# AGENDA ITEM or FINAL CONTRACT REVIEW SUBMITTAL FORM

**Agenda Item:** Visitor; WSCU Master in Environmental Management C

**Action Requested:** Discussion

**Parties to the Agreement:**

**Term Begins:** **Term Ends:** **Grant Contract #:**

**Summary:**

Please see the attached presentation materials and request for support provided by Chris Nutgrass, a WSCU Master in Environmental Management candidate.

**Fiscal Impact:**

**Submitted by:** Katherine Haase for Chris Nutgrass **Submitter's Email Address:** khaase@gunnisoncounty.org

**Finance Review:** ○ Required ◉ Not Required

Comments:

Reviewed by: Discharge Date:

**County Attorney Review:** ○ Required ◉ Not Required

Comments:

Reveiwed by: Discharge Date: Certificate of Insurance Required

Yes ○ No ○

**County Manager Review:**

Comments:

Reveiwed by: GUNCOUNTY1\mbirnie Discharge Date: 9/23/2016

○ Consent Agenda ○ Regular Agenda ○ Worksession Time Allotted: 15

Agenda Date: 9/27/2016

*Revised April 2015*

**Katherine Haase**

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**From:** Christopher Nutgrass <christopher.nutgrass@western.edu>
**Sent:** Tuesday, September 20, 2016 11:35 AM
**To:** BOCC
**Cc:** Luke Danielson; Jonathan Houck
**Subject:** Work Session Agenda items
**Attachments:** Nutgrass Methane Proposal BOCC.pdf; Coal Planning Report (3).pdf

Dear BOCC,

Thank you for taking the time to review my proposal on methane capture. I look forward to discussing this more next week. Attached you will find my proposal and a supporting report. I have also added a link to Colorado Energy Office's report on Coal Mine Methane.

https://www.colorado.gov/pacific/sites/default/files/atoms/files/Coal%20Mine%20Methane%20Report%202016%20FINAL%203_2016.pdf

Best regards,
Chris


Chris Nutgrass

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Chris Nutgrass

20 September 2016

**Coal Mine Methane Capture Project**

Dear Gunnison County Commissioners:

Coal mines in the North Fork Valley have provided revenue to Gunnison County and high paying jobs to residents of this and surrounding counties for decades. As this Commission clearly knows, with the recent downturn in the coal market, those companies have been forced to drastically reduce the number of employees at those mines. West Elk Coal Mine, the only coal mine in production in Gunnison county, laid-off eighty staff members in June and fears further reductions. Although the coal industry is not as significant an employer in Gunnison County as Delta County, impacts from decreased production will be felt.

Coal will remain a vital part of our energy mix but in a decreasing amount. Our County government has seen this coming, but needs to keep preparing for those changes. The past decade has seen a reduction in the amount of coal and an increase in the amount of natural gas used to generate electricity.

I am a student in the Masters of Environmental Management program here at Western State. I have many interests surrounding sustainable development and the way in which communities utilize their natural resource endowments for this purpose. Gunnison County, surrounding counties, Colorado, and many communities around the American West are being forced to adapt a changing resource landscape. With guidance from my advisor on this project, Professor Luke Danielson, we plan to explore opportunities for communities to ease the impacts of this transition.

**Our goal is to build on the work of the County and others to help determine if it is possible to capture and make economic use of the methane, a major component of natural gas, that is being (and will continue to be) vented from coal mines in the North Fork Valley.**

Gunnison County has the opportunity to address multiple issues by investigating the potential for methane capture from producing and abandoned coal mines.

1. Methane has a global warming potential twenty-eight times that of carbon dioxide, and keeping it out of the atmosphere would contribute greatly to Colorado's efforts as a leader in greenhouse gas reduction;

2. Captured methane is a potential energy source, which should be used rather than wasted;

3. If new business can be created based on the availability of this energy source, this could lead to badly needed new livelihoods.

This "triple-bottom" line approach sees possible benefits to the environment, economy, and society.

There are already tight restrictions of the amount of methane released from oil and natural gas development in Colorado. Regulation of methane emission from coal mines is clearly coming, and is probably just around the corner.

Exploring the potential of capturing this resource could further increase the recognition of Gunnison County as an innovator in Colorado and the US.

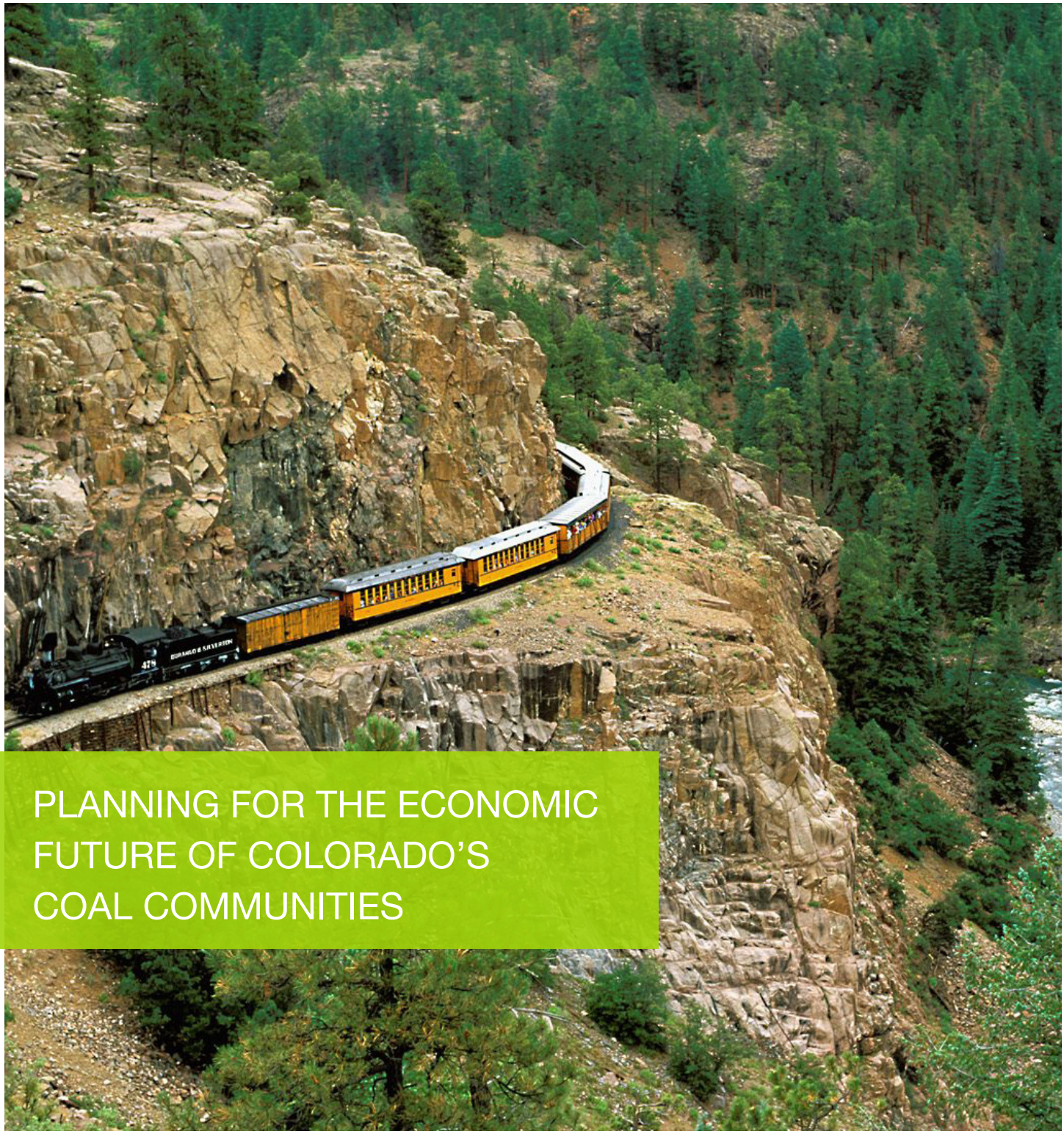
This project proposes to begin attempting to answer some of the questions that would be involved if the project goes to a full-scale feasibility assessment. A feasibility assessment often takes a team of experts many months or years of work. This project is not a full feasibility study but hopes to lay the groundwork for one should initial results be encouraging.

The resource must be characterized, the environmental impacts accounted for, the regulatory system navigated, economic considerations taken, and livelihood changes analyzed before any decision can be made to determine the potential of methane utilization in the North Fork Valley. These are only a few of the questions that will need to be answered over the coming years, and I would greatly enjoy beginning this journey.

I am here because we would like some expression of support from this County Commission for our project. We are not seeking any funding or financial commitment, simply an informal expression that the County views this as a positive effort.

Sincerely,

Christopher J. Nutgrass



# PLANNING FOR THE ECONOMIC FUTURE OF COLORADO'S COAL COMMUNITIES


Co-Authors:

Sustainable Development Strategies Group:
Sarah Wilhelm PhD, Luke Danielson,
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The Mountain Pact

SDSG
Sustainable Development Strategies Group


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The economic benefits of the coal industry are widely felt. People in large parts of the United States turn on their lights or heat their homes with electricity generated by coal, or benefit from steel or concrete made with coal. Colorado even has two of the few remaining coal-fired railroads, the Durango & Silverton and the Cumbres & Toltec.

While the economic benefits of coal mining are widely shared, many of the impacts of coal production tend to be felt very intensely in the specific regions where coal is produced. Some of these impacts are positive, such as well-paid jobs or revenues to local government during coal production. Other impacts are very challenging to manage, such as the "boom town" effects when coal development first starts, or the collapse in mine employment and tax revenues at the end of the mine life. The experience of most resource-dependent local economies is of good times and hard times, and unpredictable ups and downs.

Facing these challenges on a local level can be extremely difficult. The abrupt economic transitions can impose serious hardship on individuals and families, pose immense challenges to local government, and generate economic and political instability. It can divide communities rather than lead them to work together. In order to achieve the full benefits of exploiting nonrenewable resource endowments, economists recommend planning for the future, at all levels, from federal coal policy, to state management of revenues, to local planning for a post-coal transition when the resource runs out. Individuals, families, companies, advocacy groups, and governments all have a role in planning viable long-term options. To achieve the best economic and social results, this process should start at the outset, before resource extraction begins, and continue throughout the mine life. This opens up the widest array of options. Regardless of the timing, the best path forward for communities is to plan for economic diversification at the earliest possible stage.

**The report focuses on two key questions:**

- First, to the extent that we do use coal, what federal, state and local policies can ensure that the benefits of coal production are maximized, and the negative impacts minimized?

- Second, what are the options for a sustainable, positive future for coal dependent communities?

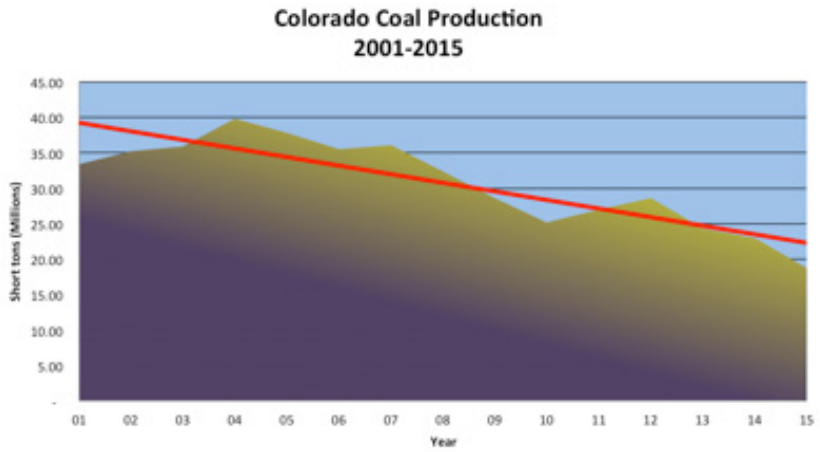
# I. A Challenging Time for Stakeholders Worldwide

The coal industry is currently in a period of transition that is characteristic of resource industries. It is facing a perfect storm of aging infrastructure, [1] environmental concerns, and cheaper energy alternatives. Coal production is down across the globe, primarily due to diminishing coal use for electric generation. This has profound effects on communities that have been economically dependent on the coal industry, including the loss of high paying jobs, revenue for localities, and the way of life that has been embraced by residents.

### Coal Production is Down in Colorado, the US, and the World

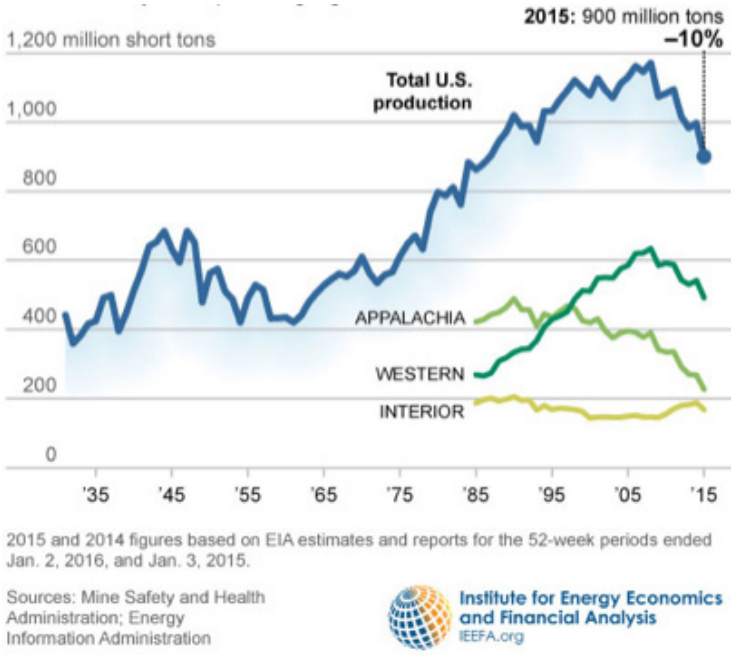
Colorado coal production has dropped from 33,411,127 tons in 2001 to 18,726,445 tons today, [2] with a peak in 2004 (Figure 1). [3]

## Figure 1 - Colorado Coal Production [4]




These trends are hardly unique to Colorado, as they have been experienced across the U.S., as shown in Figure 2. Coal production has in recent years fallen in Colorado, in the U.S., and globally. [5]

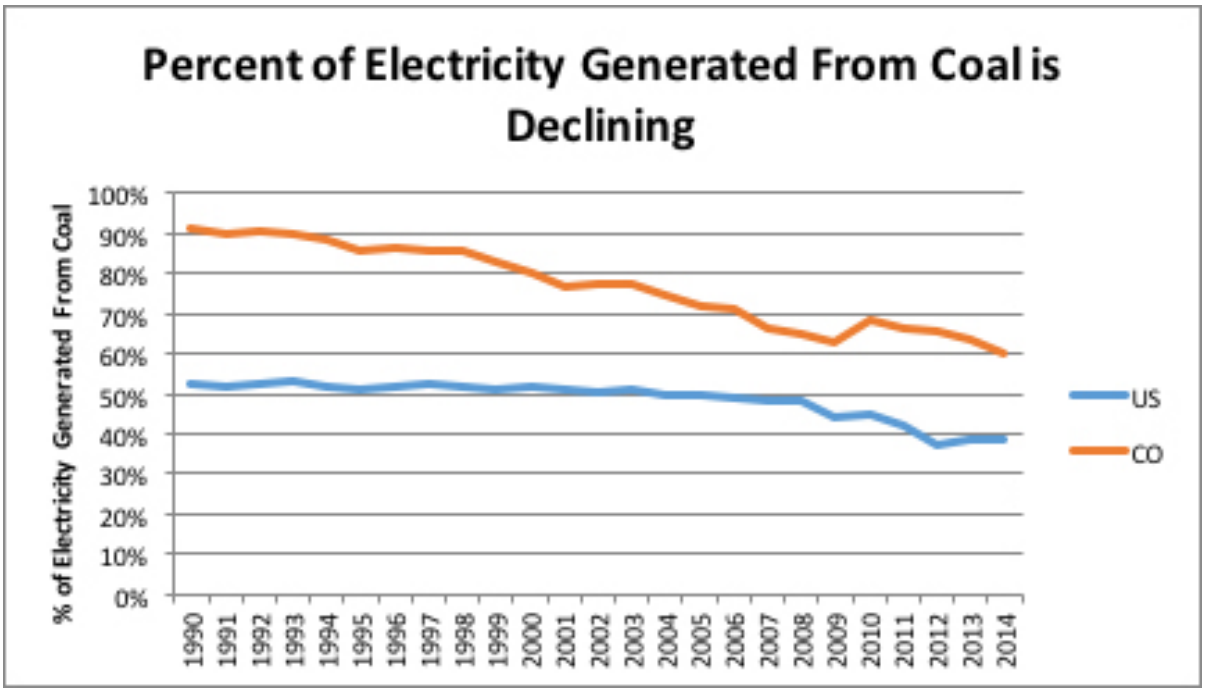
## Figure 2 U.S. Domestic Coal Production




### Coal is Losing Ground in Colorado as a Leading Fuel in Electricity Generation

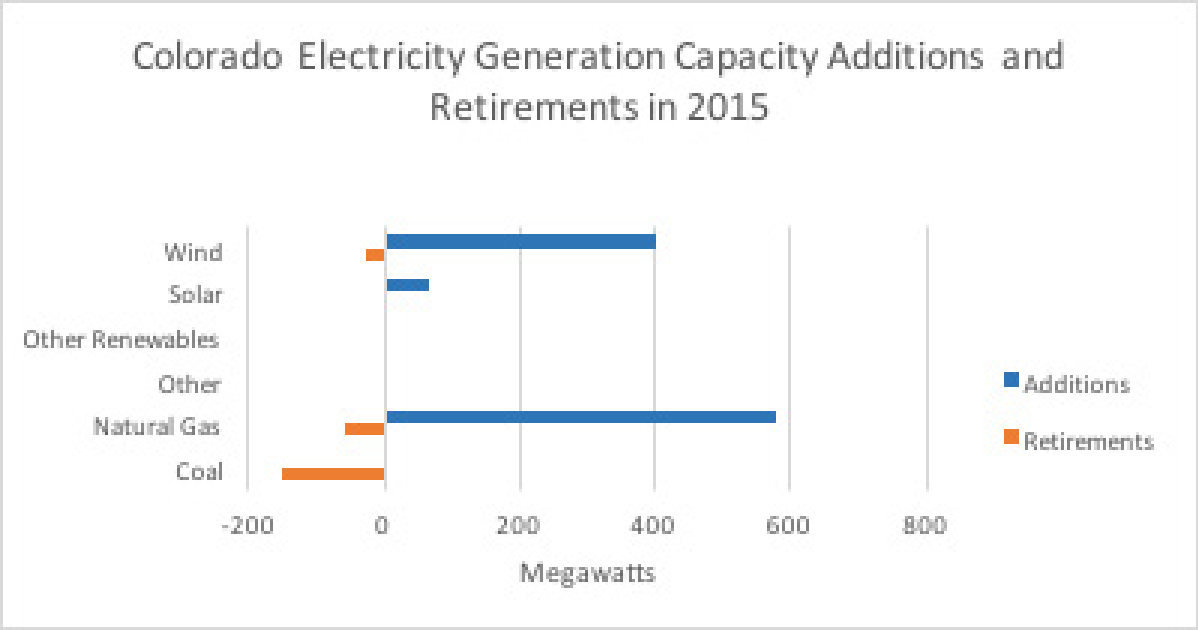
Most coal is used for electricity generation, in Colorado and elsewhere. Coal from Colorado is also used for manufacturing iron and steel, home heating, cement making, and other industrial uses. However, there has been a steep drop within the state and nationwide in the percent of electricity produced with coal. In 1990, coal was used for over 90% of Colorado's electricity generation; in 2014, coal made up just 60% (Figure 3). [6] The decline in demand from the energy industry is the primary driver of the reduction in coal mining.

