and Carbondale coal field is related to the heating caused by nearby igneous intrusions

Stratigraphic setting of the Somerset coal field

The coal-bearing units of the Mesaverde group are primarily composed of fluvial, beach sandstone, mudstone and shale that were deposited in a series of regressive marine environments, interdistributary marshes and freshwater deltaic swamps. Coal formed from thick accumulations of organic material deposited in landward swamps along the shoreline. The Mesaverde group is underlined by the marine Mancos Shale and overlain by the Fort Union and Wasatch Formations of the Tertiary Age which consist of fluvial sandstones and shales.

Figure 8 is a generalized stratigraphic cross-section of the Somerset area. **Figure 9** is a schematic of the coal measures of the Somerset coal field. The coal is Upper Cretaceous in age and occurs in the Williams Fork formation of the Mesaverde group. The coal measures shown in **Figure 9** are known as the Cameo coal zone which occurs at the base of the William Fork formation from Somerset to the Book Cliffs north of Grand Junction, Colorado.

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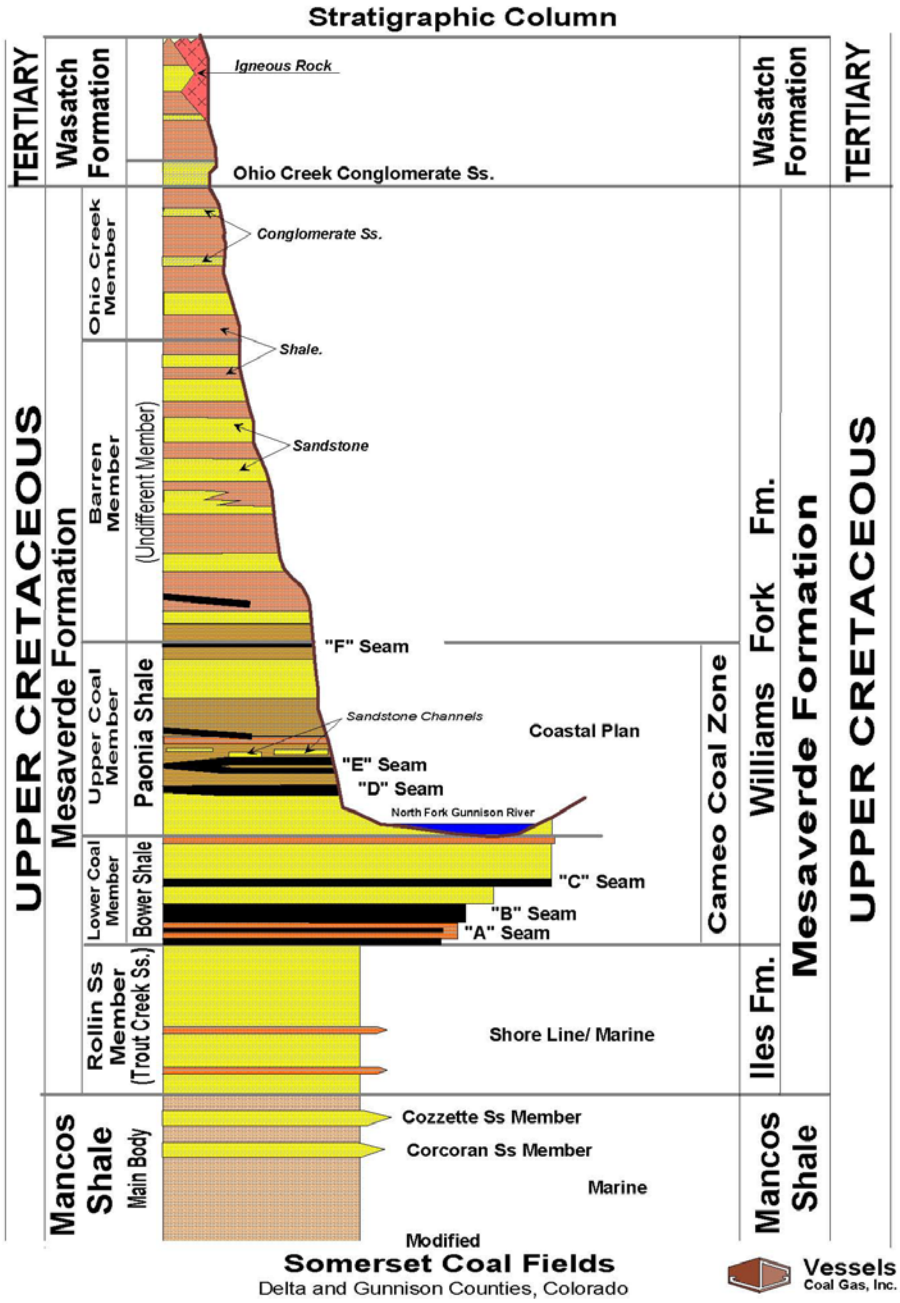