## Figure 3 Percent of Electricity Generated from Coal is Declining [7]




Coal generation has been replaced primarily by natural gas, but also to some extent by wind and solar. In Colorado, coal generating capacity decreased by 152 megawatts in 2015. Meanwhile, natural gas generating capacity has increased by 516 megawatts. In addition, new wind and solar capacity has increased by 375 and 66 megawatts, respectively (see Figure 4 below). The largest renewable energy additions are planned in Adams County, El Paso County, and Kit Carson County. [8]

## Figure 4 Additions in Wind, Solar, and Natural Gas Have Outpaced Retirements in Coal [9]



## The Effects of the Decline on Coal Communities in Colorado

Coal mining is not a large part of the overall Colorado economy. But it is an important base for local economies in several regions, principally on the Western Slope. It is important for direct employment, and also generates indirect employment. It also is a major part of the revenue base for local government.

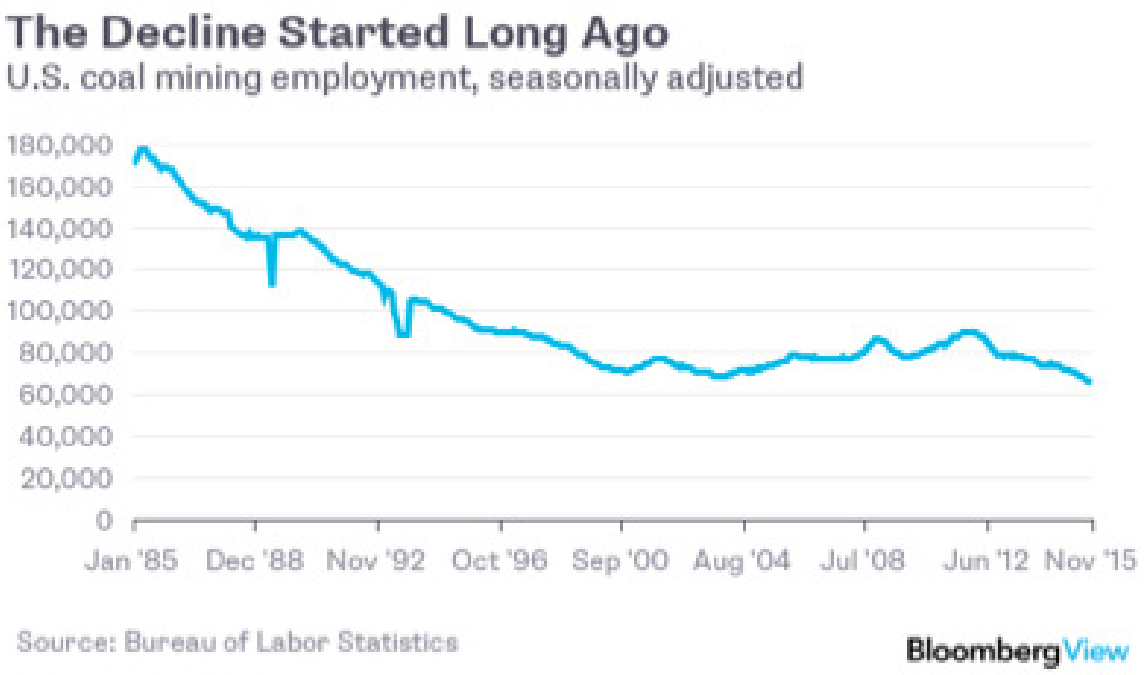
In 2001, Colorado had 12 coal mines. Today, as shown in the table below, only nine of these mines remain, with only seven of the remaining mines producing. The coal mines in Colorado are concentrated on the Western Slope.

## Table 1 - Operating Coal Mines in Colorado as of April 2016 [10]

| Mine Name | County | Status |
|---|---|---|
| Bowie- No. 2 Mine | Delta | Idle |
| Colowyo Coal Mine | Moffat | Producing |
| Deserado | Rio Blanco | Producing |
| Foidel Creek Mine | Routt | Producing |
| King II Mine | La Plata | Producing |
| New Elk Mine | Las Animas | Idle |
| New Horizon North | Montrose | Producing |
| Trapper Strip | Moffat | Producing |
| West Elk Mine | Gunnison | Producing |

With increased mechanization, coal employment has fallen faster than coal production. Coal mining employment in West Virginia fell from 130,000 in 1941 to 20,000 today. [11] China plans to close 1,000 coal mines in 2016. [12] In Ukraine, coal mine closures are a major element in the country's violent political conflict. [13] There is no end in sight to the downward trend in coal employment; even if coal production somehow stabilizes, all indications are that the employment level will continue to fall due to increased mechanization and other factors.

## Figure 5 Decline in U.S. Coal Mining Employment




Colorado's nine coal mines are in eight counties, employing approximately 1,326 miners. [14] Not all mines are open year round; the full year equivalent employment is 1,308 miners. Statewide, employment in coal mining accounts for less than one tenth of one percent of employment in Colorado. [15] In most counties with coal mines, coal mining makes up about 2% of private employment. But this should not obscure the fact that coal mining is very important to these counties, and particularly to the individuals and families that rely on coal mining income. As noted in the table below, which considers only direct employment, coal mining makes up 9% of private employment in Moffat County, and 5% of private employment in Gunnison and Rio Blanco Counties.

## Table 2 - Coal Production and Employment by County [16]

| County | 2015 production in tons | Number of miners In Dec. 2015 | Average Days worked | Full Year Equivalent | % of County total Private Employment |
|---|---|---|---|---|---|
| Delta | 1,587,976.00 | 109 | 365 | 109.0 | 2% |
| Gunnison | 5,172,878.00 | 296 | 311 | 291.9 | 5% |
| La Plata | 813,677.00 | 115 | 357 | 112.5 | 1% |
| Las Animas | 107.00 | 3 | 254 | 2.1 | 0% |
| Moffat | 4,439,479.00 | 326 | 360.5 | 322.0 | 9% |
| Montrose | 238,094.00 | 20 | 261 | 14.3 | 0% |
| Rio Blanco | 2,353,043.00 | 158 | 365 | 158.0 | 5% |
| Routt | 4,121,191.00 | 299 | 364 | 298.2 | 2% |
| Grand Total | 18,726,445.00 | 1326 | 330.9 | 1307.9 | 2% |

In these counties in Colorado, revenue from coal mining is an extremely important part of the tax base. Coal companies pay property, production, sales, and other taxes to local communities. These taxes are typically put into the county's general fund to supplement or enact programs or pay employees, though there is a growing realization that this may not be the best way to manage a nonrenewable endowment that may only be utilized once.

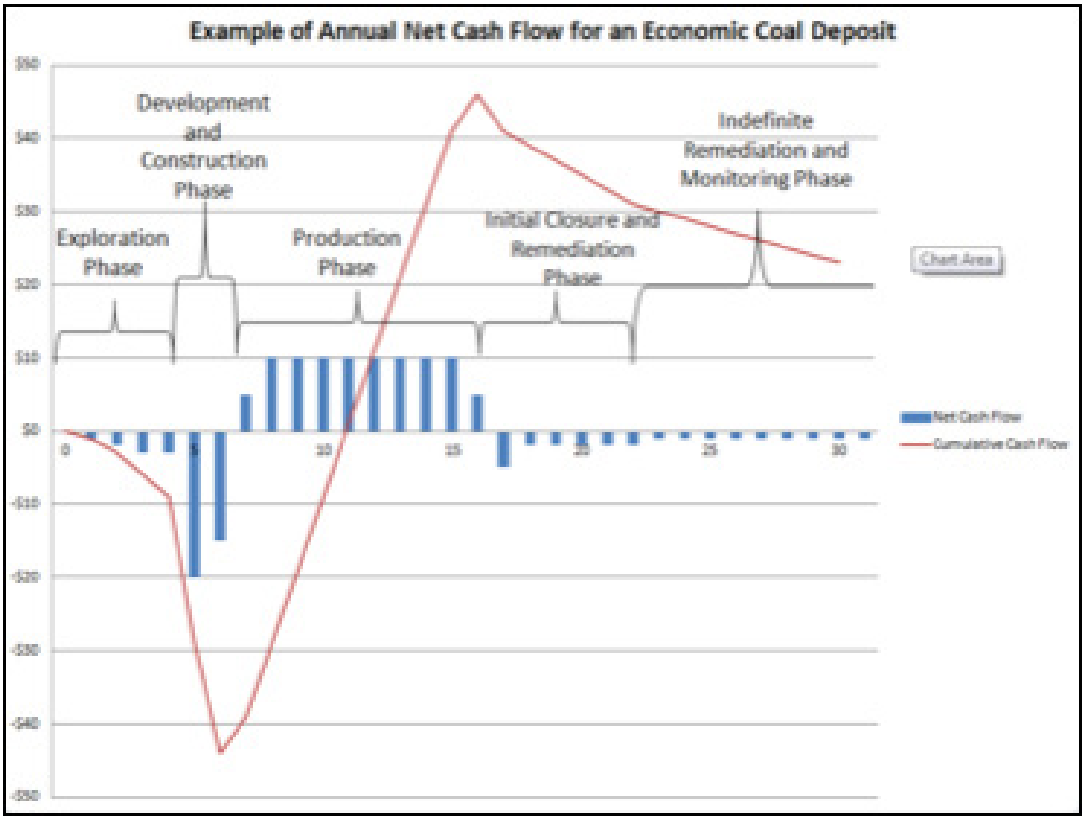
In general, local revenues pass through phases, as shown in Figure 6. During the exploration and construction phases, the costs to local government of managing influx of population, expansion of services, and dealing with other impacts will likely exceed any revenues, since there is no production to generate royalties, and many local taxes have yet to kick in. [17]

During the production phase, counties and towns will benefit from coal-based revenues. The principal question is whether these revenues are spent on current needs, as opposed to being saved to cushion the inevitable shock when production ends—due to the resource being exhausted or for other reasons. The process of economic diversification should be planned early in the life of the mining project, and begin during the production phase, when revenue is high.

Finally, in the closure and remediation phases, the situation is again reversed. The cost to local government of managing outflow of population and dealing with other impacts will likely exceed any revenues. Again, plans must be made early in the life of the mine to respond to these circumstances.

For example, in Colorado, nearly 50% of the Federal Mining Lease revenue distributed by the Department of Local Affairs goes to the State Public School Fund. Other money is distributed to locally impacted communities

## Figure 6 Example of Annual Net Cash Flow for an Economic Coal Deposit [18]




for infrastructure maintenance, community development, and discretionary spending. Managing changes in revenue are important both during the life of a mine as well as through mine closure and transition to a post-mining economy, as further discussed below.

Debate has focused on whether current trends in coal prices and production levels are temporary or long term. But the coal industry would need to overcome tremendous challenges to remain "king coal." This does not mean the coal industry will disappear from Colorado or the U.S. in the short-term. Coal is likely to remain a part of the energy portfolio in the U.S. for some time, particularly for uses other than energy production.

It is not the purpose of this paper to try to predict the future, or to speculate about how much coal we will use, or for how long. We note that world leaders have pledged to phase out all coal use by the end of this century, [19] but the end of the century is a long way off, and only time will tell how fast, or whether, coal is completely phased out. Rather, the purpose of this paper is to help communities create an environment where their livelihood is not dependent on the coal market, which is largely out of their domain of influence.

## II. How to Promote Economic Diversification

What do we do where a mine is closing? Particularly where previous attention to planning and economic diversification has been limited, there is just no "silver bullet." Communities must try a variety of strategies to diversify their economies. These can include a wide range of activities such as traditional business recruitment, retention and expansion, workforce development, entrepreneurial development, promoting tourism, leveraging university capabilities, investing in infrastructure, and many others. These strategies should attempt to satisfy one or more of the following five goals:

1. Create collaborative regional planning and implementation systems;
2. Build an environment capable of supporting a diverse array of economic activities;
3. Connect local and regional assets to external markets;
4. Develop skills and talent needed in a wide range of industries; and
5. Encourage local reinvestment of wealth. [20]

Like relying on one industry for local employment, relying on one strategy leaves a community too vulnerable to market and external factors. In addition, local economic strategies should be built around decisions that can be made locally. For example, the decision to expand a local manufacturing company would be made by the resident business owner. While, a decision about where to locate a factory of a large multi-national company would be made far away at the company headquarters. Thus, local business owners, community leaders, and other local stakeholders are more likely to make a difference in the long run when decisions must be made regarding the economic health of a local community. [21]

How does a community pursue the five goals listed above? What does this look like on the ground? The next section illustrates how several communities are working to diversify their economies through collaboration, policy changes, and creativity.

## III. Case Studies: Diversifying Local Economies and Planning for Transition

Case studies are useful tools to help imagine what is possible. These case studies are not intended to be prescriptive, but rather to generate ideas and help start the brainstorming process. There are many more examples in addition to those listed here—readers are encouraged to further research the many possibilities by reviewing the references provided in this paper; seeking out additional resources; and speaking with other stakeholders in your region, as well as in other regions that have had similar experiences. The recurrent themes from the case studies are listed in the side bar "Lessons from the Field." The following case studies include success stories, communities with a long way to go, and a few in between.

## Regional Collaboration with "PEP" in Upshur County, West Virginia

Upshur County in West Virginia has a population of 24,000 people and has an array of natural resource extraction industries including timber, natural gas, and coal. The Sago mine was the scene of a mine explosion that took the lives of 12 miners in 2006. About two years later the mine closed permanently. Yet, the county has seen above average growth from 2009–2012 and its economy is relatively diverse. Regional collaboration has been one of the primary tools used by Upshur County along with its neighbors Randolph and Lewis Counties.

Upshur has focused its diversification efforts on agriculture, hardwood products, and tourism. But the core project is creation of a major interstate between this region and the Washington D.C. area, "Corridor H." When completed, driving time to D.C. will be reduced from about five hours to three—helping to facilitate the community's effort to attract new residents, tourists, and businesses. Tom Smith, West Virginia Division Administrator for the Federal Highway Administration, said it takes "PEP" to build roads like Corridor H.

"The first P stands for partnership," Smith said. "The E stands for enthusiasm. It certainly takes persistence and enthusiasm to stay the course and get a project like this built. The final P stands for persistence. You have to take it one step at a time and eventually you have roads built." [22]

One county alone could not have built the political will to create this transportation project. Likewise, the tourism and value-added hardwood products development efforts have been regional and linked to Corridor H. The three counties did not think they had enough destinations individually to attract tourists, but as a region they certainly did. The new collaborative marketing strategy, "33 Things To Do Along Route 33," has boosted tourism for the region.

Likewise, the regional approach has been used to expand value-added hardwood product production. The regional Harwood Alliance Zone concentrates on marketing and building the infrastructure necessary to attract value-added hardwood companies to the region.

Using a Federal Rural Jobs Accelerator Grant, Upshur County has also expanded local food production. The grant supported expanding local food chains, helping local organic growers produce for homes and restaurants, and also start a farmers' market.

Upshur County exemplifies the need for regional collaboration and avoiding the "beggar thy neighbor" [23] strategies that often occur when communities get desperate and fail to take the long-run view. The County has avoided competing with neighboring communities for businesses that are basing their location decisions on tax breaks. Such businesses are rarely stabilizing forces in an economy.

## Delta and Gunnison County, Colorado Conduct Research for Economic Diversification

In response to the recent decline in coal mining employment, the closure of Oxbow coal mine in Gunnison County, Colorado, and the related out-migration of miners, Delta and Gunnison Counties, through a non-profit organization called Region 10, hired a consulting firm called Better City to aid them in identifying economic development solutions. Region 10 utilized a U.S. Economic Development Administration Economic Adjustment Assistance Grant for the Counties, to "improve and enhance the economic resiliency and sustainability" of the Counties. [24]

Better Cities worked with the State Demographers Offices to compile and analyze economic indicators; conduct market analysis; create a report with recommendations and an action plan; conduct a feasibility study analysis; and monitor results. [25] The analysis fed into proposals focused on "leveraging local assets, building upon the communities' natural strengths, and developing vision for a variety of potential economic development projects." [26] They held several open houses in communities to discuss a development vision, and utilized the www.region10.net website to collect public feedback.

In Gunnison County, the consultants proposed that the high-altitude county become the "altitude training center of the country," leveraging the market for endurance sports. The study recommended that Gunnison become the "Endurance Sports National Center of Excellence," with strategic investments in business recruitment, hosting well-marketed competitions and training seminars. The county's higher education resources also position it to focus on technological innovation. [27]

Stakeholders in Delta County identified strengths in the county as outdoor recreation, general agriculture, organic agriculture, scenic beauty, hunting, and quality of life. [28] The study identified Delta County as the hub of organic agriculture in Colorado, and proposed that it leverage this strength by developing an "Organic Industry National Center of Excellence" to engage in the market state-wide. The study proposed strategies for marketing, infrastructure, and distribution, coupled with downtown revitalization, to factor into an equation for success of the organic market. [29]

### LESSONS FROM THE FIELD

**Avoiding wasteful "beggar thy neighbor" strategies—instead focus on regional collaboration.**

Partnering with nearby institutions of higher education, investing in programs that are most likely to boost economic development in the region.