Figure 8: Stratigraphic column of the Somerset area

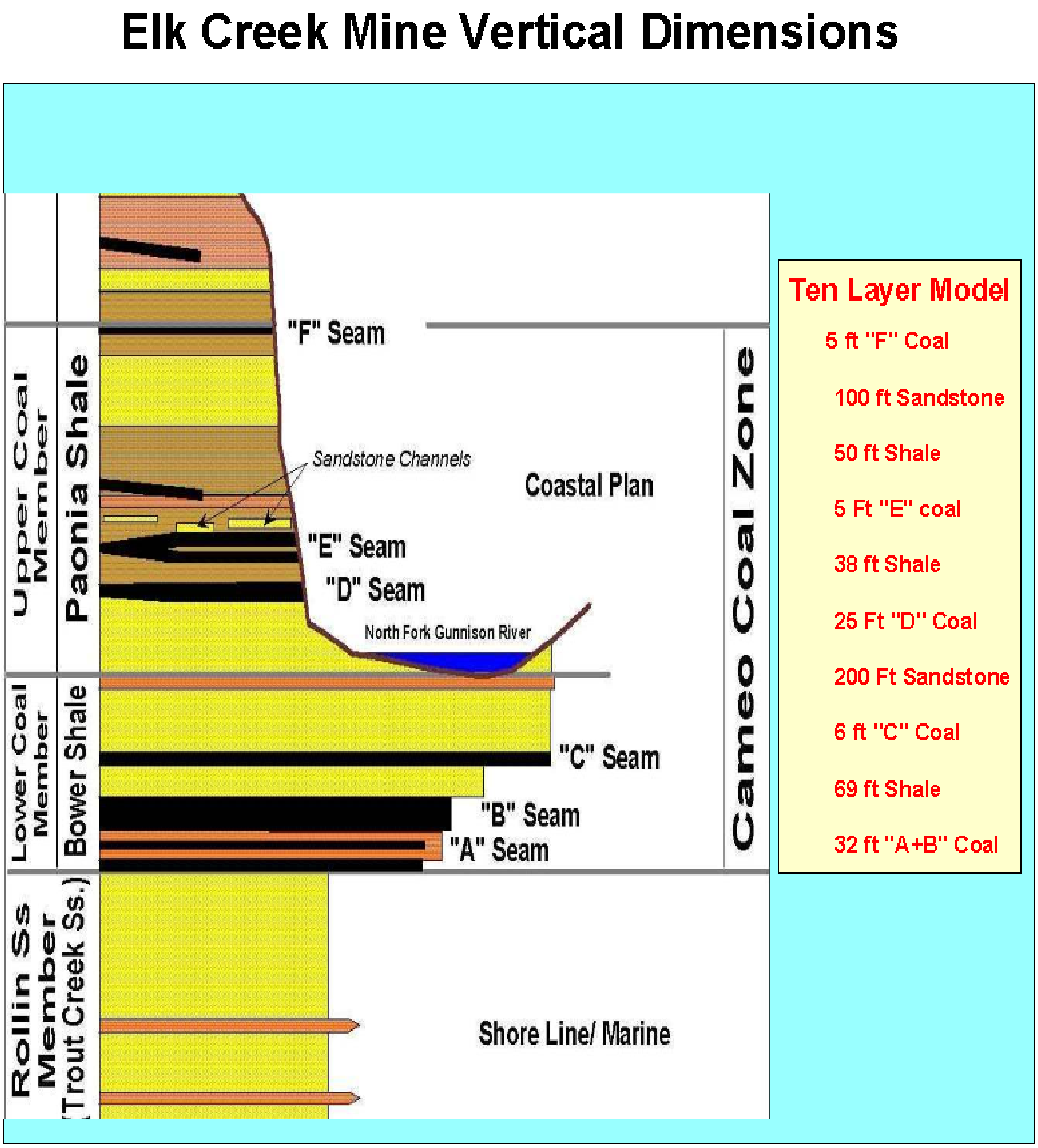

Figure 9: The coal measures in the Somerset coal field

Coal properties of the Somerset coal field

The coal of the Somerset area is low ash, low sulfur and high Btu steam and coking coal. Because of its high carbon content, the coal can contain significant amounts of adsorbed methane. **Figure 10** compares the adsorption isotherms from the major coal basins of the United States. This shows that Western coals can adsorb more methane than the coals of the other basins.

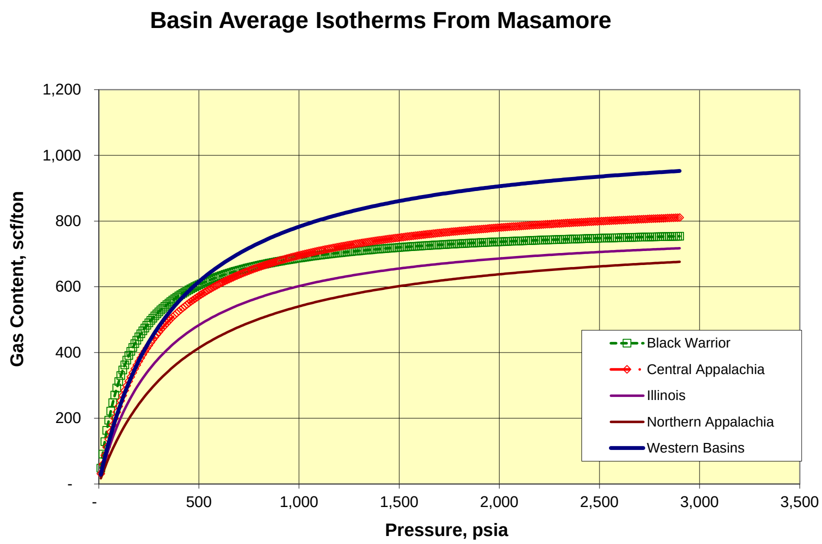

Figure 10: Average adsorption isotherms from the major coal basins of the U.S.

Gas saturation of interbedded sandstone and shale layers within the stratigraphic section

The Piceance basin is considered to be a basin-centered gas system, characterized by regionally pervasive gas saturation in the sandstone bodies and shale both within and above the coal measures. This is illustrated in **Figure 11**. This basin centered gas is the focus of the tight gas-sand gas play in the Piceance basin centered on Rulison Colorado. Because of this, the interbedded sandstone bodies in the Somerset area are also gas charged. However, because the coal measures outcrop in the valley of the North Fork of the Gunnison river some of this gas has escaped. Farther back from the outcrop (as in the Elk Creek Mine) the gas saturation of the both the sandstone and the coal is greater. Gas migration up from the Mancos shale is ongoing, however determining how fast the recharge rate is into the coal section has not been quantified.