An honest assessment of the community's strengths, weaknesses, opportunities, and threats.

All hands on deck, breaking down silos—collaboration must include public, private, and government sectors.

Staying in touch with local business needs and crafting strategies to overcome their impediments to growth.

Frequent updating of planning strategies and goals—ensuring that the plan continues to meet short and long-term local needs.

Maintaining focus on diversity and not being seduced by another potential single employer.

Patience and commitment to diversification efforts that may require years of work.

Use data to inform all stages of planning.

Create trusts or funds to smooth funding streams over the long run.

The study also identified a strong manufacturing sector in Delta County compared to Colorado as a whole, and suggested an innovation center to aid entrepreneurs in prototyping concepts for manufactured goods. It recommended technical support for new startups, and access to regional and national markets. [30]

Following public comment on these and several other concepts, Delta County ultimately decided to conduct feasibility studies on three of eight proposed projects: development of a hotel and conference center, riverfront "activation" (development of recreation activities, retail activity, and office space along the county's riverfront property), and specialty food manufacturing. The county is currently developing implementation plans for the three projects, and has obtained a Colorado Department of Local Affairs Rural Economic Development Initiative Grant to begin waterfront engineering. [31]

## Trusted Community Leaders Start the Conversation in Eastern Kentucky Coalfields

A five-county region of eastern Kentucky has lost 8,500 jobs since 2008. Communities have seen declining tax revenues, population declines, and home foreclosures.

One of the key components of the development strategy in the region is collaboration: an "all hands on deck" strategy including businesses, nonprofits, government at all levels and, of course, residents. Unusual allies must come together and work side by side to push for economic diversification and stability.

This strategy requires leadership and spokespeople who can inspire residents across the spectrum. One example is the creation of Shaping Our Appalachian Region (SOAR), a bipartisan effort led by Congressman Hal Rogers and Governor Matt Bevin. These leaders were able to begin the conversation around "what do we do next?," [32] a conversation that many in the region were not willing to have, because they did not want to let go of the bounty of the coal mines.

During this process, several priorities were identified by local communities. One priority is providing broadband access throughout Eastern Kentucky. Kentucky Wired has been funded by a public-private partnership. Local institutions of higher education are providing training for high-tech occupations in industries that will utilize the broadband. In addition, a private group is working on retraining coal miners to be coders.

The health care sector is the primary source of employment growth in the region. The higher education community is also training workers to meet the growing demand for employees in this sector.

## A Different Look at Manufacturing in New Mexico

The Northwest New Mexico Council of Governments (NNMCOG) covers three counties in Northwestern New Mexico and includes part of the Navajo nation. Coal mining and power plants created much needed employment in this area, which has high levels of poverty. Fifty-one percent of the Navajo Nation's annual budget is derived from coal. [33] In 2015, this area saw the largest increase in unemployment in the nation.

In October 2015 San Juan College and the NNMCOG applied for and received a $1.4 million federal Partnership for Opportunity and Workforce and Economic Revitalization (POWER) grant. The POWER program is funded through a collaboration of the Department of Commerce's Economic Development Administration, the Department of Labor, and the Small Business Administration.

"We're helping to bridge [students] into high-demand, high-growth sectors like other forms of energy, information technology and health care," College President Dr. Toni Pendergrass said. "This will help diversify our economy and transition workers to areas [that don't have] such a strong dependence on fossil fuel, mainly coal." [34] The college is also hosting job fairs to help laid-off workers find new jobs.

The area has decided to focus on three sectors in which it has a competitive advantage: energy, logistics, and manufacturing. While the energy economy has driven the boom and bust cycles that have upset the economic stability of the region, area leaders feel that the energy sector cannot be ignored. In addition, the transportation infrastructure that the energy economy has created (particularly railroads) leaves the region with a competitive advantage in the logistics industry. The area has a unique environment for manufacturing. The area is also the Native American Jewelry capitol of the nation. Thus, helping very small scale manufactures succeed is a primary focus, including removing barriers to expansion. David Hinkle, NNMCOG Program Manager, highlighted two important strategies:

1. Utilizing data-driven strategies and making sure they have the best information on the situation.
2. Realizing the importance of having a long-term plan and not losing sight of the importance of diversification during boom times. [35]

## Long Term Planning in Sánchez Ramírez, Dominican Republic

Sánchez Ramírez is a region of the Dominican Republic where the economy is based primarily on a major gold mine. Revenue from the mine began to flow to Sánchez Ramírez in the 1970's, and was originally managed by municipal governments. However, in response to community demands for greater participation in decision-making and increased benefits from the mine, in 1979, Sánchez Ramírez enacted a decree calling for more efficient management of the funds. The decree established a Board charged with managing the funds in a way that would meet the objectives of social and economic development of the region.

The funds were used to create public markets and schools, as well as to invest in improving infrastructure such as sewers and health care facilities. The largest investment was creation of a university focused on technical skills-building programs.

In 1991, gold and silver prices fell. The mine stopped producing and ultimately was abandoned by its original owner. As a result, the Board stopped receiving funds, but continued to use a reserve of existing funds to strengthen the university and continue other beneficial activities. This reserve helped the region manage impacts for almost a decade without revenue from the mine.

In 2000, the Dominican Republic enacted a law providing that municipalities in which non-renewable natural resources are exploited must receive 5% of the net profits generated from the exploitation. When the mine in Sánchez Ramírez came under new ownership on 2001 and began to produce again, the profits to Sánchez Ramírez under the new law were extremely high in comparison with those the government had managed in the past. Concerns of corruption emerged, and in 2005 a more diverse Board was established under a new law aimed at transparent management of funds.

The 2005 law established the current "Regional Council for the Administration of Mining Funds in Sánchez Ramírez," abbreviated as "FOMISAR" in Spanish. The mission of FOMISAR is to promote sustainable development of Sánchez Ramírez through the identification and implementation of projects that promote the key values of integration, transparency, equity, participation, and commitment.

FOMISAR is a multi-sector network including the Lions Club, Chamber of Commerce, Rotary Club, ecological and trade associations, university representatives, leaders of religious congregations, the city councils of each municipality, the Governor of Sánchez Ramírez, mining company representatives, and others. The General Assembly of the Council holds regular public meetings each December to discuss budgets, operations, progress on a five-year plan, and renewing members of the Board. The Board membership reflects FOMISAR's multi-sector network, including government, community organizations, and company representatives.

FOMISAR's short and long-term work plans are based on meetings among diverse stakeholders across the region, sub-regional assemblies, and regional seminars, all with the objective to better understand the needs and aspirations of the people of Sánchez Ramírez at present and in a post-mining economy, and to reflect these in the use of the funds.

The major themes of the long-term plan are governance, social inclusion, economy and employment, and land use and environment. Major activities are focused on education; small business and "micro-enterprise" development, improvements to infrastructure and health care, culture, and sports.

FOMISAR regularly provides leadership and capacity building programs for its Board and General Assembly, and continually works to build public and private alliances. Only a portion of the funds may be used for current programs, with a portion reserved for continuing activity during periods when the mine is not producing and, importantly, for supporting future generations after the mine has closed.

## Revenue Management in Royal Bafokeng Nation, South Africa

One interesting model for the capture of mineral revenues, with the explicit goal of diversifying local economies and funding social development, is an example from the Royal Bafokeng Nation in South Africa.

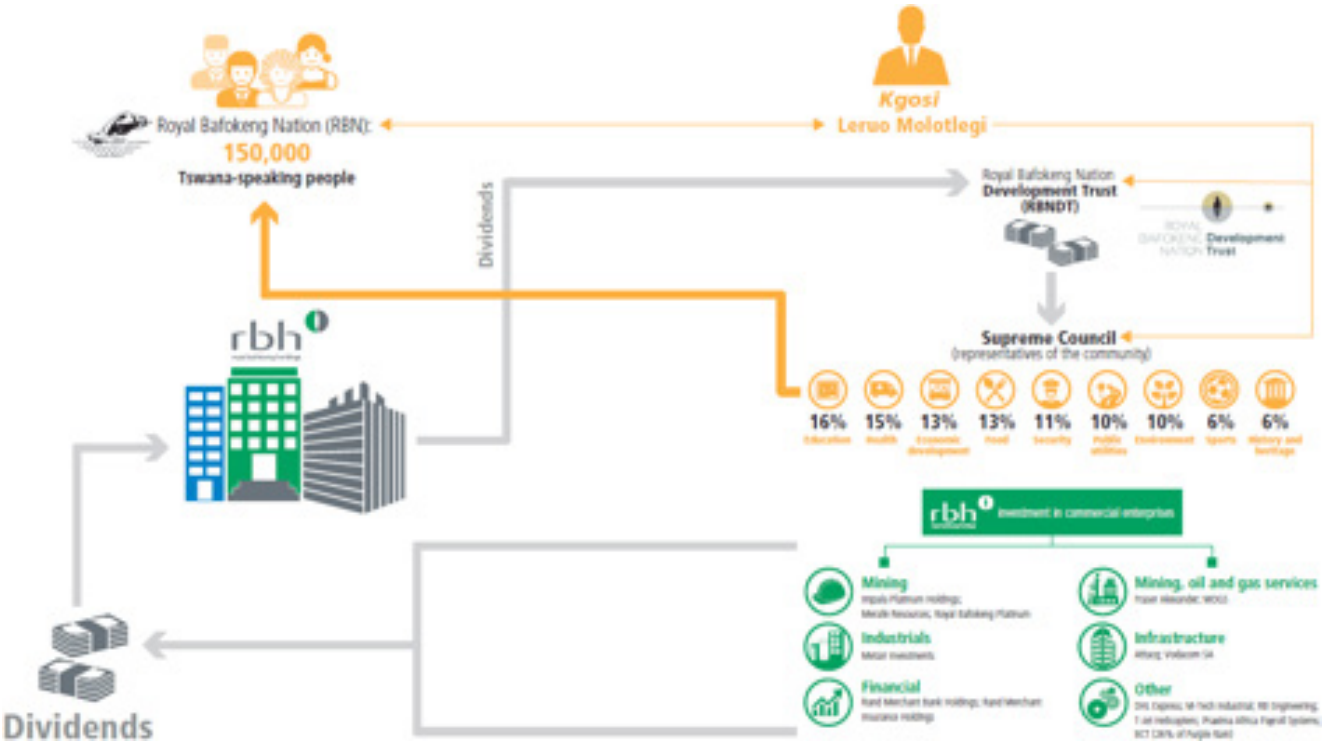
The Royal Bafokeng Nation is led by the Bafokeng Supreme Council, [36] which was able to secure private surface and mineral rights to its ancestral lands in what became one of the richest platinum districts in the world. The Royal Bafokeng Nation successfully negotiated profitable agreements with some of the largest platinum mining companies in the world.

Initially, mineral revenues were directly used for the benefit of the surrounding community. In 2002, Royal Bafokeng Resources was established to manage the community's mining interests. Two years later, Royal Bafokeng Finance was established to develop a diversified investment portfolio from the mineral revenues of Royal Bafokeng Resources, with the goal of maximizing financial return. In 2006, these two entities merged to form Royal Bafokeng Holdings (RBH), which functions like a private company and has the same profit motive. The people of the Royal Bafokeng Nation were to be the beneficiaries of this structure through a specific set of objectives known as "Vision 2020." The Royal Bafokeng Nation Development Trust (RBNDT) was set up to receive distributions from RBH for this purpose.

In this system, the Nation is represented by the Bafokeng Supreme Council, which provides the mandates for RBH and is "responsible for identification, prioritization, and delivery of social needs to the community." [37] Key expenditures are in infrastructure development, social programs, education, and health care. Every three years, a household survey is conducted to determine attitudes about how the RBNDT should update its saving, spending, and allocation of expenditure shares.

Importantly, this model of revenue management works because annual revenues are not spent every year, but a portion is saved and reinvested. When funds are spent, expenditures are focused on projects that will strengthen and diversify the economy. Also, expenditures were not ad hoc; a collective vision was laid out by the community and is consistently updated.

Figure 12 Royal Bafokeng Nation Development Trust Organizational Chart [38]



# IV. Policy Recommendations

We believe that there are a number of actions that federal, state, and local governments can take to help strengthen the economic future for coal dependent communities. In general, local decisions should be made at the local level, by those most affected by policy changes. At the same time, it is evident that coal development can pose challenges that local governments lack sufficient resources to resolve. Therefore, the appropriate federal role is to be a source of information, advice, ideas, and financial resources at key points in the development process, especially as markets shift more rapidly than communities can adjust.

The loss of employment that comes with closing coal mines has created political challenges around the world, and has led some governments to resist the trend by subsidizing the coal industry. But the lesson everywhere is that the appropriate response is not to look to government to prop up coal mine employment, swimming upstream against the trends of mechanization of mining and lower energy prices. **Where government can assist is:**

- **Targeting workers with transition assistance and skills retraining;**
- **Targeting impacted communities with resources for planning diversification of local economies; and**
- **Providing transitional assistance to communities to deal with the range of problems from declining school enrollment, falling real estate values, unemployment, and lower tax collections.**

**Specifically we recommend the following policies to support communities that have become dependent on coal (or extraction of any finite resource).**

**Recommendation 1. Local Stabilization Funds.** Local governments in areas that are heavily dependent on natural resource extraction should consider establishing stabilization funds, in which revenues are saved when resource prices are high, and disbursed at times of very low mineral prices, in order to smooth out the fluctuation in government receipts and spending.

The Chilean Copper Stabilization Fund (CSF) is one of the older and more widely known examples. [39] This fund, created in 1985 in response to a 1982 financial crash, requires deposits (or withdrawals) once the price of copper goes above (or below) predetermined trigger prices. [40] It has been successful in mitigating volatility, and has even provided a valuable rainy day fund for catastrophes like the 2010 earthquake. [41]

Stabilization funds have been tried in countries as diverse as Norway and Azerbaijan, and the experiences with the funds have been equally diverse. [42] While these are examples of this sort of mechanism at the national level, there are also similar ideas at state and local levels. In the U.S. they are sometimes referred to as “rainy day funds.” [43]

**Recommendation 2. Permanent Trusts.** Many jurisdictions have benefited from creating permanent trust funds, in which a portion of resource revenues is placed in trust for future generations. In principle, income from such funds is then available to support education, health, economic development, and other local priorities even after mines have closed.

Trusts have been established in the U.S. and around the world on national, regional, and local levels. Financed by natural resource revenues, this reserve may be utilized to transparently manage revenue to benefit sustainable local and economic development for current and future generations. [44]

In the U.S., state governments have established trusts in Alabama, Alaska, Louisiana, Montana, New Mexico, North Dakota, Texas, and Wyoming. [45] Colorado does not have such a trust. On an international level, over $4 trillion has been invested in natural resource trusts. [46]

**Recommendation 3. Technical Assistance.** Federal agencies should stand ready to support regions where federal resources such as coal play an important part in local revenues. Agencies can provide technical assistance in the design and management of stabilization funds, where these are desired, either by grants to state government or by working directly with local government.

**Recommendation 4. Employment and Skills Training.** There is an obvious decline in the number of coal mining jobs in Colorado. Many miners who have built their careers in highly skilled mining jobs may have to transition to other forms of employment. In regions where federal coal production is a dominant part of the economic mix, there needs to be federal support—likely from dedicating a fraction of federal coal revenues—for this purpose. These programs need to be up and running while mining is still operating robustly, as they take considerable time to be effective and their impact is less if they are not in place until after closures have occurred.

**Recommendation 5. Planning for Economic Diversification.** Planning for economic diversification of communities dependent upon mineral revenues is primarily a local function. However, federal and state governments can help provide resources that are important for diversification. A perfect example is the process undertaken by Gunnison and Delta Counties discussed above, where communities were able to turn their initiative into action utilizing state and federal funding. Planning for diversification is an essential part of making the transition from mining to post-mining economies. Where diversification is delayed until closure is occurring, it is far too often unsuccessful.

**Recommendation 6. Reclamation Bonding.** A fundamental part of the public's trust in mining is the understanding that mining will not occur unless there is a plan for reclamation of the mine site, backed by a real financial guarantee that the closure costs will be funded when the mine eventually closes, as all mines do. Allowing "self-guarantees" or "self-bonding" of reclamation bonds understandably undermines public trust in the industry, and recent events demonstrate—not for the first time—that the option of a "self guarantee" of reclamation obligations should simply be prohibited. [47]

## Resources for Transitioning Economies

The National Association of Counties and the National Association of Development Organizations recently held a Coal-Reliant Communities Innovation Challenge to support "county and regional leaders in coal-reliant communities with retooling their economies to become more resilient to changing conditions." See the Diversifying Economies website, http://DiversifyingEconomies.org,for information on the Challenge, including numerous workshop materials from their recent Grand Junction, Colorado workshop, available at http://DiversifyEconomies.org/grand-junction-colo/. Teams representing Moffat County, Delta and Montrose County, Rio Blanco County, and Routt County, Colorado participated in the Grand Junction workshop. The Diversifying Economies website also has links to guides and toolkits for downtown revitalization, strengthening rural-urban connections, cultivating a competitive advantage through regional partnerships, workforce development, and economic development.

## V. Planning is the Right Choice for Our Communities

While no one can predict with certainty what the future may hold for coal production in Colorado or across the globe, the one thing that is certain is that every coal mine will eventually close. Communities, states, and the federal government all must work to implement policies and strategies that help mitigate the social, economic, and environmental impacts of the boom and bust cycles of coal development.

Our hope is that this report serves as a resource for communities and governments at all levels to support communities that have borne a disproportionate burden of the decline in the coal economy. Many examples exist of communities doing the work necessary to diversify their economies. These communities are all unique in their assets and history, but can provide inspiration, information, and support to other communities working to diversify their economies. The lessons learned from the case studies will save time and resources for communities just embarking on a diversification project.

But communities should not have to go it alone—federal and state governments must work to support coal mining communities, communities whose work and sacrifices have benefitted the public for decades. The state and federal government must ensure that local communities have the resources to recover on their own.