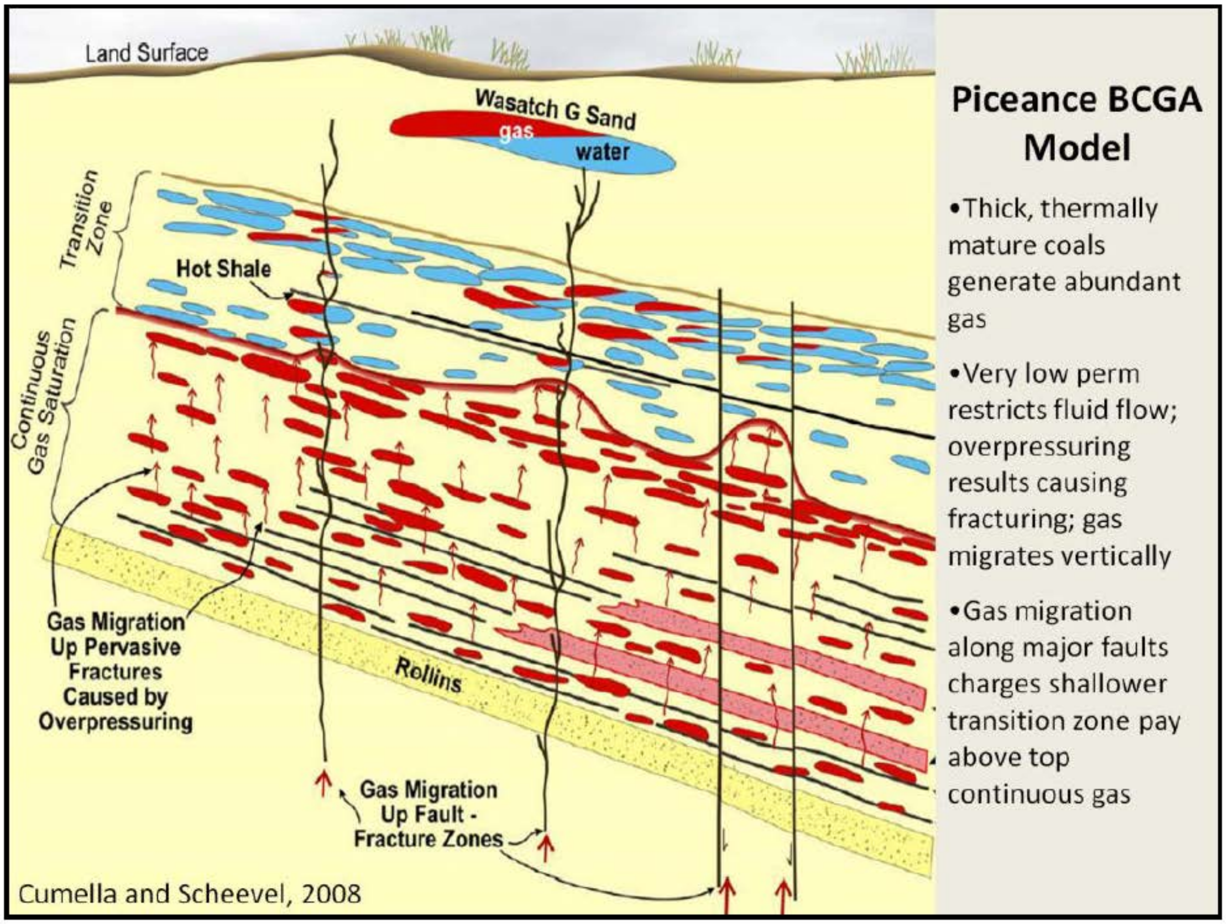

Figure 11: Gas generated in the Mancos shale and Cameo coals saturate sandstone bodies (red) until hydraulic forces and tight shale layers stop the migration above which the sandstone bodies are water saturated (blue)

Historical methane emissions from North Fork mines

Methane related mining issues in North Fork mines

The modern mines of the North Fork Valley use the longwall mining method. Panel widths can be as much as 1,000 feet with a length of 11,000 feet under favorable circumstances. Continuous miners, which are mobile cutting machines are used to delineate the panel. A shear mounted on a track is then used cut swaths of coal from the coal face (**Figure 12)**.

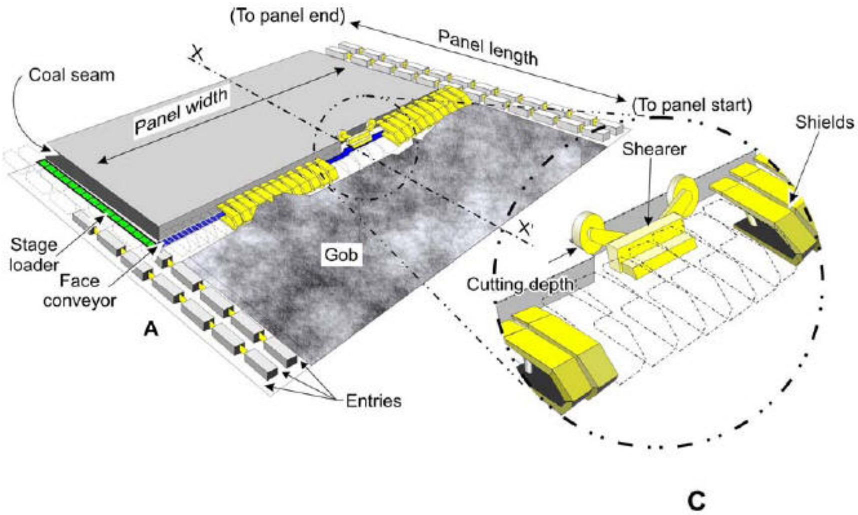

Figure 12: Primary components of a longwall operation

Periodically the hydraulic shields that hold up the roof are lowered slightly and moved forward so that the shearer can make more cuts. As the shields are moved the roof collapses into the gob (aka goaf). **Figure 13** is a cross-sectional view of the longwall operation showing the rubble zone at the base of the gob and the fracture zone that extends for as much 150 meters above the mined seam. Also, with the removal of the coal the floor of the mine tends to heave, fracturing the strata below which often includes more coal. Emissions from below also then enters the gob.

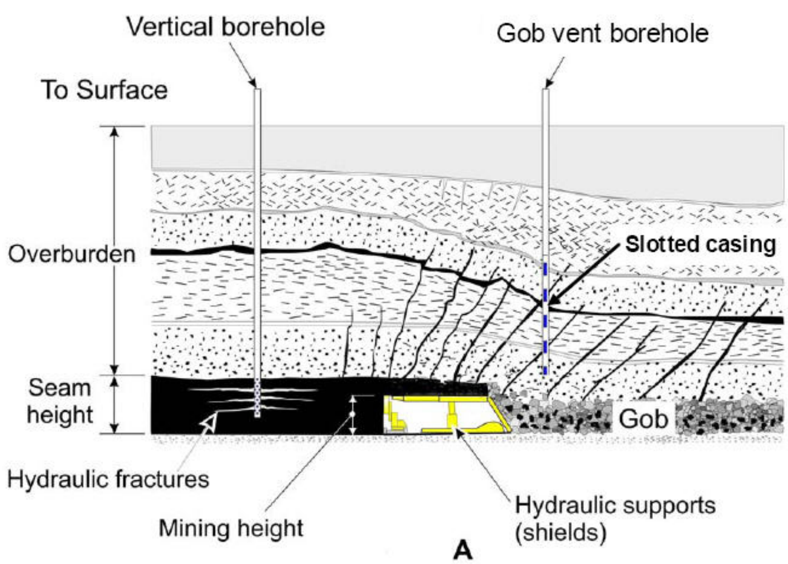

Figure 13: Cross-sectional view of longwall operation and the development of the gob

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Mined coal seams in the North Fork valley are found within a stratigraphic series of thick coal alternating with sandstone and shale. When the gob develops, and the fracture zone reaches into that strata, the coal will be destressed releasing water and gas contained within the coal, and because the air pressure in the mine workings is much less than the original confining pore pressure, the gas will migrate toward the mine face. If the amount of methane entering the working area cannot be adequately diluted by the ventilation air, then some type of gob gas drainage is required. In the North Fork valley all modern mines use vertical wells drilled into the gob as vent boreholes (see **Figure 13**). These are attached to a suction blower and the gas is vented to the atmosphere. Without these gob vent boreholes (GVBs) mining could not be done in the deeper areas of the mines because the ventilation air could not dilute the methane to safe levels.

The Elk Creek Mine started near the coal outcrop and worked under deeper overburden through time. **Figure 14** shows how the methane emissions increased as the mine went deeper.

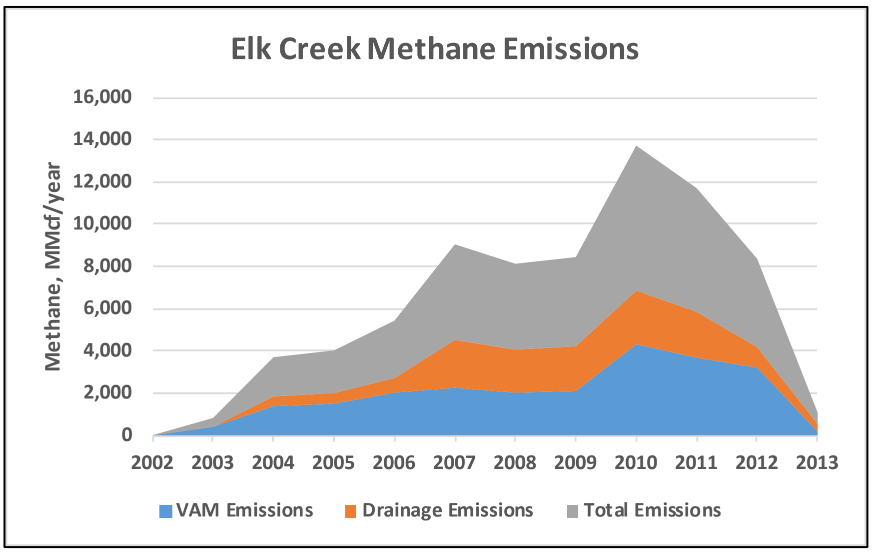

Figure 14: Methane emissions from the Elk Creek Mine increased as the mine went deeper

Estimations of the total methane emissions from the Elk Creek Mine Area and a forecast of future emissions is provided in subsequent sections.

Forecasting Future Emissions

Our approach to estimating the methane emissions from abandoned mines in the Elk Creek Mine Area and hence the methane resource potentially available for use and the probable rate of recovery of that resource is based on a combination of gas material balance and emission rate calculations. The material balance calculations are based on:

1. Original volume of methane in place
2. The amount of methane liberated during active mining
3. The amount of gas emitted to the atmosphere post mining (during abandonment) based on a decay function
4. A projection of this decay function into the future

In order to perform the necessary calculations, the following data is needed

Regional data:

- Percent methane in the coal gas
- Adsorption isotherm coefficients
  - Langmuir volume
  - Langmuir pressure

Mine specific data:

- The thickness of the mined seam
- The total coal thickness (Including the mined seam) in the region within 500 feet above and 160 feet below the mined seam
- Original gas content of the coal
- Mined area
- Total coal produced over the life of the mine
- Year of initial coal production
- Year of mine closure
- Average methane emission rate
- Specific Emissions

Tables 2, 3 and 4 lists the values used in the analysis

Table 2: Regional parameters and values used in model

Parameter	Value
Percent Methane in coal	86%
Langmuir Volume (scf/ton)	963 scf/ton
Langmuir Pressure (psia)	484 psi

Table 3: Mine and coal properties in Elk Creek Mine Area

Mine	Mined Seam Thickness, ft	Total Seam Thickness, ft	%CH4 In Coal	Area, acres	Seam	Coal Recovered, tons
Elk Creek	12	68	86	5,715	D	42,502,711
Sanborn Creek	11	70	86	2,432	B	16,662,826
Hawks Nest	7	27	86	1,491	E	9,578,925
Somerset B & C	18	70	86	6,816	B & C	45,666,057

Table 4: Original gas content of coal and mine operating parameters

Mine	Start Year	Closure Year	Average Rate, Mcf/d CH4	Coal Methane Content, scf/ton	Specific Emissions, scf/ton mined
Elk Creek	2002	2016	8,106	207	981
Sanborn Creek	1991	2003	5,210	290	1408

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Hawks Nest	1975	1988	1,053	185	526
Somerset B & C	1910	1986	1,001	140	608

This data was obtained from Mine Safety and Health Administration (MSHA), mine management and geologic studies of the area. The average rate for Elk Creek includes estimated emissions from gob vent boreholes. The higher methane content for the Elk Creek and Sanborn Creek Mines reflects the fact that they are at greater depths and farther down dip from the outcrop.

Original Methane In-Place

The parameters used to determine this value are

- The total coal thickness within 500 feet above and 100 feet below the mined seam which will most likely fracture during mining. Methane contained in coals within this zone may contribute to mine emissions where longwall mining is used, or pillars are pulled or crushed.
- Mining area. This is based on the mine boundary upon completion of mining and does not consider methane migrating into the mine from outside the permit boundary.
- The original gas content expressed as standard cubic feet of gas adsorbed within one short ton of coal.
- Percent methane in the coal seam gas

Methane Liberated During Mining

The amount of methane liberated during mining includes methane ventilated and drained from the mine during operations. This includes methane contained in the coal that was removed as well as methane that entered the mine workings from above and below the mined seam. This is generally a measured value and is often reported as specific or relative emissions which is expressed scf/ton of coal production. Methane liberated is a product of specific emissions and tons of coal mined over the life of the mine.

Methane Emitted Post Mining

This is the volume of methane that is estimated to have been emitted to the atmosphere after mine closure. This is a function of the average methane emission rate over the life of the mine, the adsorption pressure at closure (as determined by the adsorption isotherm) and the time since closure. A decay function is generated based on the adsorption isotherm of the coal.

Methane flow through coal can be approximated by general rules of fluid flow through porous media using Darcy’s law. Gas production from oil and gas wells is predicted using Darcy's Law together with material balance equations. In this context, the well acts as a material sink whose rate of withdrawal is a function the permeability of the rock, the viscosity of the gas, the geometry and configuration of the pressure sink and outside gas reservoir, the thickness of the flow unit and the difference between a specified pressure at the well and the pressure at some outside boundary of the gas reservoir. This function can be expressed as the productivity index (PI). The PI can be empirically derived from observed data so that individual values of the relevant parameters don’t need to be known. The PI has units of rate per pressure difference over a given period of time.