Adding more tools to your community's economic toolbox can only help to improve the way of life for this generation and those to come. This would be true even if coal started to boom again. Communities have the opportunity to begin planning and diversifying their economies now. Resources and information are available to help Colorado's coal communities take the next step (see Appendix). Diverse local economies are resilient enough to withstand any changes that are beyond our control. Planning will make our communities great places to live now and for many generations to come.

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**Sustainable Development Strategies Group** is a non-profit 501(c)(3) organization based in Colorado, USA. We operate on local, national, and international levels to develop collaborative policy and legal frameworks that address the enormous challenge of using natural resource endowments to reduce poverty while protecting human rights and safeguarding the integrity of ecosystems. Learn more about us at www.SDSG.org.

**The Mountain Pact** educates, empowers and mobilizes mountain communities in the American West that are experiencing extreme economic loss and environmental degradation as a result of climate change. The Mountain Pact unites these vulnerable communities around their common challenges and elevates their shared voice on federal policy. Learn more at www.TheMountainPact.org

# Appendix - Resources for Transitioning Communities

## A. Data Resources

Successful strategies are data driven. A multitude of data resources are available on current economic conditions and projections for the future. A few places to start are:

**Economic Profile System - Headwaters Economics**

http://headwaterseconomics.org/tools/economic-profile-system/about

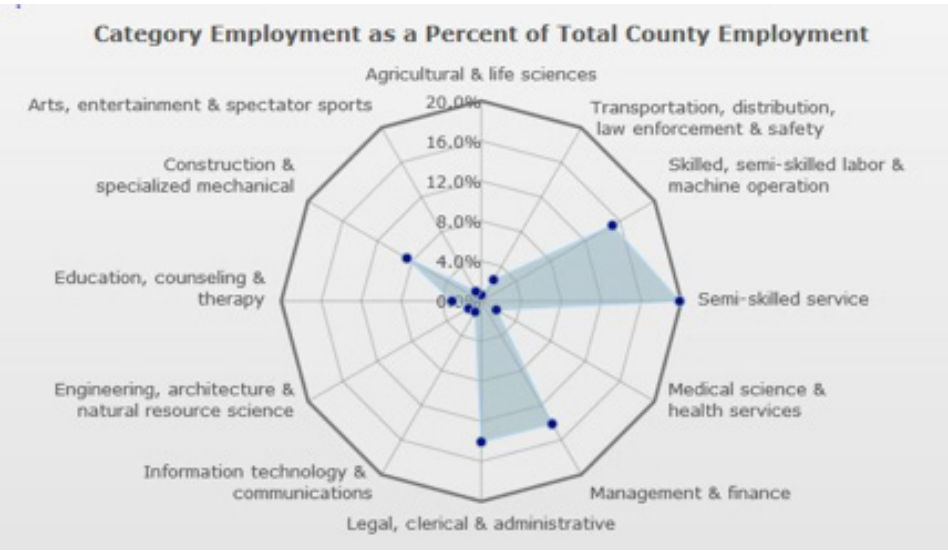
This resource allows researchers to access data on social and economic measures and allows for comparisons and compilations across regions, states, and c ounties.

**Economic Diversity in Appalachia -Appalachian Regional Commission**

http://economicdiversityinappalachia.creconline.org

This tool for guiding diversification efforts has a multitude of data on all counties in the U.S. (not just Appalachia) including three measures of diversification, knowledge, commuting sheds, etc. For example, see the figure below on knowledge clusters in Gunnison County. This is a great place to start to understand key parts of a county's economy.

## Knowledge Clusters in Gunnison County



## B. Funding Resources

A variety of funding sources are available to communities looking to diversify their economies after relying on coal. In particular, federal resources have been mobilized to start to address impacts of federal policy on communities. The most prominent is the recent announcement of the Partnership for Opportunity and Workforce and Economic Revitalization (POWER) Grants for communities negatively impacted by changes in the coal economy.

**Resources for Transitioning Economies**

http://diversifyeconomies.org/funding

This resource keeps an updated list of government and private funding opportunities for communities that want to diversify.

**Other grant resources include:**

- Power Initiative https://www.eda.gov/power
- Just Transition Grants (created to help small communities apply for Power grants not just in Appalachia) http://www.appalachiafunders.org/jtf
- Rural Jobs and Innovation Accelerator http://www.rd.usda.gov/about-rd/initiatives/rural-jobs-and-innovation-accelerator
- Energy/Mineral Impact Assistance Fund (EIAF) https://www.colorado.gov/pacific/dola/energymineral-impact-assistance-fund-eiaf
- Other Colorado Department of Local Affairs Financial Assistance Programs https://www.colorado.gov/pacific/dola/financial-assistance-0
- Colorado Office of Economic Development and International Trade Programs http://www.advancecolorado.com/funding-incentives/financing

## Endnotes

[1] The 1980s was the big coal boom, and much of Colorado's coal mine infrastructure dates back to that era. According to the Colorado Division of Reclamation Mining & Safety data, first permits for Colorado mines were issued between 1977-1997: Trapper Mine in 1977, West Elk Mine in 1981, Deserado Mine in 1981, Colowyo Coal Mine in 1982, Foidel Creek in 1983, New Elk in 1984, King II in 1987, New Horizon North in 1988, Bowie #2 Mine in 1997. See www.mining.state.co.us.

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COLORADO
Energy Office

# Coal Mine Methane in Colorado Market Research Report

MARCH 2016

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# Coal Mine Methane in Colorado Market Research Report

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## PROJECT DESCRIPTION

The Colorado Energy Office (CEO) contracted Ruby Canyon Engineering, Inc. (RCE) (PO EFAA2016-1437) to prepare a Market Research Report ("Report") that identifies opportunities for using coal mine methane (CMM) captured at active and inactive coal mines as a fuel source to generate electricity. Among other things, the Report focuses on the Inclusion of CMM as an "eligible energy resource" under Colorado's Renewable Energy Standard (RES), with the passage of SB 13-252 in 2013.

In preparing the Report RCE investigated three main areas:

(i) An assessment of the current CMM resource opportunities in Colorado,

(ii) Data analysis of potential market size in Colorado, including a breakdown listing specific sites with high potential, and

(iii) Identification of key barriers to developing CMM projects in Colorado and potential solutions.

The Report includes a description of RCE's sources of information and the research methodology used to develop methane emissions estimates.

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(c) Imply endorsement of the information mentioned in this Report.

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# Executive Summary

In 2013, the U.S Energy Information Administration (EIA) ranked Colorado 11th among major coal producing states. Three coal basins in Colorado contain methane volumes sufficient enough to potentially generate commercial electricity: the Uinta Basin in western Colorado and the Raton Mesa Basin and San Juan River Basin in southern Colorado. The U.S. Environmental Protection Agency's (U.S. EPA) GHG Inventory for 2013 identified several gassy underground coal mines in western Colorado as the state's largest sources of CMM emissions.

Colorado's Renewable Energy Standard (RES) defines CMM as "methane captured from active and inactive coal mines where the methane is escaping to the atmosphere" (CRS 40-2-124 (1)(a)(II)). Including CMM as an "eligible energy resource" under the RES accomplishes several key public policy objectives. First, CMM optimizes the use of methane gas, an important energy resource, released during or as a result of coal mining operations. Second, utilizing CMM improves mine safety and reduces a major source of anthropogenic greenhouse gas (GHG) emissions that contribute to climate change. Third, CMM's RES inclusion promotes the development of smaller scale electrical generation and transmission capabilities at coal mines that can serve as distributed energy sources in remote rural areas.

The U.S. EPA's 2013 GHG Inventory divides methane emissions from coal mines into three subcategories: (i) CMM vented from active coal mines, (ii) ventilation air methane (VAM) from active coal mines, and (iii) abandoned mine methane (AMM) emissions. Total methane emissions from coal mines in Colorado as reported by the EPA have the potential to generate upwards of 89 megawatts (MW) of electricity while a more realistic and technically feasible value is approximately 34 MW.

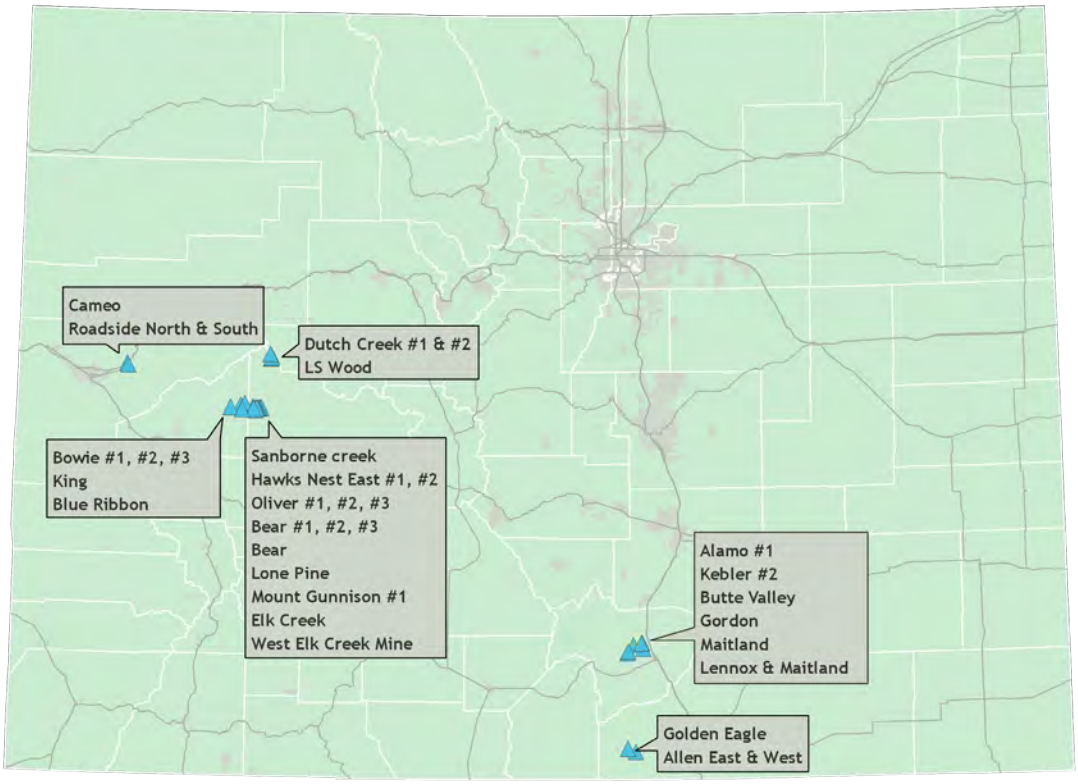
Initial capital and development costs of CMM generated power generally range from $700,000 to $1.5 million dollars per MW. This primarily depends on the quality and quantity of the CMM fuel resource as well as the capital and operation costs for the gas collection system, electrical generation, and transmission facilities. Based on market conditions, a rule of thumb for the economic feasiblity of a project is a $0.05 per kilowatt-hour levelized cost, excluding RES incentives, carbon credits, or other incentives.

A detailed inventory of over 30 active and inactive coal mines in Colorado with reported CMM emission volumes is included within the report. The impacted areas include six counties: Mesa, Delta, Gunnison, Pitkin, Huerfano, and Las Animas. Of all the mines evaluated, most of the "high value" CMM recovery targets are located within and around the North Fork Valley Coal Mining Area (Somerset) in Delta and Gunnison counties, and near the town of Redstone in Pitkin County. In the Somerset area, there are three active coal mines and 15 inactive or abandoned coal mines. The Somerset area mines estimated electrical generation potential from CMM (consisting of VAM, drainage, and AMM) emissions is about 76 MW, of which 25 MW may be economically and technically feasible to develop. The second area with highest potential is about 6 to 8 miles west of Redstone, where there are four abandoned mines with CMM emission volumes capable of generating in excess of 5 MWs. Permitting operations at these locations could be complicated, since a portion of the wellbores and gas gathering systems are located on or near public lands.

**ESTIMATED ELECTRIC POWER GENERATION FROM VAM, CMM AND AMM EMISSIONS IN COLORADO (MW)**

| | VAM Emissions | CMM Emissions | AMM Emissions | Total |
|---|---|---|---|---|
| Potential | 46 | 23 | 20 | 89 |
| Feasible | 10 | 12 | 12 | 34 |

## LOCATION OF COLORADO'S ACTIVE AND ABANDONED COAL MINES WITH METHANE RECOVERY OPPORTUNITIES




While the potential economic and environmental benefits of CMM generated electricity are recognizable, an uncertain energy market and declining coal production impedes project development. Moreover, legal, regulatory, and technical challenges make CMM project business risks and commercial feasibility difficult to assess, particularly at active mines where production can be highly variable.

Image Courtesy of Vessels Coal Gas, LLC

# 1 | Coal

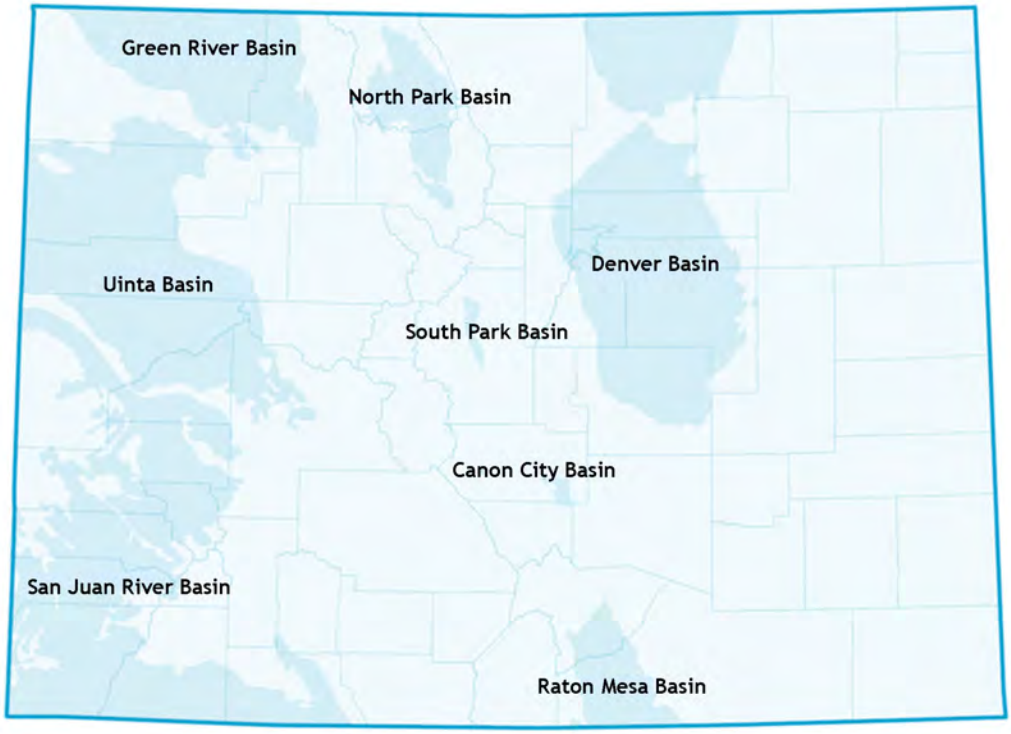
## Coalification

Coalification is the formation of coal and associated methane from vegetation buried and subjected to extreme pressures and temperatures over a long period of time. Coal is classified with a ranking system based on the amount of metamorphism undergone by the vegetation. Lignite is the lowest ranking coal with low energy content and a light color while anthracite is the highest ranking coal with high energy content and a shiny black color. During coalification, methane becomes trapped and stored within the coal seam and surrounding strata. The quantity of the methane being stored is directly related to the rank and depth of the coal. A higher rank coal is higher in carbon content and contains a greater amount of methane while the deeper the formation of a coal seam, the greater the quantity of methane stored in the coal seam. As more material is deposited on the top of the coal seam, pressure in the seam increases and the associated strata has a greater capacity to store methane.

Methane within a coal seam and surrounding strata is held in place by surface and hydrostatic pressures. As the earth's crust shifts and changes, coal seams can be lifted naturally to the surface, exposing coal layers to the atmosphere and creating outcrops. The decrease in pressure at the outcrop allows methane to flow more freely and escape to the atmosphere. Essentially, the same process releases methane to the atmosphere during surface mining when overburden is removed and pressure is reduced on the coal seam.

During the mining process, coal is dewatered and fractured, reducing the confining pressure and releasing methane. At underground mines, coal is removed by long-wall or room and pillar mining. Concurrently, the mine reduces methane concentrations in the mine workings by employing ventilation and degasification systems. The methane being vented from active underground mines is known as CMM while the ventilation air methane is referred to as VAM.

FIGURE 1: COAL BASINS OF COLORADO (AMUNDSON ET AL., 2009)



Russell L. and Lyn Wood Mining History Archive. Between 1930-1950. Coal Mine Town. Photograph. DSpace Repository. http://hdl.handle.net/11124/9981. Accessed February 2016.

Abandoned underground mines produce another source of methane known as abandoned mine methane (AMM). As an abandoned mine's tunnels and passageways continuously collapse, the released methane from coal seams above and below the mined seam moves to the surface through poorly sealed shafts, boreholes, and fractures in the overburden.

Anthropogenic coal mine methane emissions are those that are liberated as a result of the extraction and storage of coal. All underground and surface mining liberates methane as part of normal mining operations. In 2013, U.S. coal mines liberated about 134 billion cubic feet (BCF) of methane from coal mining, enough to heat almost 2 million households for one year. The amount of methane released per ton of coal mined from active underground coal mines is significantly greater than that of surface mines. According to the 2013 U.S. EPA GHG inventory, methane emissions from active underground coal mines were about five times greater than emissions from surface coal mines while underground coal mines produced half as much coal as surface mines. The majority of underground mine emissions are emitted from the ventilation system.

## Colorado Coal

Coal mining has been an integral part of Colorado's economy for over a century. In 2013, Colorado produced about 19.5 million short tons of coal from underground mines and about 5 million short tons of coal from surface mines. Colorado was ranked 11th among states for coal production from 10 mines and employed more than 2,000 people (EIA, 2015).

There are six major coal basins in Colorado (Figure 1) that contain large amounts of recoverable, high quality coal. Colorado's coal mining industry makes up 3.6 percent of total U.S. liberated CMM emissions. Current coal extraction is focused in the Green River, Piceance, and San Juan basins. Underground and surface mines operate in Colorado with underground mines producing 80 percent of the total coal extracted. Almost half of the coal mined for domestic consumption is used to produce Colorado electricity and most of the coal exported to other states also is used to produce electricity.

## Coal Mine Methane

Methane gas, or CMM in coal, is released during or as a result of mining operations, creating a major safety hazard for miners. Although the Mine Safety and Health Administration (MSHA) and its state counterparts require mines with high levels of methane to be ventilated in order to protect miners, there are no requirements to either use or destroy CMM that is treated as a "waste gas" and emitted into the atmosphere during mining operations (Mandatory Safety Standard, 1996).

Methane is also a potent GHG that the scientific community considers to be a short-lived climate pollutant (SLCPs) (CCAC, 2014). Methane emissions in the atmosphere survive for 11 to 14 years (Myhre et al., 2013) compared to carbon dioxide emissions, which can have a much longer lifetime, upwards of a thousand years or more. The global warming potential of methane is 28 times that of carbon dioxide (EPA, 2015).

# 2 | CMM Ventilation and Degasification Systems

## Active Underground Coal Mines

### Ventilation Air Methane (VAM)

Methane in active underground mines is removed to protect the miners and maintain safe working conditions. MSHA and related state mine safety agencies require mine operators to maintain methane concentrations below 1 percent in mine working areas and 2 percent in all other locations. All active underground mines utilize mine ventilation systems in which large quantities of fresh air are pumped into the mine to dilute the methane. Ventilation air flows leaving the mine typically contain concentrations of <1 percent methane; this methane source is known as ventilation air methane (VAM). Despite the low concentration, VAM is released into the atmosphere and is the largest source of CMM in the United States.

VAM abatement technologies now can destroy low concentrations of methane through oxidation. The resulting thermal energy (waste heat) can be used to produce heat and power. While there is one active VAM abatement project operating in the U.S, the facility does not recover waste heat generated.

### Drainage Systems

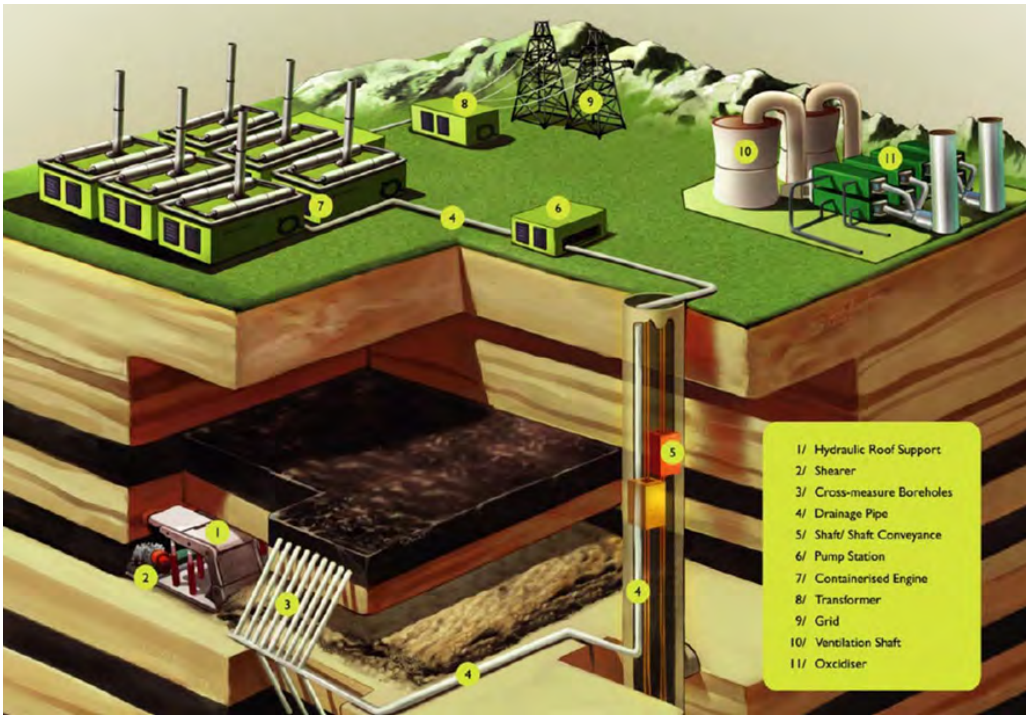
At particularly gassy mines, ventilation systems alone are not enough to maintain safe methane concentrations. Underground and surface drainage systems are employed to reduce methane quantities within the mine working areas by extracting gas from the surrounding strata before, during, and after mining operations.

An efficient methane drainage system can both significantly reduce mine ventilation system costs and be a source of additional mine revenue. By collecting and removing large volumes of methane with higher BTU content (35 percent – 85 percent) the gas can be used for energy generation or pipeline sales. Several drainage techniques typically are employed at gassy active underground mines (Figure 2).

### Pre-mining vertical drainage wells

Pre-mining drainage wells are drilled vertically into the target coal seam from the surface to remove methane from the coal and surrounding gas-bearing strata. This activity usually takes place two to 10 years prior to mining activities. Recovering gas from pre-mining drainage systems

FIGURE 2: VERTICAL PRE-MINING DRAINAGE AND GOB WELLS, AND HORIZONTAL BOREHOLES (GREEN GAS INTERNATIONAL).



usually ensures that the methane is not contaminated with ventilation air and is of high quality (>80 percent). Production of methane may require fracturing of the coal seam, similar to methods utilized in oil and gas extraction. During the first several months of operation, these wells may produce large quantities of water and little methane; however, as water is removed, the hydrostatic pressure is lowered and gas production increases.

The quantity of gas a pre-drainage system will produce over its lifetime will depend on site-specific conditions of the coal seam (i.e. gas content, permeability) and on the number of years the wells are in operation before mining activities encroach into the well's effective radius. For example, aggressive pre-mining gas drainage systems in operation more than 10 years in advance of mining can recover over 50 percent of the coal's methane that would normally be vented to the atmosphere via the ventilation system (CMOP, 2009).

**Horizontal Boreholes**

Horizontal boreholes can be drilled from the mine workings into the target coal seam prior to the advancing longwall miner. Wells typically are short lived – less than two years, and up to 1,000 feet in length. Like other pre-mine degasification wells, horizontal boreholes produce high quality gas.

**Longhole Horizontal Boreholes**

Similar to horizontal boreholes, longhole boreholes are drilled horizontally from within the mine into the target coal seam. Directional drillings techniques are used to create boreholes greater than 4,000 feet in length. Longhole boreholes produce high quality methane that can be utilized for most end-use technologies or commercial pipeline sales. Drilling longhole horizontal boreholes can be most effective for gassy coals with medium to high permeability.

**Post Mining Gob Wells**

The largest producing underground coal mines in Colorado are "longwall" mines. Longwall mining is highly efficient (80 percent coal recovery), recovering significantly more coal than room and pillar mining methods (50 percent coal recovery). As the longwall equipment advances along the face of the coal, the roof supporting shields move forward as well, allowing the roof to collapse behind the equipment, creating a gob area. This collapsed and fractured zone can extend hundreds of feet into the strata above the mined seam and is the source of additional methane releases. To manage gob gas, degasification wells typically are drilled from the surface to about 10 to 50 feet above the mined coal seam. As mining operations advance beneath the wells' locations, the wells are activated.

Blowers attached to the wells at the surface create a suction pressure that allows the methane released from the gob area to flow to the surface rather than into the mine workings and/or ventilation system. Gob well gas quantity and quality is initially very high but decreases over time. Gob wells are an effective method to recover useable medium-quality gas (30 percent to 80 percent) normally vented during mining operations.

**Cross-Measure Boreholes**

For particularly gassy longwall areas of a coal mine, cross-measure boreholes are drilled in any direction from inside the mine to the gob area or overlaying and underlying strata. Cross measure boreholes are typically less than 600 feet in length with a gas quality similar to production of surface gob wells. This drainage technique is more commonly used outside the United States.

## Active Surface Coal Mines

In general, opportunities for methane recovery at surface coal mines are somewhat limited compared to underground mines. This is in large part because coals have low gas contents at the shallow depths of surface mining operations. An overburden-to-coal thickness ratio usually determines the economics of a surface mine operation, and usually once the overburden exceeds 250 feet, the mining operation switches to an underground mining operation.

However, there are exceptions to the depth-to-coal rule, such as the Powder River Basin (PRB) in eastern Wyoming and southeastern Montana. Commonly referred to as the "Saudi Arabia of Coal," the PRB is the largest coal producing basin in the U.S. With coal seams more than 60 feet thick, the PRB also has been a major source of commercial CBM production. Relatively, low-cost shallow CBM wells were drilled into the large highly permeable coal seams in advance of mining operations. Before producing the methane from the coal, however, substantial volumes of water had to be removed from the coal seam in order to reduce the hydrostatic pressure holding the gas in the coal matrix. Dewatering operations typically took an average six to 12 months before gas could be produced in commercial quantities.

## Abandoned Coal Mines

Once the coal resource is recovered, mines close and become abandoned. Even though operations have terminated, methane or CMM continues to be released from the mine's remaining coal bearing strata. As many of the safety issues associated with active mining operation are no longer concerns, abandoned coal mines can offer an excellent opportunity for methane recovery. Prior to abandonment, shafts and portals are filled and sealed, and boreholes and wells are plugged. Depending on the mine's location and gassiness, some mines are allowed to vent in order to prevent methane build up from making its way into surface structures.

Following abandonment, mines have been shown to release methane at a declining rate for an extended period of time. However, mines that become flooded from surface or ground water infiltration will produce methane for only a few years until the mine void is full of water, blocking methane from the remaining coal and from entering the flooded area.

There are several factors used to determine the potential methane volumes being produced at abandoned mines:

- Time since abandonment;
- Gas content and adsorption characteristics of the coal;
- Methane flow capacity of the mine related to the methane emission rate during active mining;
- Mine flooding;
- Presence of vent holes; and
- Mine seals.

Commonly, wells are drilled vertically into the mine workings to extract the gas. However, open vents remaining after abandonment also can be used. Blowers are attached to the well network to create a negative pressure that pulls the CMM from the mine. The quality of methane is site specific and can vary greatly. If the mine is well sealed, the methane concentrations can range from 70 percent to 90 percent. If the atmospheric gasses are drawn into the mine, the methane content can degrade to the point of not being usable as an energy source (<25 percent).

The Golden Eagle Mine, in southern Colorado, has been producing methane for pipeline sales since its closure in 1995. Other abandoned mine CMM projects in the U.S., United Kingdom, and Germany have shown similarly long lives.

United States Bureau of Mines. Date Unknown. Miner starting fan after blasting. Photograph. DSpace Repository. http://hdl.handle.net/11124/6116. Accessed February 2016.

# 3 | Coal Mine Methane Utilization Options

Depending on methane content and volume recovered, CMM can be used in a variety of applications, such as electricity generation, pipeline sales, or for the mining operation as a fuel source for heating or cooling. With the 2013 amendment to the RES, Colorado now joins five other historic coal producing states by including CMM as an alternative energy, clean energy, or a renewable energy fuel source in each state's energy portfolio standards. The other states are Pennsylvania (Alternative Energy Portfolio Standard 2004), West Virginia (Alternative and Renewable Energy Portfolio Standard 2009), Ohio (Alternative Energy Resource Standard 2009), Utah (Energy Resource Procurement Act 2010), and Indiana (Comprehensive Hoosier Option to Incentivize Clean Energy 2011).

**Power Generation – Mandatory Purchase Obligations and RES**

CMM can be used to generate power for onsite use or sale to local utilities. Power can be generated with a lower concentration of methane than that required for commercial pipeline gas sales. Reciprocating engines generate electricity using mine gas with a minimum heat content as low as 350 Btu/cf (approximately 35 percent methane). There are 122 power generation projects in operation worldwide with 70 projects at active mines and 52 at abandoned mines. The projects are located in Australia, China, and throughout European countries (GMI, 2015).

Vertical degas wells, gob wells, and in-mine boreholes are all acceptable methods of recovering CMM for generating power. Gas turbines, internal combustion (IC) engines, and boiler/steam turbines can be adapted to generate electricity from CMM. Fuel cells also may prove to be a promising power generation option. Currently, the most likely generator choice for a CMM project is an IC engine. Boiler/steam turbines generally are not cost effective in sizes below 30 MW, while gas turbines are not the optimal choice for projects requiring 3.0 MW or less. However, when used in the right applications, gas turbines are smaller and lighter than IC engines, and have had lower historical operation and maintenance costs.

Since the 1970s, federal and state legislative and regulatory actions have promoted the development of certain small power production facilities using renewable energy and waste fuels with little or no commercial value, such as CMM. At the federal level, under the Public Utility Regulatory Policies Act of 1978 (PURPA), utilities are obligated to purchase electricity from qualifying small power production or cogeneration facilities to which a utility is directly or indirectly connected. Under PURPA, a "small power production facility" or "qualifying facility" is a generating facility of 80 MW or less whose energy source is a renewable (hydro, wind, or solar), biomass, *waste*, or geothermal resource. [emphasis added] A "qualifying facility" must either be self-certified or certified by the Federal Energy Regulatory Commission (FERC). For a CMM project to be eligible under PURPA, the CMM fuel source must fit the definition of "waste" in the regulations, which includes certain gaseous fuels that exist in the absence of a qualifying facility. For example, such fuels may include CMM volumes at an active or inactive coal mine (18 CFR §§ 292.101 et seq. (2015)).

On June 18, 2015, FERC issued an Order in Delta-Montrose Electric Association (DMEA), EL15-43-000, stating that DMEA was required under PURPA to purchase power from a qualifying facility (to-be-built) in its service area notwithstanding any conflicting provisions DMEA may have in its power supply contract with Tri-State Generation and Transmission Association, Inc. (Tri-State). FERC's decision could enable CMM project developers to overcome industry barriers by securing reasonable power supply contracts with utilities in Tri-State's service area in western Colorado, where most of the "high value" CMM emission targets are located.

A major benefit of being a qualifying facility under PURPA is that the project developer may have the right to sell energy or its capacity to the host utility for either the utilities "avoided costs" or a negotiated rate. "Avoided costs" are the incremental costs the host utility would otherwise incur to generate or purchase the power from another source. Typically, the state public utilities commission establishes the method for calculating avoided costs (18 CFR §§ 292.101 (b)(6) (2015)).

At the state level, Colorado's RES requires qualifying retail service providers, cooperative electric associations, and municipally owned utilities to achieve percentage targets for generating electricity sales from "eligible energy resources" that now include CMM. The State's RES requirements are coupled with a range of possible incentives to make near-term eligible energy resource project development commercially feasible. Depending on the specific circumstances for each CMM project developed with a qualifying retail utility, potential incentives may include, among other things: (i) accelerated cost recovery; (ii) opportunities for the qualifying retail utility to earn extra profit or its most recent authorized rate of return; or (iii) retail rates sufficient to recover all just and reasonable costs associate with an eligible energy resource contract. The combination of federal and state requirements coupled with the right incentives provides an important synergy in promoting CMM recovery and use for power generation.

**Pipeline Injection**

High quality CMM can be commercially sold and delivered to natural gas companies through an extensive network of interstate pipelines and local distribution companies in and near coal mining regions. In order to be sold in the natural gas markets, CMM must meet pipeline quality, volume, and deliverability standards. Vertical degas wells are the preferred recovery method for producing pipeline quality methane from coal seams because the recovered methane is not contaminated with ventilation air from the working areas of the mine. Gob wells, in contrast, generally do not produce pipeline quality gas as the methane is frequently mixed with ventilation air. However, it is possible to enrich gob gas to pipeline quality by using technologies that remove carbon dioxide, oxygen, and nitrogen.

Horizontal boreholes and longhole horizontal boreholes also can produce pipeline quality gas when the integrity of the in-mine piping system is closely monitored. However, the amount of methane produced from these degasification systems often warrants a financial investment. In cases where mines are developing utilization strategies for larger amounts of gas recovered from vertical or gob wells, it may be possible to use the gas recovered from in-mine boreholes to supplement production.

**Waste Heat Recovery from Thermal Oxidation**

Typically, the methane content in CMM released to the atmosphere by a mine ventilation system is below 1 percent and cannot be used. VAM constitutes the largest source of CMM methane emissions. In 2013, approximately 60 percent of the all CMM released from underground mines was released through mine ventilation shafts.

The U.S. EPA identified two technologies for destroying or beneficially using VAM: (i) a thermal flow-reversal reactor, and (ii) a catalytic flow-reversal reactor. Both technologies employ similar principles to oxidize methane in mine ventilation airflows; however, the catalytic reactor operates at lower temperatures. Waste heat from a thermal flow-reversal reactor has been used to generate 5 MW of power at an Australian coal mine, but at a significant additional capital cost.

In addition, a variety of other conventional technologies such as boilers, engines, and turbines may use ventilation airflows as combustion air. At least two other technology families may prove to be viable candidates for beneficially using VAM: volatile organic compound (VOC) concentrators and new lean fuel gas turbines.

**Local Use**

Most large underground coal mines have surface preparation plants and administrative and maintenance facilities, which may use coal mined on site to provide energy for surface operations. CMM recovered from the mine can be used as a fuel source in addition to or as an alternative to coal. Other local uses could include selling recovered methane to nearby industrial or institutional facilities. A mine's ideal gas customer is located within 5 miles of the mine to reduce gas transportation costs and requires a continuous fuel supply for a variety of uses, such as fuel for a cogeneration system, to fire boilers or chillers, or to provide space heating.

**Flaring**

From a climate change standpoint, emitting carbon dioxide is much less harmful on the environment than a mine's direct emission of methane into the atmosphere. Accordingly, flaring methane, which converts the residual gas emission to carbon dioxide, has nearly the same environmental impacts as using methane to generate electricity or heat. Generally, flaring yields GHG reductions equal to about 87.5 percent of those achieved through CMM recovery and use.

Although flares recently have been employed at the Elk Creek Mine in Colorado, flaring to reduce CMM emissions has not been implemented on a widespread basis at active mines because of safety concerns. Of particular concern is the distance between the surface flare and the wellhead CMM collection point in the mine because of the potential for the flame to propagate back down to the mine and cause an underground explosion. A properly engineered, manufactured, and operated flare with redundant safety systems can fully address these concerns.