By analogy, the borehole or vent in the abandoned mine acts as the wellbore, the gas in the mine void (workings) and the coal within and peripheral to the mine is the reservoir of the stored methane. The PI can be considered a constant at the low pressures involved in an abandoned mine system. **Table 5** shows the results of the material balance analysis.

Table 5: Material balance showing estimated methane originally in-place, produced and remaining

Mine	Original CH4 In-Place, BCF	CH4 Liberated During Mining, BCF	CH4 Emitted Post Mining, BCF	CH4 Remaining at 2019, BCF
Elk Creek	128	42	9	77
Sanborn Creek	78	23	17	38
Hawks Nest	12	5	3	4
Somerset B & C	106	28	13	65
TOTAL	**324**	**98**	**42**	**184**

The Decline Function

Knowing the adsorption isotherm of a coal; that is the methane storage capacity of the coal as a function of pressure, allows the calculation of the adsorption pressure if the volume of methane and mass of coal remaining in the system at closure has been determined. As methane is removed from the system at the rate determined by the PI and adsorption pressure at a given time, the amount of gas removed over that period can be determined as well as the adsorption pressure calculated at the end of that time period. A new (lower) emission rate is determined by using this new adsorption pressure together with the PI. **Figure 15** shows the decline curve associated with the methane released from the coal since the Sanborn Creek Mine closure.

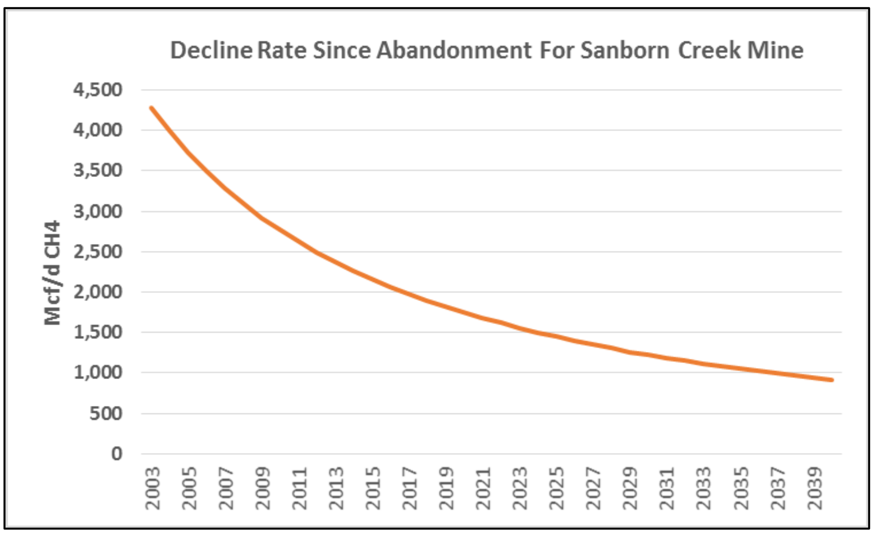

Figure 15: Post mining emission decline rate for Sanborn Creek Mine

Based on this analysis a total of 42 BCF of methane has escaped from the abandoned mines in the mine area to 2019 (**Table 5**). An estimated 35 BCF will escape by 2030. A portion of this gas could be captured and either utilized for power generation or destroyed therefore significantly reducing the GHG impact of the escaping gas.

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GWP Impact on Methane Emissions

The use of 100-year GWP versus the 20-year GWP has significant impacts on the total GHG emissions at abandoned mines. Using the modeling data for the Sanborn Creek Mine (also used in Figures 15 and 17) the emissions from mine closure to 2050 would total 12 million metric tons of carbon dioxide equivalent (tCO_2e) using a GWP of 21 compared to 48 million tCO_2e using a GWP of 84 as shown in **Figure 16**. Given this significant difference, it is important to begin methane recovery soon after mine closure.

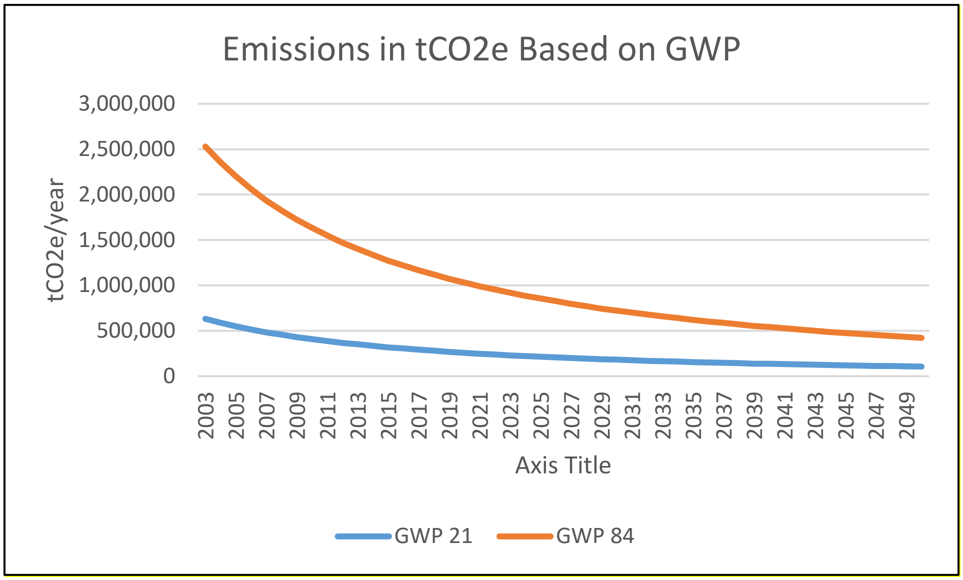

Figure 16: Estimated methane emissions from the abandoned Sanborn Creek Mine from closure to 2050 in terms of tons of carbon dioxide equivalent

Evidence and mechanisms of diffuse fugitive emissions from abandoned mines

The Elk Creek Mine suffered a fire caused by spontaneous combustion in 2012 and was closed shortly afterward. Subsequently several surveys were performed to measure methane emissions at various abandoned mine portals and boreholes. The survey performed on October 25, 2018 found numerous locations with emissions of greater than 1,000 ppm in the atmosphere (average atmospheric methane concentration is approximately 1.7 ppm). These locations correlated with vegetation that had died due to high methane flux through the soil. The survey was necessarily incomplete because of the size of the area involved. Results of that survey are provided in **Exhibit A** at the end of the report.

There is also evidence that diffuse emissions occur above the mines where the collapse of the roof caused surface disturbance and therefore a pathway for the more buoyant gas (methane is about one half as dense as air) to reach the atmosphere. In 1976 the United States Geological Survey did a study of engineering and geologic factors controlling surface subsidence above coal mines in Utah and Colorado. **Figure 17** shows what the field inspection uncovered over the Somerset Mine. There were both extensional fractures as well as compressional fractures above an old gob.

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There have been numerous accounts, especially in the United Kingdom of subsidence over old mines that subsequently released methane that led to explosions and fires in overlying buildings. An entire village in Derbyshire was moved because of methane from a mine closed the previous year was seeping into houses and shops (The Guardian 1/30/2001).

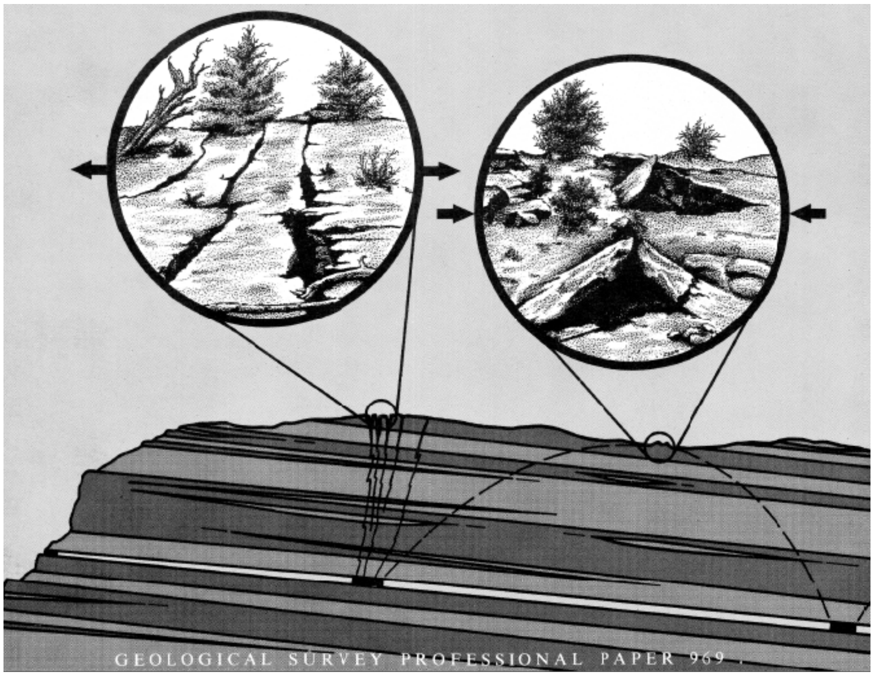

Figure 17: Diagrammatic illustration of extensional and compressional surface disturbance above the Somerset Mine, Colorado

As explained above, in describing the generation of the decline curve for emissions from an abandoned mine, the adsorption pressure declines through time as the gas leaves the workings. **Table 6** shows the estimated adsorption pressure at initial conditions, at closure and after emitting the gas through diffuse emissions to the present time.

Table 6: Material balance showing the estimated methane initially in-place, remaining at closure and currently in-place in each mine's zone of influence

Mine	Original CH4 In-Place		CH4 Remaining at Closure		CH4 Remaining at 2019	
	BCF	Psi	BCF	Psi	BCF	Psi
Elk Creek	128	110	86	74	77	67
Sanborn Creek	78	169	55	115	38	78
Hawks Nest	12	96	7	59	4	28
Somerset B&C	106	69	78	52	65	43

It is the difference between the adsorption pressure and the atmospheric pressure that is the driving force for the continued emissions. As this difference decreases so too does the rate of emissions. **Figure 18** illustrates this for the case of the Sanborn Creek Mine.

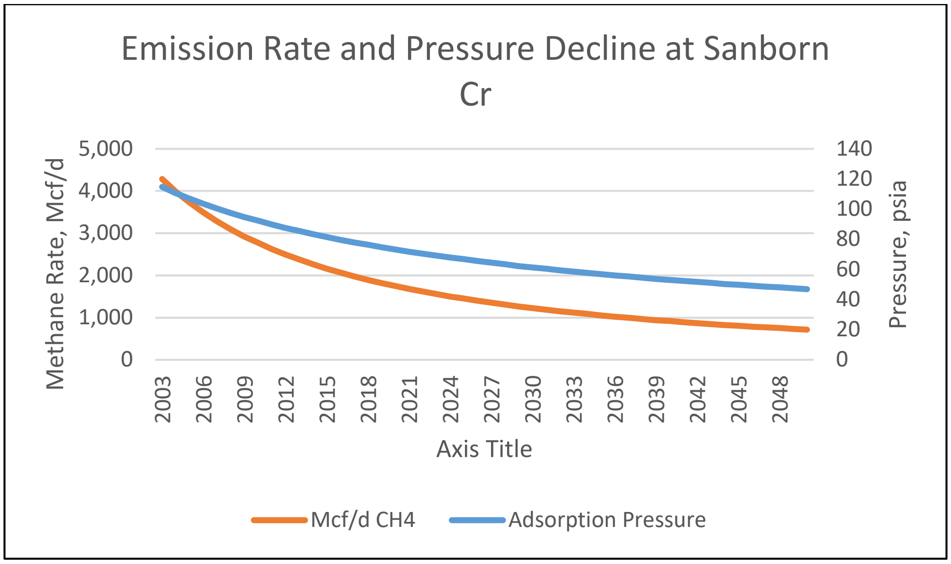

Figure 18: As methane is emitted the adsorption pressure in the system declines, which, in turn reduces the pressure differential between the atmosphere and the adsorbed methane

Abandoned mines can exhibit down-hole pressures in void areas of from zero to several psig (usually less than 10 psig) so there remains a pressure differential sufficient to continue to produce adsorbed gas from the coal. The ability of a mine to retain a positive bottom-hole pressure depends on the ease with which the gas can penetrate the strata above the mine. A mine with poor communication to the atmosphere through faults and fractures will retain more pressure than a mine with good communication pathways to the surface.

An example of natural emissions from an abandoned mine is from a flow test at a mine in Pennsylvania. This mine had held a bottom-hole pressure of 4 psig prior to the test as measured at a borehole that had been closed at the surface with a valve. Upon opening the valve and measuring the flow rate together with the atmospheric pressure, the sensitivity of the flow rate to the variable atmospheric pressure was demonstrated. **Figure 19** shows the correlation between atmospheric pressure and flow rate.