# 4 | Benefits

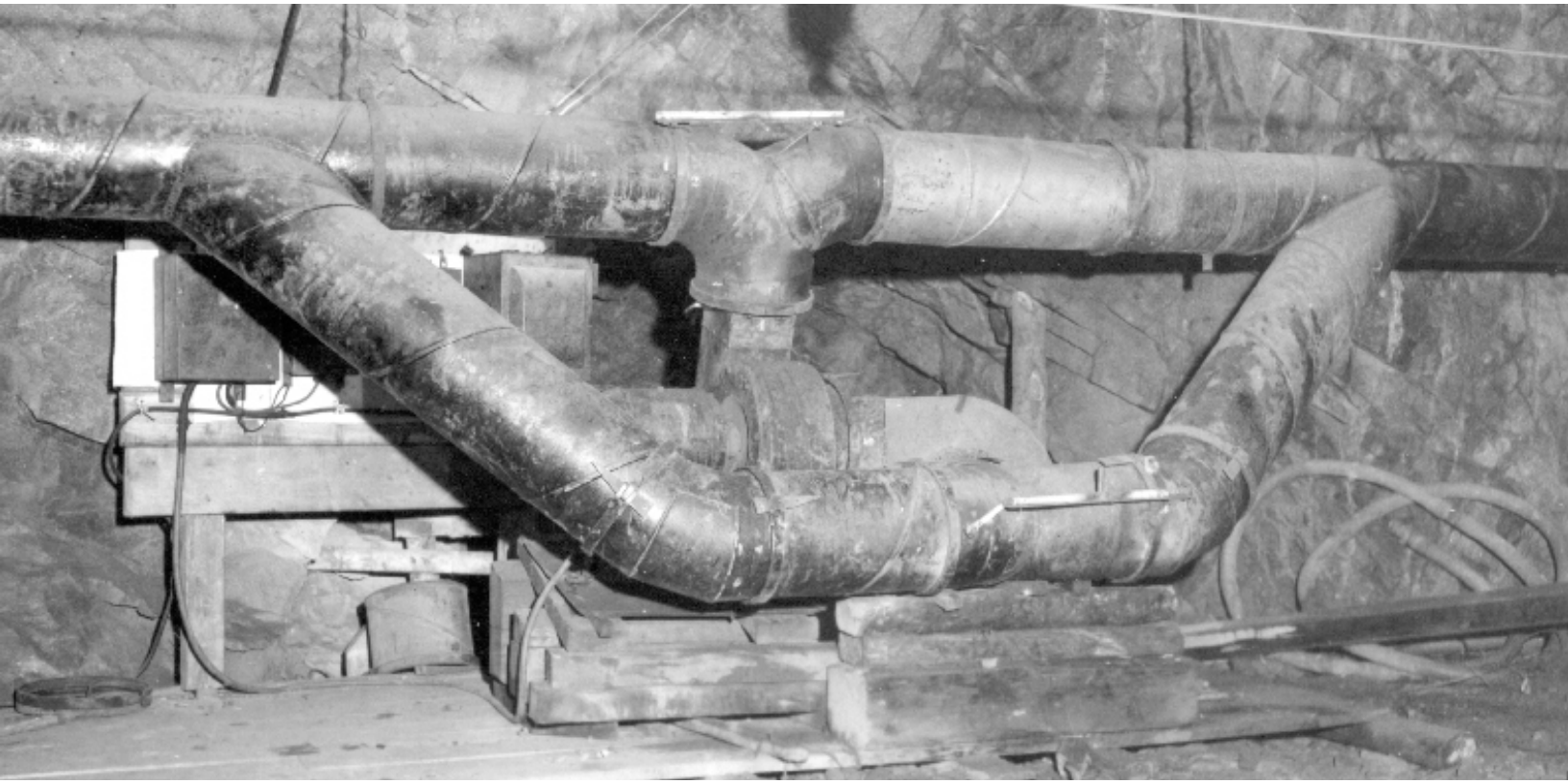
Major benefits from CMM recovery and use at active coal mines include energy resource conservation, improved gas management and mine safety practices, and climate change mitigation. Achieving these benefits is possible in the near term, since the CMM resource has a known location (boreholes, pipes, or vents), and the quantity routinely is monitored and measured. In addition, capturing the mine gas technically is feasible with off-the-shelf equipment and limited infrastructure. As a result, in the right situations, CMM capture and use can contribute meaningfully to either reducing mine operating costs (self-generation) and/or generating additional revenues (electricity sales).

Similarly, at inactive or abandoned underground coal mines, methane emissions can be reduced or eliminated through drilling into underground mine workings and voids and pumping the gas to the surface where it can be used or flared with fewer safety concerns than at active mines. Because the mine is a network of tunnels and roadways, only two to three boreholes or extraction wells need to be drilled to drain an abandoned mine that may cover several thousand acres.

Landfill and livestock waste methane projects are similar to CMM in that the volume of methane in the waste stream is quantifiable. CMM, however, is generally a cleaner gas that does not contain corrosive sulfur compounds and carbon dioxide and an acid gas that must be dealt with for the machinery to operate effectively. CMM contains methane, nitrogen, and small amounts of carbon dioxide and oxygen, which modern IC engines can burn efficiently.

CMM is recovered from shallow wells at atmospheric pressure, while conventional (and unconventional) natural gas generally is recovered from deep wells under high pressure (hundreds or thousands of psi). For site specific uses, the economic investment required to capture and use CMM can compare favorably with developing or using conventional natural gas to provide energy for mining operations.

One of the primary environmental benefits of capturing and using CMM as a fuel is the reduction in GHG emissions. Using or destroying CMM achieves that objective, and may qualify for GHG emission reduction credits or offsets.



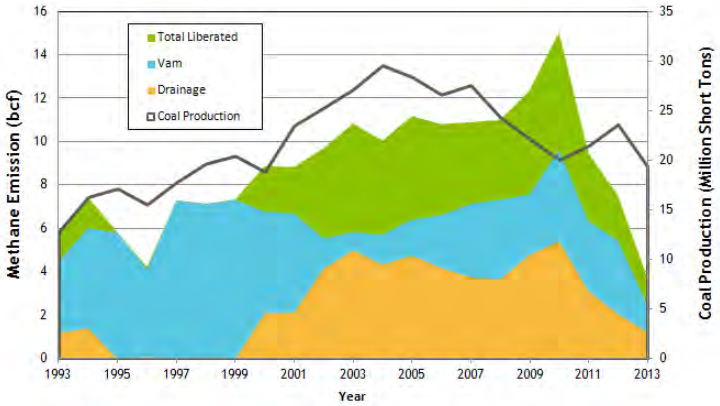
Petersen, Max S. United States Bureau of Mines. 1945. Newport Mine, vent air blowers. Photograph. DSpace Repository http://hdl.handle.net/11124/6494. Accessed February 2016.

## Historical CMM Emissions in Colorado

As previously noted, Colorado's largest source of CMM emissions historically have been VAM from underground coal mines, which peaked in 2010. As Figure 3 shows, CMM emissions do not necessarily correlate with coal production on a year-over-year basis, although this is a contributing factor. Beginning in 2000 and peaking in 2010, degasification systems produced a significant portion of Colorado's active underground mine emissions

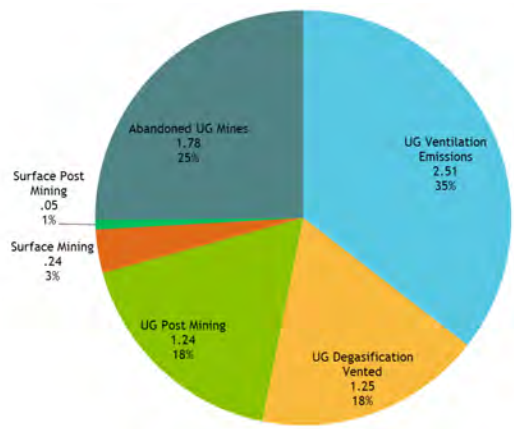
The quality and volume of CMM is determined by coal depth, methane content, permeability, and thickness. In Colorado's mountainous areas, coal depth from the surface can differ significantly, thereby creating fluctuations in CMM liberation rates. Changes in mining operations underground, such as longwall machine movement to a new panel, can also reduce emission rates for weeks at a time. Figure 3 below shows a significant increase in CMM emissions after 1999, primarily because the operating coal mines in the Somerset area were mining deeper underground, often at depths greater than 2,000 feet.

FIGURE 3: COLORADO ACTIVE UNDERGROUND MINE EMISSIONS, 1993-2013




In 2013, Colorado mines reported 7.06 BCF of CMM emissions. Based on the U.S. EPA's methane inventory for 2013, Figure 4 shows BCF sources of CMM emissions for underground (UG) and surface mines. Emissions data for abandoned underground coal mines were calculated using the methodology presented in section 5.4.1 below. Values for underground and surface post-mining emissions are based on emission factors using the volume of methane per ton of coal mined. The estimated methane volumes are then adjusted to take into account CMM emitted during transportation and storage of the coal after leaving the mine site; post-mining emissions are considered non-recoverable.

FIGURE 4: COLORADO COAL MINING METHANE EMISSIONS BY SOURCE.




## Active Underground Coal Mines – CMM

### Methodology

The U.S. EPA's mandatory reporting rule enables the public to have data on CMM emissions. As of 2013, six mines reported CMM emissions data to EPA: Foidel Creek (also known as Twentymile Mine) in Routt County, Deserado Mine in Rio Blanco County, McClane Canyon Mine in Garfield County, Bowie #2 Mine in Delta County, and the West Elk and Elk Creek Mines in Gunnison County. Table 1 shows reported CMM emissions for the six mines. For the purposes of this study, the lower 3 methane emitting mines were not considered as their respective CMM emissions volumes were projected to generate less than 1 MW.

In order to develop an estimate of the power generation potential from the three highest emitting mines (all in and around the Somerset area), the three-year average VAM emissions and gas drainage volumes were used. The Somerset area mines are the only mines in the state with gas drainage systems that can deliver usable concentrations of methane directly to power generators. Power generation estimates from VAM are based on waste heat recovery/ steam turbine from a thermal oxidizer that destroys VAM.

ESTIMATED ELECTRIC POWER GENERATION FROM VAM, CMM AND AMM EMISSIONS IN COLORADO (MW)

| | VAM Emissions | CMM Emissions | AMM Emissions | Total |
|---|---|---|---|---|
| Potential | 46 | 23 | 20 | 89 |
| Feasible | 10 | 12 | 12 | 34 |

## Opportunities & Energy Potential

Additional assumptions for estimating energy potential from captured CMM include the use of IC engines for drainage gas, which operate at a 38 percent electrical efficiency and 90 percent availability. VAM emissions are assumed to be used in a combustion steam turbine operating at a 30 percent electrical efficiency and 90 percent availability. Based on these assumptions and 100 percent CMM recovery factor, the forecasts are optimistic. As seen from Table 1, CMM emissions rates vary greatly on an annual basis. Based on the CMM being emitted to the atmosphere, the total electric power generating potential for the three mines would be about 69 MW with the gas drainage portion (23 MW) offering the greatest CMM recovery and use opportunities.

**West Elk**

The West Elk Mine, operated by Mountain Coal Company, is an underground longwall mine producing about 6 million tons of coal per year. Mountain Coal has operated the coal mine since the early 1980s. In late 1990, while mining the B seam, the mine began to deploy degasification wells to manage the methane. The mine deployed a variety of techniques including vertical gob wells and in-mine horizontal boreholes. Because of the remote location of the surface gob wells, CMM was used to power the blowers extracting methane at each wellhead. In addition, nearly 50 percent of the drainage gas was recovered from the in-mine efforts and brought to the surface at a single location. In 2003, West Elk began utilizing CMM from in-mine wells to operate mine ventilation air heaters during the colder months from October to April. In 2009, West Elk moved the mining operation from the B seam to the higher (and less gassy) E seam. Total methane liberation rates from E seam mining have been about one half that of the B seam operations for the previous 10 years. West Elk continues to use methane from a sealed gob area of the mine for mine air heating, and in 2013 reported 88 MMcf of CMM usage.

**Bowie Mine** (Recently Idled)

The Bowie #2 mine is an underground longwall mine operated by Bowie Resources, LLC. The mine began coal production in 1998 and produces up to 5 million tons per year. From 2008 to 2010, Bowie #2 mined in much deeper areas (~2,500 ft.) of their coal lease, and found the need to deploy gas drainage systems in order to manage their methane. The mine primarily used vertical gob wells to extract the excess CMM. Since 2011, the mine has moved to shallower areas and their total methane liberation rates are only about one-fifth of the methane emissions generated from the deeper areas. Bowie #2 does not use its drained gas except to fuel the blowers used to vent the gob areas. In February 2016, Bowie Resource Partners announced that Bowie #2 would be idled while the market for its coal is further evaluated.

**Elk Creek** (Idled)

The Elk Creek Mine is an underground longwall mine operated by Oxbow Mining, LLC. The mine began producing coal in 2002, shortly after the closure of Oxbow's Sanborn Creek Mine. Elk Creek has deployed degasification wells

TABLE 1 - 2013 CMM EMISSIONS FROM ACTIVE UNDERGROUND COAL MINES IN COLORADO

| Mine | VAM Emissions (MW) | Drainage CH4 (MW) | Total (MW) | Households powered per year* |
|---|---|---|---|---|
| West Elk | 17 | 10 | 27 | 28,382 |
| Elk Creek (Idled) | 24 | 11 | 35 | 36,792 |
| Bowie No. 2 (Recently Idled) | 5 | 2 | 7 | 7,358 |
| Total | 46 | 23 | 69 | 72,533 |

*Megawatt hours per year is based on capturing 100 percent of VAM and drainage gas at 90 percent operating capacity.
The households powered per year in Colorado are based on 7.5 MWhr/year (EIA, 2009).

since its initial development, primarily vertical gob wells. Beginning in 2011, the mine began degassing CMM from behind sealed gob areas using an in-mine gathering system that delivered gas to the surface at a single location. Later that year, Elk Creek used a portion of the CMM to heat mine ventilation air in the winter months. In 2012, Elk Creek began using CMM for both a 3 MW power generation and a flaring facility (see case study below). Annual coal production was approximately 6 million tons per year before the mine was as abruptly idled in January 2013.

## Case Study – Elk Creek Mine

In 2012, Vessels Coal Gas, Inc. (Vessels) officially began generating GHG emission reductions from the project under the Climate Action Reserve. Vessels had The Elk Creek Coal Mine Methane Destruction and Utilization Project verified, registering the first offset credits via the Climate Action Reserve in September of 2014 (CAR, 2015). Currently, the mine sends drainage gas to a thermal oxidizer and three 1 MW electrical generating engines with the potential to install additional engines. The mine modified the borehole that drained coal mine gas in 2010 in order to combust the CMM through heaters that warmed mine intake air. The project has destroyed about 1 BCF of CMM via heaters, an enclosed flare, and three 1 MW reciprocating engines since its inception in June of 2011 (Figure 5).

A series of equipment processes the CMM through chilling, dehydrating and finally compressing the gas prior to engines combusting the CMM. The generated electricity is sent through a small substation connected to the Delta-Montrose Electric Association (DMEA) grid. The power is wheeled to another rural electrical utility, Holy Cross Energy. The Project produces approximately 24,000 MWhs annually (Blevens, 2012).

## Surface Coal Mines

Currently, there are four surface coal mines operating in western Colorado. In 2013, the mines produced about 5 million tons of coal and generated about 240 mmcf of methane emissions. However, the methane emissions are emitted diffusely from the exposed coal face and not considered to be of recoverable volumes.

## Abandoned Coal Mines – AMM

The Colorado Geological Survey developed a database of Colorado coal mines in 2002 (Historic Coal Mines of Colorado Information Series 64), which was updated in 2009. The database provides the mine name, historical ownership, location, geologic setting, coal quality, and production information. Of the 1,751 mining permits listed in the database, 11 are active mines. Of the remaining mines, 1,122 reported producing greater than 1,000 tons of coal and are abandoned. Of those, 32 mines were selected for further evaluation as to their potential to produce power over a 10 year period. These mines are estimated to have approximately 20 MW of electric generating capacity.

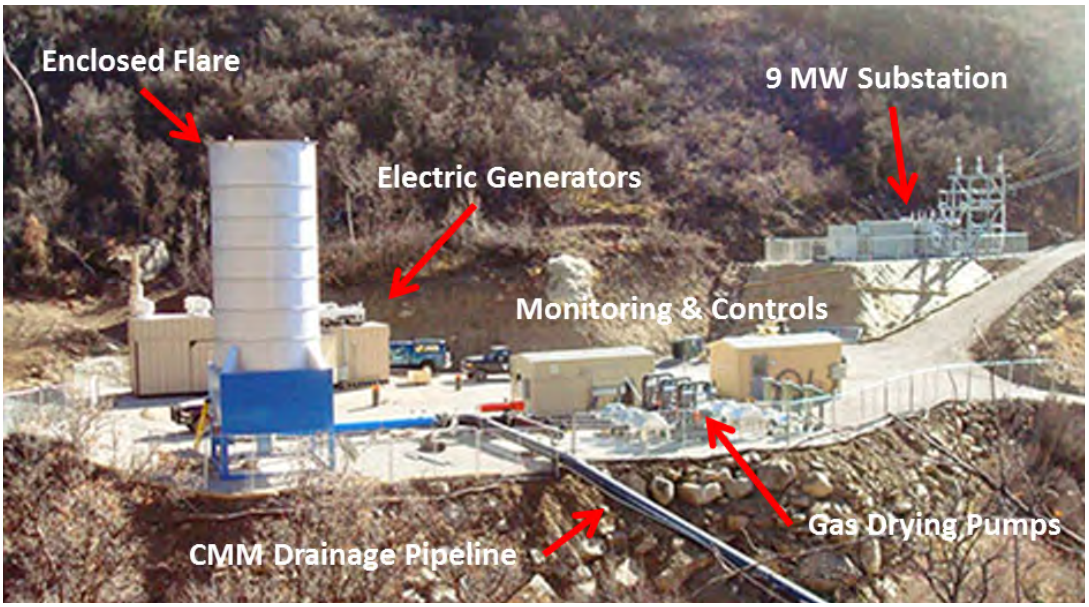
### Methodology

In order to prioritize the mines for evaluation the following parameters were used:

- Mine Size;
- Mine gassiness;
- Years from mine closure;
- Reported gas explosions; and
- Mine groupings.