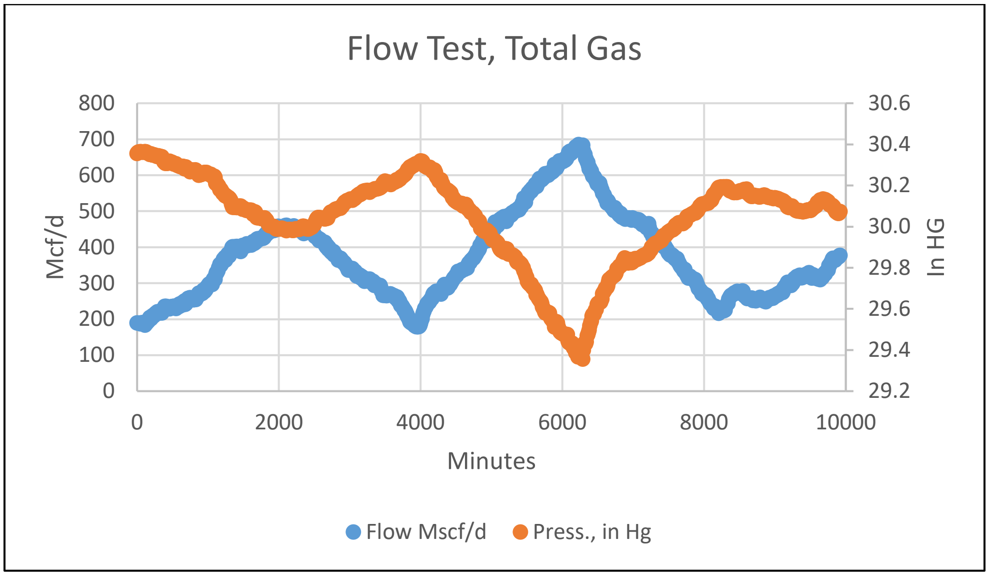

Figure 19: Flow test results from a borehole in an abandoned mine in Pennsylvania

In this case, because there was an open pipe, the variable atmospheric pressure had an exaggerated effect on the flow rate, but it demonstrates the point that in the case where there is easy access to the atmosphere (where the mine void pressure is essentially zero psig) the mine will be "breathing". That is bringing air into the mine under high pressure conditions and exhaling mine gas under low pressure conditions. Because methane continues to desorb into the mine void, there will always be a net emission of gas through time.

Uncertainties in Forecasting

Although the use of this modeling technique has proven itself in other abandoned mines that have long term recordings of the methane recovered from those mines, there are obviously uncertainties in the approach especially where good historical data is lacking as in the Somerset and Hawks Nest Mines. Therefore, a range of probable outcomes have been constructed based on varying the initial gas content of the mines for which there is no measured data. The mid case gas content of the mines is shown in **Table 4.** These were derived based on matching measured parameters such as reported emission rate and specific emission rate when the mines were active. The initial gas content was determined by varying this parameter until the average emission rate and specific emission rate were closely matched. To illustrate a possible range of uncertainty the high case value of the methane content of the coal was changed by +/- 30% to show a low and high case. The high case results are illustrated in **Figure 20** and **Table 7. Table 7.1** shows best estimated total emissions from mine closure to 2040 as a daily average (Mcf/day) from the date of closure, tCO_2e (GWP 84), the number of cars that produce that same amount of CO_2 and the acres of US forests necessary to sequester that amount of CO_2.

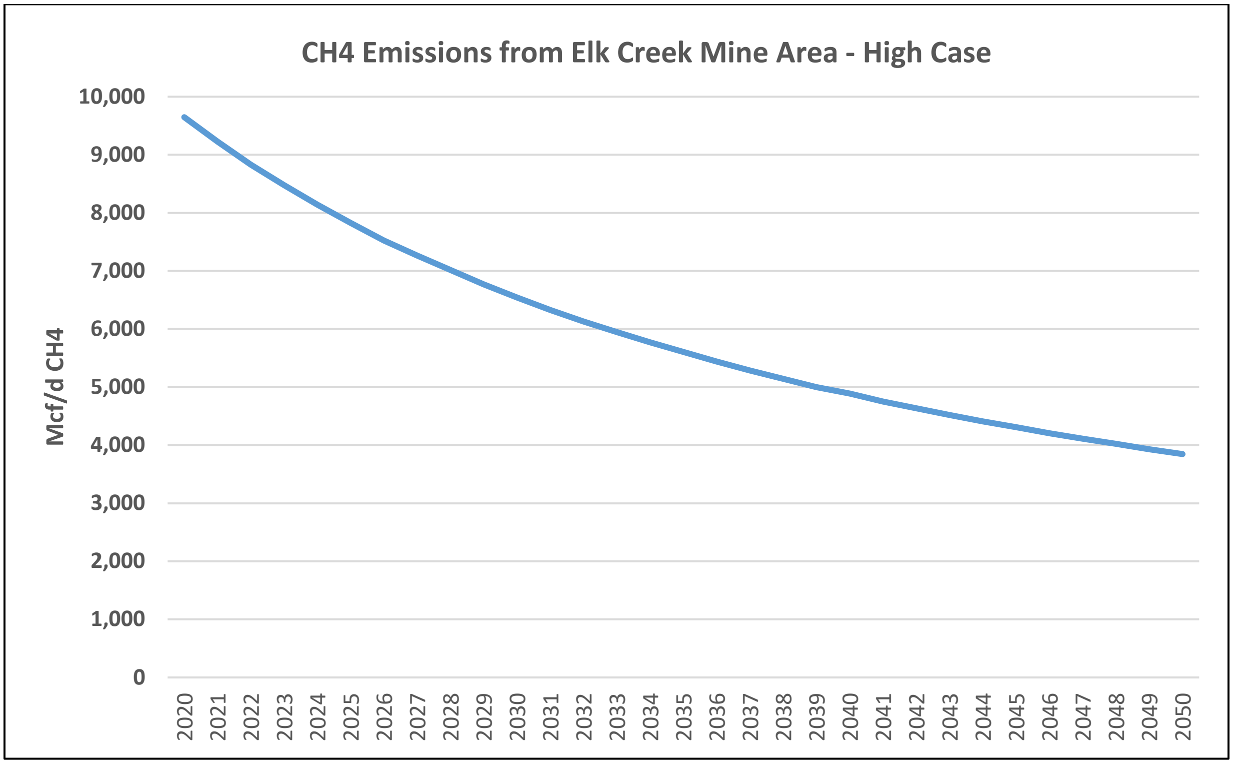

Figure 20: Expected methane emissions from abandoned mines in Elk Creek Mine Area

Table 7: Methane Emissions from Closed Mines 2020-2050 High Case Using tCO_2e GWP of 84 and with tCO_2/car/year of 4.7 (US EPA)					
	Somerset	**Hawks Nest**	**Sanborn Cr**	**Elk Cr**	**Total**
Methane Mcf	10,670,560	1,322,983	15,585,997	40,143,505	**67,723,046**
Metric tons CO_2e	17,259,169	2,139,868	25,209,677	64,930,384	**109,539,098**

As a comparison, the entire state of Colorado is projected to emit ~201 million metric tons of CO_2e in 2020 (2019 CO GHG Inventory – adjusted to use GWP 84 for CH4). This single source of mine emissions is estimated to emit ~55% of the entire state's yearly GHG emissions in the next 30 years.