FIGURE 5: ELK CREEK MINE PROJECT SITE

(COURTESY OF VESSELS COAL GAS, LLC)



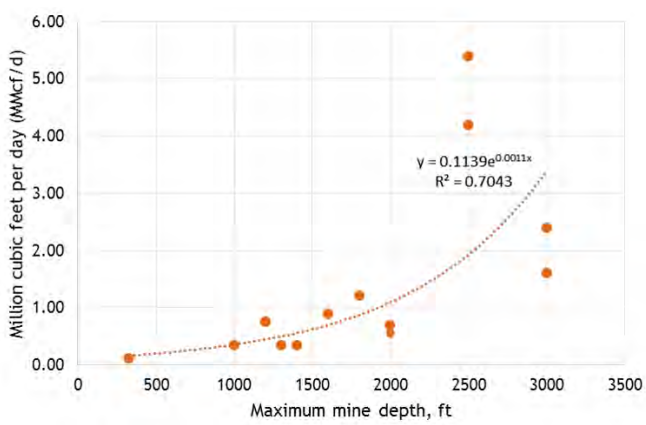
### Mine Size

Larger mines cover more area and have larger void areas to hold gas and deliver gas at high rates. There is also more exposed coal surface area in the mine, which allows methane remaining in the coal to desorb into the void areas. However, to recover that gas, larger mines also may require more degasification wells and gas collection infrastructure.

### Mine Gassiness

The methane emission rate is expressed in cubic feet per day (cfd) or in cubic feet per ton of coal mined. The rate provides a good indicator of the total amount of gas originally contained in the coal as well as the ability of the gas to move through the coal to the mine workings or void area. This can be correlated with the depth of the mine where the greater the depth, the greater the emission rate. This is shown in Figure 6, which shows the relationship of mine depth with emission rate, where the emission rate is known for more recently closed mines.

FIGURE 6: CORRELATION OF COAL MINE DEPTH TO METHANE EMISSIONS AT COLORADO COAL MINES



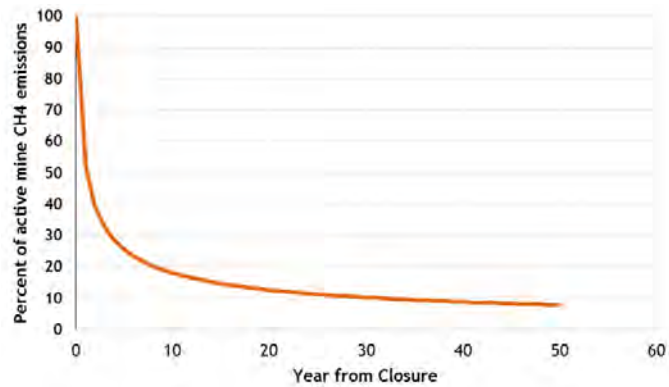

This correlation was used to assign estimated emission rates for mines that did not have documented active mining emission rates.

### Years from Mine Closure

It is generally accepted in the mining industry that abandoned mines emit methane at the surface, either through poorly sealed shafts and boreholes or as diffuse emissions through the overlaying strata that has been fractured as the result of mining. The emission rate from abandoned mines also has been shown to decrease over time as the reservoir of methane remaining in the coal is depleted (much like the depletion of a natural gas well).

The California Air Resources Board (CARB) has recognized abandoned mine methane emission reduction projects as an emission offset project type and has accepted the emission rate decline curve shown in Figure 7 as the generic baseline emission rate from an abandoned mine. This decline curve is based on the active mine emission rate and the elapsed time from abandonment.

FIGURE 7: CALIFORNIA AIR RESOURCES BOARD BASELINE NATURAL EMISSION DECLINE CURVE FOR ABANDONED MINES




Assuming similar CMM emission rates while active, a more prospective mine for CMM recovery will be the one closed more recently. However, given the uncertainty of the gassiness of some mines, the efficiency of the shaft, and the efficiency of the borehole seals, this estimate may not apply to any given mine. Indeed, some mines can build methane pressure up to several pounds per square inch, and therefore have more recoverable methane than the decline curve suggests. Also, this curve is based on passive emissions under atmospheric pressure, whereas AMM projects normally extract the gas under vacuum and therefore accelerate gas recovery.

### Reported Gas Explosions

Gas explosions during active mining can be an indicator of gassy mines. However, it is just one factor to be considered because older mines may not have the safety infrastructure and procedures in place as newer mines now have.

### Mine Groupings

It is not uncommon for several abandoned mines to be near each other within a mining district. This can be important to establishing a power generation project because often a single mine may not provide the amount of gas necessary to economically establish a power generation project. Aggregating several mines into a project by networking the recovered gas through pipelines to a common site can supply the economies of scale that can make the project profitable.

Although there are several abandoned coal mines in the Boulder/Weld, Canyon City, Colorado Springs, Crested Butte, Durango, and Yampa coal fields, these were not included in the evaluation list because they were generally low gas, smaller, and poorly grouped mines. Appendix C shows the mines evaluated by group (A through H) which occur in the Book Cliffs, Carbondale, Somerset, Trinidad, and Walsenburg coal fields.

## Opportunities & Energy Potential

Based on the above criteria for selecting abandoned coal mines with potential power generation capacity, this study divided the mines into seven groups based on coal field and geographical mine groupings. A brief discussion of each group's characteristics follows each table.

**GROUP A – REDSTONE AREA**

| Primary Mine Name | Abandoned Date | Estimated Area (acres) | Est. 10 year production from current Mcf | MW potential |
|---|---|---|---|---|
| Dutch Creek #1 | 10/4/1992 | 1,403 | 1,887,303 | 2.30 |
| Dutch Creek #2 | 7/1/1988 | 477 | 1,528,557 | 1.86 |
| LS Wood | 12/2/1985 | 705 | 837,777 | 1.02 |
| Coal Basin | 2/27/1981 | 185 | 521,202 | 0.63 |
| **Total** | | **2,770** | **4,774,839** | **5.81** |

Group A mines are at located high altitude 9,900 to 11,000 ft. above the town of Redstone. They were large gassy mines, and abandoned fairly recently in the 1980's and 1990's. The mines are located on a combination of federal and private land.

**GROUP B – SOMERSET**

| Primary Mine Name | Abandoned Date | Estimated Area (acres) | Est. 10 year production from current Mcf | MW potential |
|---|---|---|---|---|
| Sanborn Creek Mine | 10/1/2003 | 874 | 2,811,412 | 3.42 |
| Hawks Nest East | 1/3/1986 | 371 | 314,595 | 0.38 |
| Somerset | 2/16/1989 | 3,285 | 257,505 | 0.31 |
| Hawks Nest #1 | 6/30/1970 | 136 | 211,823 | 0.26 |
| Hawks Nest #3 | 6/30/1975 | 145 | 200,710 | 0.24 |
| Oliver #1 & 3 | 6/30/1960 | 118 | 192,264 | 0.23 |
| Oliver #2 | 6/30/1954 | 118 | 182,780 | 0.22 |
| Bear #1, 2, 3 | 4/1/1997 | 917 | 151,564 | 0.18 |
| **Total** | | **5,965** | **4,322,653** | **5.26** |

Mines located in the Somerset area were split into three groups based on their relative positions to active coal mines. The Group B (Somerset mining district) area has been active since 1903 and has been known for its thick section of very gassy but tight (low permeability) coal. As many as six different coal seams have been mined in the area. It may be possible to extract methane from numerous abandoned mines that overlay each other with a minimum number of boreholes. The project developer at the Elk Creek CMM project has plans to add Sanborn Creek abandoned mine gas to the project in 2015.

The mines are located on a combination of federal and private land. The gas rights to the methane on the federal land in this group are controlled by the Oxbow Group company, Gunnison Energy, LLC. Another Oxbow Group company, Oxbow Mining LLC, owns and operates the nearby active Elk Creek Mine.

**GROUP C – TRINIDAD**

| Primary Mine Name | Abandoned Date | Estimated Area (acres) | Est. 10 year production from current Mcf | MW potential |
|---|---|---|---|---|
| Golden Eagle | 5/30/1996 | 1,548 | 3,185,193 | 3.88 |
| Allen-East and West Portals | 6/10/1982 | 3,949 | 248,682 | 0.30 |
| **Total** | | **5,497** | **3,433,875** | **4.18** |

The Golden Eagle Mine is the subject of the case study which follows. The neighboring Allen mine was re-entered to develop a new adjacent mine called the New Elk Mine in 2010. However, in 2012, the New Elk Mine was idled due to poor coal market conditions. The methane potential of the New Elk mine is unknown at this time, and not included in the energy potential assessment. These mines are located within an active coalbed methane field and operations, and multiple gas leases. XTO Energy, Inc. currently owns the gas leases and operates the Golden Eagle AMM wells.

### GROUP D – SOMERSET

| Primary Mine Name | Abandoned Date | Estimated Area (acres) | Est. 10 year production from current Mcf | MW potential |
|---|---|---|---|---|
| Bowie #1 | 12/10/1998 | 1,113 | 546,329 | 0.67 |
| King | 6/30/1974 | 190 | 308,016 | 0.38 |
| Blue Ribbon Coal | 6/30/1984 | 114 | 252,444 | 0.31 |
| Bowie #3 | 6/30/2006 | 1,281 | 594,541 | 0.72 |
| **Total** | | **2,698** | **1,701,331** | **2.07** |

Group D mines are located between the towns of Paonia and Somerset, near the Bowie #2 mine and west of the Group B and E mines. As with other mines in the area, they are located on a combination of federal and private land. Gunnison Energy controls much of the gas rights to federal land of the group.

### GROUP E – SOMERSET

| Primary Mine Name | Abandoned Date | Estimated Area (acres) | Est. 10 year production from current Mcf | MW potential |
|---|---|---|---|---|
| Bear | 5/27/1982 | 388 | 248,548 | 0.30 |
| Lone Pine | 6/30/1965 | 44 | 201,357 | 0.25 |
| Mount Gunnison #1 | 6/30/1991 | 752 | 163,639 | 0.20 |
| **Total** | | **1,183** | **613,544** | **0.75** |

These mines are on the south side of Highway 133, adjacent to the West Elk Mine and across the river from the Group B mines, and also are located on a combination of federal and private land. Private gas leases exist on a portion of the group area.

### GROUP F – BOOK CLIFF – CAMEO

| Primary Mine Name | Abandoned Date | Estimated Area (acres) | Est. 10 year production from current Mcf | MW potential |
|---|---|---|---|---|
| Cameo | 6/30/1982 | 677 | 341,106 | 0.42 |
| Roadside No. & So. Portals | 4/25/2000 | 1,678 | 257,615 | 0.31 |
| **Total** | | **2,354** | **598,721** | **0.73** |

These two mines, the Cameo on the north side of the Colorado River and Roadside Mines which are north and south of the river, supplied coal to a mine-mouth power station up until 2000. The coal-fired power station eventually was dismantled by Xcel Energy in 2013. They were considered relatively gassy mines and are near existing power infrastructure and along Interstate 70.

### GROUP G – WALSENBURG

| Primary Mine Name | Abandoned Date | Estimated Area (acres) | Est. 10 year production from current Mcf | MW potential |
|---|---|---|---|---|
| Alamo No.1 | 6/30/1936 | 125 | 179,552 | 0.22 |
| Gordon | 6/30/1965 | 605 | 88,242 | 0.11 |
| Maitland #1 | 6/30/1962 | 540 | 85,786 | 0.10 |
| Kebler #2 | 6/30/1953 | 836 | 83,958 | 0.10 |
| Lennox and Maitland | 6/30/1953 | 651 | 79,465 | 0.10 |
| Butte Valley | 6/30/1952 | 145 | 78,843 | 0.10 |
| **Totals** | | **2,901** | **595,845** | **0.73** |

The mines in the Walsenburg area mostly have been closed since the 1950's and 1960's and were reportedly not as gassy as the Somerset and Carbondale mines, limiting their potential. Much of the abandoned mine locations are on private or fee land. Elk Creek Mine project developer, Vessels Coal Gas, LLC, owns gas leases at several on the mines in Group G.

## Case Study – Golden Eagle

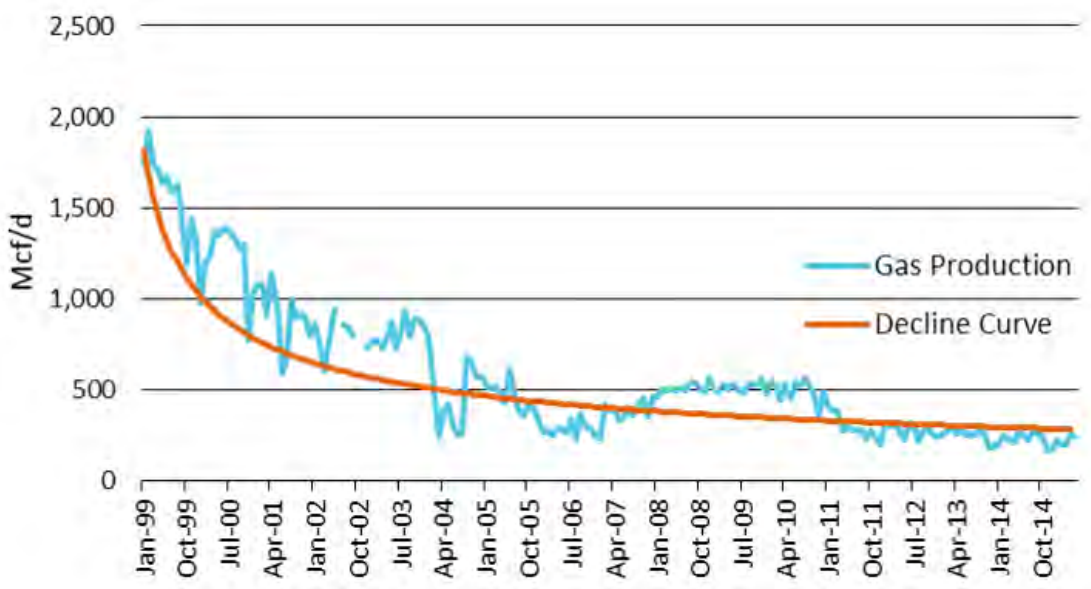
Golden Eagle Mine is an abandoned underground coal mine located in south-central Colorado, just west of Trinidad. Coal production began in 1978 and ceased in 1995. Golden Eagle produced coal from the Maxwell seam in the central portion of the Raton Basin. The seam thickness ranges from less than 5 feet to 10 feet and the overburden thickness ranges from 500 feet to nearly 1,200 feet. The mine workings are split into north and south sections, bisected by the Purgatoire River and Colorado Highway 12. The estimated area of the abandoned mine is 1,548 acres. During operation, Golden Eagle drained mine methane from gob wells as a gas control method.

In 1996, shortly after the mine closure, Stroud Oil Properties Inc. (Stroud) started the AMM recovery project. Stroud converted the already existing gob wells, boreholes, and mine shafts into drainage wells, drastically reducing the cost of methane recovery. Compressor pumps and gathering lines were installed to convey the methane to the nearby Colorado Interstate Gas line for sale. Initially, Stroud produced methane only from the south section of the mine to test for sustainability. Gradually, other gob wells and boreholes were added to the system. From 1999 to 2012, six wells produced methane for pipeline sales. Currently, there are only two wells in the north section and one well in the south section still producing methane. Figure 8 below displays the total methane recovered over time as well as the forecasted baseline methane emissions decline curve.

Stroud faced several operational challenges during the project. Maintaining the optimal vacuum pressure on the wells has been difficult due to limitations in methane desorption and diffusion. Stroud continuously adjusts the compressors for maximum methane recovery void of oxygen. Another challenge was gas communication between the north and south sections; when the north wells were first connected to the system, production of the south wells decreased equally. The wells needed to be far enough outside each adjacent well's radius of influence. The final challenge was that the methane being produced was slightly below pipeline quality and required blending with nearby high quality coalbed methane.

Through trial and error, Stroud managed to create a successful coal mine methane recovery project. Over the years, approximately 3.5 BCF (Figure 8) of methane that would have been vented to the atmosphere was recovered and used. The success of this project suggests there may be opportunities for other AMM project in Colorado and the United States.

**FIGURE 8 GOLDEN EAGLE AMM PRODUCTION 1999 TO 2015.**
**The red line is the theoretical decline curve for the Golden Eagle mine.**



# 6 | Applicability to PUC regulations

## CMM RES Eligibility

On December 1, 2004, Colorado was the first state in the nation to enact by popular vote a renewable energy standard (RES) when it adopted Amendment 37. The RES, which is set forth in CRS 40-2-124, requires providers of retail electric service to more than 40,000 customers to generate a percentage of their retail electricity sales from certain "eligible energy resources." The RES subsequently has been increased by the Colorado General Assembly through HB07-1281, HB10-1001, SB13-252, and SB13-252.

Most recently, SB13-252, signed by Governor Hickenlooper in 2013, amended the RES to include as a nonrenewable "eligible energy resource" CMM captured from active and inactive coal mines that is escaping into the atmosphere. As previously noted, there are obvious potential benefits to utilizing CMM as an energy source, including providing distributed electrical generation primarily to rural populations and reducing a major source of GHG emissions.

It should be noted that in order for a CMM project at an active or inactive/abandoned coal mine to be RES eligible under the statute the Public Utilities Commission (PUC) must determine the following:

- The electricity generated is GHG neutral (discussed further below in Section 6.2);
- The extent to which methane vented in the normal course of active mine operations is naturally escaping to the atmosphere;
- The extent to which the CMM electrical generation technologies utilized in an optional pricing program may be used to comply with the RES.