Table 7.1: 2020 Daily Average Methane Emissions from Closed Mines – High Case Using tCO_2e GWP of 84					
	Somerset	**Hawks Nest**	**Sanborn Cr**	**Elk Cr**	**Total**
Years Abandoned	55	63	48	35	
Methane Mcf/day	1,091	170	2,103	6,283	**9,647**
Metric Tons CO_2e/day	1,760	274	3,393	10,136	**15,562**
[1]**Passenger Cars eq.**	136,648	21,267	263,496	787,157	**1,208,568**
[1]**Acres of US Forest eq.**	834,087	129,811	1,608,352	4,804,725	**7,376,975**

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As noted in Table 7.1, using the high-case scenario the daily emissions by all of the mines is equivalent to the daily emission from over 1.2 million cars. Similarly, it would require over 7.3 million acres of U.S. forests to sequester the amount of emissions the mines emit daily.

The potential recovery of future emissions is highly uncertain. Not all emissions can be recovered economically or even theoretically because of the large area of diffuse emissions. Establishing pressure sinks through strategically placed wellbores with suction blowers such as at the most recent mine in the area, the Elk Creek Mine, can capture significant quantities of mine gas. This may be more problematic at the Somerset and Hawks Nest Mines because of their long abandonment times and being near outcrop (Somerset) or higher in the coal section (Hawks Nest). Nevertheless, methane emissions are detected at the Somerset and Hawks Nest Mines shaft portals and one old unplugged vent.

A recent methane reserves analysis for the Elk Creek Mine came from methane captured from two boreholes, the Elk Creek Fan Site Borehole which provides methane to the 3 MW power project and the Bear Creek Fan Site Boreholes. The analysis provides an average production rate of 3,200 Mcf/d CH4 for 2017 which is about half the mid-case forecasted emission rate from the Elk Creek Mine using the model. This indicates that the Elk Creek Mine alone is emitting another 3,200 Mcf/d from diffuse emissions from the outcrop or from fractures at the surface. This might act as an indicator about how much of the forecasted emissions are not being captured. Activating additional wells in the mine, such as inactive gob wells might capture more of these fugitive emissions.

Power Generation from AMM in the Elk Creek Mine Area

The declining nature of the methane liberated from the abandoned mines in the Elk Creek Mine area must be considered when designing power generation projects. Fortunately, containerized internal combustion engines driving power generators can be added or removed depending on the gas production performance. **Table 8** shows the adjusted high, mid and low rate at the year 2032 together with the plant size at those rates. Unfortunately, electricity prices in the current range of $.03 to $.015 per kilowatt hour are not sufficient to incent any additional electricity generation using methane emissions. If attention is paid to the tons of CO_2e emissions avoided rather than Megawatts generated, then electricity generation from methane emissions becomes economic. Approximately 9 mcf of methane will generate 1 megawatt hour (MWh) of electricity equivalent to over 14 tCO_2e. Since the electricity market does not currently consider the value of GHG reductions by methane destruction adding a high efficiency gas incinerator can take advantage of any market-based emission reduction credits.

Table 8: Potential CH_4 Recovery and Power Generation at Year 2032

	High	**Mid**	**Low**
Predicted CH_4 Rate in 2032, Mcf/d	3,065	2,474	1,803
Potential Plant Size, MW	15	12	9

Under the high case scenario in 2032, a potential expanded power generation project could produce over 111,000 MWh of electricity annually (assuming 85% capacity factor). Generating this amount of electricity would typically produce almost 70,000 tCO_2e of emissions in Colorado based on its electricity grid mix. In contrast, the project would generate MWh that actually reduce emissions by over 1.5 million tCO_2e in a year.

Disclaimer

The gas-in-place and recoverable gas volumes presented in this report are estimates only and should not be construed as being exact quantities. These volumes could be more or less than the estimated amounts. It is also important to understand that the economically recoverable volumes may increase or decrease because of changes in the electricity and greenhouse gas emission reductions market. As in all aspects of oil and gas evaluation, there are uncertainties inherent in the interpretation of engineering and geologic data, and therefore, our conclusions represent only informed professional judgments.

Ronald Collings, PE

Exhibit A

Summary of the field trip October 25, 2018 methane survey of Elk Creek Mine Area

There were six people participating in the field trip. Vessels Coal Gas, Inc. sent three representatives, the Western Slope Conservation Center sent a representative, the U.S Bureau of Land Management sent a representative, and one member of the general public was present.

The entire group visited an abandoned Hawks Nest West Mine vent borehole and the closed Hawks Nest East Mine portals. The representative of the Bureau of Land Management departed, and the remaining parties continued on to visit the Hawks Nest West and Sanborn Creek mine closed portals and the closed Elk Creek and Bear Creek Fan sites of the Elk Creek Mine where the following information was obtained. See the following map for locations.

Note: 1% concentration equals 10,000 ppm. Average methane in air is 1.7 ppm

Hawks Nest West Mine Vent WSC DH-12. located at N 38*56'32.9" W 107* 25'53.0.

- 3,000 ppm of methane was measured outside of casing of vent.
- Background of methane was 3.5 ppm away from the vent.
- Barometric Pressure 22.83 Inches Hg

Hawks Nest East Mine portals

- Several seeps with the largest volume at 18% methane
- Barometric pressure 24.1 Hg

Hawks Nest West Mine portals.

- The highest concentration of methane at the Hawks Nest West portals was 1,500 ppm.

Sanborn Creek Mine portals.

- The highest concentration of methane at the Sanborn Creek portals was 2,400 ppm; from the C Seam portal.

Bear Creek Elk Creek Mine Fan Site.

- The highest concentration of methane at Bear Creek Fan site was 53% methane, coming from the Fan shaft cap.

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UNCONTROLLED METHANE EMISSIONS OBSERVED FROM ELK CREEK MINE AREA OCTOBER 25, 2018