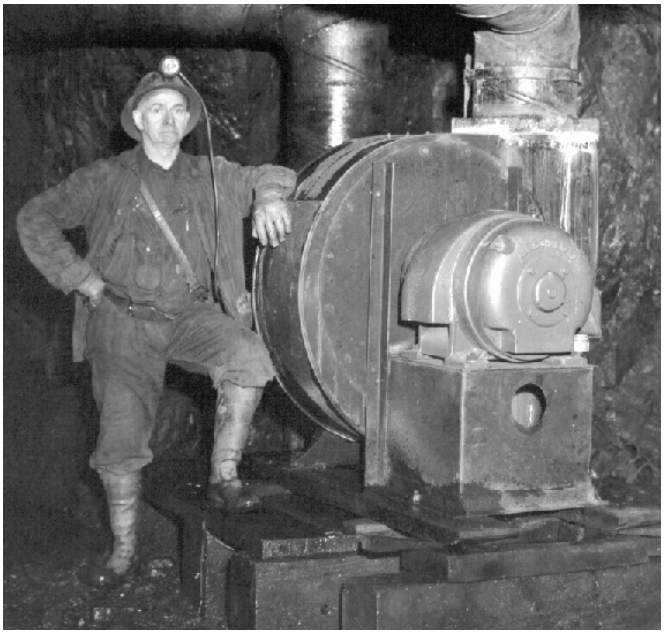
## Greenhouse Gas Neutral

For electricity generated from CMM to meet the renewable energy standard, CRS 40-2-124 expressly requires the PUC to determine that the use of CMM as a fuel source is "greenhouse gas neutral." The statute defines "greenhouse gas neutral" as:

> "the volume of greenhouse gases emitted into the atmosphere from the conversion of fuel to electricity is no greater than the volume of greenhouse gases that would have been emitted into the atmosphere over the next five years, beginning with the planned date of operation of the facility, if the fuel had not been converted to electricity, where greenhouse gases are measured in terms of carbon dioxide equivalent." (C.R.S. §40-2-124(1)(a)(IV) (2013))

On August 21, 2013, the PUC issued a Notice of Proposed Rulemaking (NOPR) (Proceeding No. 13R-0901E) to revise and clarify the RES rules contained in 4 Code of Colorado Regulations (CCR) 723-3-3650, et seq., in order to conform to SB13-252. Among other things, the NOPR included amendments to Rule 3668, Environmental Impacts, to provide that "greenhouse gas neutrality" should be determined on a case-by- case basis for CMM electric generation projects.

On April 2, 2014, the PUC adopted Rule 3668(d), which requires an evidentiary hearing for each CMM project to determine whether it complies with the greenhouse gas neutral standard as defined in SB13-252 (Decision No C14-0390). While the amended RES Rules incorporate the statutory definition of "greenhouse gas neutral," they have not provided a framework or protocol for certifying GHG neutrality or permitting CMM projects. It is important to note that because of the significant GHG emission reduction benefits of destroying fugitive methane like CMM, GHG neutrality will not be difficult to demonstrate. However, the methodologies and data inputs for determining GHG neutrality for active vs. abandoned coal mines are likely to be different.



Petersen, Max S. United States Bureau of Mines. 1944. Spies-Virgil Mine Fan. Photograph. DSpace Repository http://hdl.handle.net/11124/6481. Accessed February 2016.

**Distributed power and self-generation**

Large-scale power generation serves large populations, requiring direct access to large quantities of fuel. Distributed power generation, in contrast, ranges from a few kilowatts up to 30 MW and can best benefit areas where electricity prices and peak-demand usage are high (40-2-124 C.R.S). Distributed generation differs from self-generation in that distributed generation projects typically are placed close to a limited number of consumers to enhance the capability of the existing power grid. Many of Colorado's large coal mines are located in relatively remote regions with limited load growth and generally low electricity prices compared to the rest of the country. Those factors combined can negate some of the direct economic and service benefits of distributed generation.

Other barriers for using CMM as a fuel source to generate electricity are the capital cost of equipment and operation and maintenance costs. Certain fixed fees such as electric grid interconnect fees can be burdensome for projects smaller than 10 MW. Also, existing power supply agreements between local utilities purchasing power from wholesale utilities historically have been barriers to new small renewable power generators seeking to enter the market. The recent FERC decision in the DMEA case may create a pathway under PURPA for qualifying facilities, which may include CMM power generation.

Active coal mines are large consumers of electricity. While CMM power projects can help reduce a mine's electricity needs, CMM and power generating equipment will incur downtime on occasion due to certain mining activities or equipment maintenance. Electricity reliability at coal mines is paramount because of underground mine safety requirements. Utilities typically charge a standby fee to coal mines that self-generate in order to have available the grid-based electricity. Such fees can negatively impact the economics of CMM electric power project for self-generation.

**Methane quantity and quality**

Through effective CMM gas management, a stable quantity of usable quality CMM can be supplied to a small-scale power generation facility. Due to mining variations and degas well types, the quantity and quality of CMM will vary. Post-mining gob well methane concentrations can vary significantly through time from the lower limit of use (~30 percent) up to 90 percent. Gob wells can produce large quantities of methane at high rates initially then decline steeply in rate and concentration. Therefore, it is common to move a gathering system from well to well as mining progresses.

Improved engineering and new technology for in-mine drainage systems enables mines to tap into sealed gob areas and produce high quality gas. System improvements eliminate the need to move surface pipelines and blowers from place to place as mining progresses. These systems are monitored closely to ensure that the gas pressure behind the seals is balanced with the working area pressure and that there is never an explosive mixture of gases behind the seals.

Underground degasification systems can be left in-place after mine abandonment to drain the methane that continues to be released into the gob areas, enabling a project to produce electric power long after mine closure. Most of the gas produced from abandoned mines will generally be at concentrations between 50 percent to 85 percent methane. However, if there are boreholes open to the atmosphere, air ingress can contaminate the gas reducing methane concentration. Therefore, it is important to identify and adequately plug all sources of dilution.

Today's small-scale power generation equipment can use CMM as a feedstock throughout the 30 percent to 90 percent methane concentration range. While equipment such as IC engines can operate on CMM with methane concentration as low as 30 percent, turbines and micro turbines require at least 60 percent methane concentrations. Assessing a CMM power project's size requires an analysis of historical CMM emission rates and mining activities. Many commercial projects are constructed below the peak capacity of CMM volumes while flaring the excess methane as part of the project.

**Ownership and Control**

Colorado has a rich mining and oil and gas history dating back to the 1800's. However, mineral ownership and much of the natural resource production in Colorado is complicated by the fact that the state's largest landowners are the federal and state governments. Each has its own separate administrative policies and procedures, management practices, rules, and regulations relating to the acquisition and development of mineral rights. In addition, they also are responsible for environmental and operational permitting and regulatory compliance on both public and private lands in the state.

To put this in perspective, Colorado covers over 66 million acres. About 24 million acres is federal land (36 percent), most of which is managed either by the Department of Agriculture's United States Forest Service (USFS) or the Department of Interior's Bureau of Land Management (BLM). The BLM primarily is responsible for mineral

operations on federal land. However, all mineral revenues received by BLM essentially are divided 50/50 between the federal government and host state (Gorte et al., 2012).

The Colorado State Board of Land Commissioners (State Land Board) owns and manages mineral rights to about 4,000,000 acres held in trust for the benefit of public schools and institutions. The State Land Board has a dual mandate of producing reasonable and consistent revenues over time for the trusts and promoting sound stewardship of the trust assets (Colo. Const. art. IX, § 10).).

The situation further is complicated by the fact that responsibility for determining title to mineral or property rights to resources such as CMM rests with the judiciary. It is not surprising that as a result of a dispute over coalbed methane gas ownership, in 1999, the U.S. Supreme Court held in the case of *Amoco Production Company v. Southern Ute Indian Tribe,* 526 U.S. 865 (Amoco), that the 1909 and 1910 Homestead Acts enacted by Congress did not intend to include the conveyance of methane gas in a coal seam with the conveyance of the coal, thereby severing the methane from the coal estate. The issue of gas ownership further was complicated in the case by the fact that the Court held a coal owner or mine operator he unrestricted right to freely vent methane (now determined to be part of the gas estate) during the normal course of mining operations in order to protect the safety of the miners.

The Amoco decision gave rise to a number of cases throughout the country relating to disputes over CMM ownership. Cases in the western U.S. dealing with large federal land holdings typically have followed the reasoning in the Amoco decision and held that the methane gas in coal is part of the gas estate and not part of the coal estate. Cases in the eastern U.S. on private fee lands typically have held that the gas in the coal is part the coal estate. Predictably, there are a number of exceptions to these general rules, so CMM project developers have to seek legal advice on the applicable federal or state law pertaining to title to CMM where the project is located. Since the Amoco decision, the BLM has worked to develop procedures to resolve conflicts between coal and gas lessees and operators over rights to CMM (which they refer to as Waste Mine Methane (WMM)). On April 29, 2014, the BLM published in the Federal Register an Advance Notice of Proposed Rulemaking (ANPR) for WMM Capture, Use, Sale, or Destruction, seeking public comment. Comments received from the public in response to the ANPR are still being reviewed by the BLM as of August 2015.

In dealing with the CMM title issues resulting from the Amoco decision, the Colorado State Land Board and the Colorado Oil and Gas Commission modified the State's standard Oil and Gas Lease form to allow the coal lessee to produce, save, or sell CMM from mineable coal seams. The lease also provides that CMM, which is uneconomic, can be produced or flared during mining operations.

Issues concerning CMM ownership are separate from matters pertaining to project permitting and regulatory compliance. While CMM permitting requirements are highly site and project specific and generally beyond the scope of this Report, there are several key starting points to keep in mind when conducting a preliminary assessment:

- Proponents of projects on state and private lands generally prepare preliminary environmental assessments to identify, among other things, the specific site location, potential direct and secondary environmental, economic, and physical impacts of the proposed project, and federal, state, and local agencies that may have responsibility for the project's regulatory compliance. While the environmental assessment is intended to develop a concise project description and scope, it is important to note that Colorado does not have a comprehensive state-specific environmental protection act like California's California Environmental Quality Act or "CEQA" that requires a detailed project description and analysis.
- At active or inactive coal mines on federal or Native American lands, obtaining approvals and permits for CMM project development likely will require a federal action triggering a National Environmental Protection Act (NEPA) analysis by the appropriate federal land management agency, which is generally BLM or USFS. The level of analysis can range from a Finding of No Significant Impact (FONSI) to a full-blown Environmental Impact Statement (EIS) that fully evaluates actions or operations that may have a significant impact on the environment and measures required to mitigate those impacts. Examples of federal action that triggers a NEPA analysis specifically include:
    - If the project involves CMM emissions from federally owned coal, assuming the gas has not already been leased to a third party, the BLM may have to amend the existing coal lease to enable the mine operator or its designee to use or sell methane gas removed from the coal. The act of amending the existing coal lease probably will require a NEPA type analysis.
    - If the project involves federal surface lands managed by either BLM or USFS, a request for a federal agency to issues an access agreement, right of way, or surface lease resulting in any surface disturbing activity, such as site clearance or road or power line construction.
    - In addition, at an active mine that includes both federal and state lands, if a CMM project involves amending any of the mine's existing permits, such as an air quality permit, surface management plan, or the design and operation of an underground ventilation system, the relevant federal and state agencies will all will be actively involved in a collaborative permitting program.

While the environmental assessment and permitting process can be complicated, depending on the location and ownership of the site, it is intended to be transparent and to disclose important information and plans to decision makers, stakeholders, and the general public. In Colorado, where agricultural, recreational, and industrial users frequently seek to use property for different purposes, the permitting process provides an opportunity to obtain meaningful citizen input.

**Institutional challenges**

One of the biggest challenges to developing a CMM project at an active coal mine is addressing the mine operator's business risk. Mine managers have concerns that CMM projects can pose a risk to maintaining the mine's productivity and profitability. In general, the profits from any small-scale CMM power project are a fraction of the coal mine's revenue. Also, coal mine operators are not typically in the business of generating power as part of their core business activities, and can be reluctant to engage in CMM utilization as a result. In order to mitigate these risks, CMM project developers must establish a close working relationship with the mine operator to ensure that the CMM project will not distract or interfere with mining operations, and/or reduce the mine's ability to change their future mine plans.

**Location of Abandoned Mines**

While all the gassy active coal mines are in the North Fork Valley Mining Area, over 1,500 abandoned coal mines are located across the six major coal basins. Abandoned mine development has the advantage of not having to interface with active coal mining operations and limitations. A number of abandoned mine candidates are in relatively remote locations, while others are situated near cities, facilities, electric substations, etc. In order for a project to be economically viable, it is essential that abandoned mine locations be in close proximity to electric power infrastructure.

Abandoned mines generally produce a fraction of the methane generated when the mine was producing coal. As a result, individual mines may not be large enough to sustain a viable AMM recovery and use project by themselves. Therefore, combining the methane produced from several nearby abandoned mines (or an active mine) is an important consideration.

## Aggregating Coal Mine Methane

Three active coal mines in Colorado all have power generating capacities ranging from 2 MW to 11 MW from their CMM gas drainage systems. As few as five abandoned coal mines in the state may have the ability to generate greater than 1 MW of electricity. Because of economies of scale, the most viable project opportunities will result from combining AMM from several abandoned mines or from combining AMM with nearby active mine CMM. This study finds four abandoned mine groups that could potentially generate 2 MW to 5 MW of electricity, of which two of the groups are located in the Somerset area. Moreover, 15 of the 29 abandoned mines identified are in the Somerset area near each of the three gassy active coal mines. This area of high abandoned mine concentration together with active mining operations offers the greatest opportunity for successful CMM project development.

## Additional Abandoned Mine Assessment

The estimated methane emissions and resulting energy potential from abandoned mines is based on modeling because abandoned mine emissions are difficult to measure and quantify. The modeling uses a decline curve approach that has been calibrated against actual AMM vents and methane production rates from recovery and use projects. The 17-year decline curve-actual methane production comparison shown in the Golden Eagle case study speaks to the validity of using the modeling approach. The model contains an uncertainty range of approximately 20 percent. Actual AMM production cannot truly be assessed until after a well is drilled into the mine void and flow tested.

Prior to drilling high risk AMM wells, additional technical due diligence is recommended along the lines of identifying (and possibly measuring) any methane seeps originating from abandoned mine workings and assessing the degree of flooding that may have occurred over time. Mine flooding can greatly impact a mine's ability to emit or produce methane. Methane seeps can be identified from field studies at ground level or via remote sensing. Evidence of mine flooding is difficult to assess from the surface without the benefit of monitoring wells, but an investigation of mining records and permits can show the water discharge rates or incidences of flooded during active mining operations.

## State Policy Recommendations

The state should consider the following potential next steps:

1. To the extent legally feasible, develop a range of RES financial incentives such as CMM offset protocols for GHG credits, RECs, and other financial and tax incentives, which can be essential to drive CMM project development in the near term.
2. Work with Colorado's PUC to establish a clear framework and procedures for:
   i. Confirming that at active coal mines, methane vented in the normal course of mine operations is naturally escaping to the atmosphere so as to fully qualify as an eligible energy resource under the RES.
   ii. Utilizing standard decline curves for establishing CMM residual resources and historic and projected future emission estimates at inactive/abandoned coals mines similar to the decline curves developed and adopted by EPA and CARB.
   iii. Certifying GHG neutrality for CMM electrical generation technologies with the objective of seeking to reduce unnecessary delays and costs of Rule 3668(d)'s case-by-case analysis.
3. Advocate for the adoption of the BLM's WMM rulemaking that resolves CMM ownership issues on federal lands and incentivizes, rather than requires, major capital investment in CMM electrical generation. Having an economic incentive based system is important to encourage all existing coal mine operators to consider CMM project development where they do not presently have any legal obligation to do so. For example, a possible incentive could include limited federal coal royalty relief to accelerate the recovery of project capital and operating costs and expenses.
4. Promote better coordination of federal and state land management leasing and permitting programs. This can provide a clear pathway for the acquisition of CMM rights, and expedite permit issuance and other approvals. For example, including in future federal gas and coal leases a provision similar to the provision in the State Oil and Gas Lease form granting the coal lessee rights to the gas in the coal could avoid ongoing uncertainty over rights to ownership and control of CMM on federal lands.
5. Support CMM project developers, mine operators, and local utilities efforts to obtain FERC approval for treating CMM as a qualifying "waste" under PURPA. This will enable CMM electrical generation projects to have viable opportunities for securing long-term power supply contracts on reasonable terms.

# 9 | Conclusions

This study concludes that there may be potentially up to 89 MW of electric power generating capacity from active and abandoned coal mine methane emissions. This is based on current and historic methane emission rates. Approximately half (46 MW) of this energy potential originates from VAM recovery and use projects. Unfortunately, there has been only one successful commercial-scale VAM power plant (6 MW) ever constructed at an Australian coal mine. Including the cost of the VAM oxidation equipment, the installed cost for power generation is five times that of using high methane content drainage CMM with IC engines rendering it uneconomic at this time. There is currently one VAM abatement project of similar size operating at a West Virginia coal mine. Based on its capacity, it is technically feasible to install VAM abatement equipment and recover approximately 20 percent of the VAM emissions found at Colorado mines.

For CMM at active mines, it may be technically feasible to capture 25 percent to 75 percent of the emissions. The largest obstacle is often gathering the gas from dozens of surface wells (sometimes with short two-to-five-year lives) through difficult terrain in western Colorado. Other operational challenges include U.S. BLM land approvals, moving temporary pipelines and operating equipment in harsh winter conditions.

In general, there is a large degree of uncertainty in assessing AMM potential. The decline curve estimation approach applied for this study contains uncertainties of about ±25 percent. Moreover, approximately one-third of all underground coal mines eventually become flooded, thus negating their methane liberation potential. Additional assessment work may be necessary to reduce the AMM uncertainty in the state. Slightly over half of the 29 identified abandoned mines are located in the Somerset area adjacent to the three active mines (representing 8 MW of the total 20 MW potential). Other areas of high AMM potential are located near Redstone, Palisade, Walsenburg, and Trinidad, CO.

This study concludes that while up to 89 MW of energy potential exists at Colorado mines, a more realistic and technically feasible value is approximately 34 MW. Of this amount, nearly 80 percent (or 26 MW) originates from the Somerset area mines. Clearly, efforts to promote coal mine methane-to-energy projects in this region would be considered the greatest opportunity in the state.

**ESTIMATED ELECTRIC POWER GENERATION FROM VAM, CMM AND AMM EMISSIONS IN COLORADO (MW)**

| | VAM Emissions | CMM Emissions | AMM Emissions | Total |
|---|---|---|---|---|
| Potential | 46 | 23 | 20 | 89 |
| Feasible | 10 | 12 | 12 | 34 |

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# Appendix A

## WEST ELK MINE

Mine Status: Active
Drainage System: Yes
Use Project: Heaters

GEOGRAPHIC DATA
Basin: Piceance State: CO Coalbed: B Seam County: Gunnison

CORPORATE INFORMATION
Current Operator: Mountain Coal Company, LLC
Parent Company Website: www.archcoal.com
Owner/Parent Company: Arch Coal Inc.
Previous Owner(s): Atlantic Richfield/ITOCHU Corp
Previous or Alternative Name of Mine: Mt. Gunnison

MINE ADDRESS
Physical Address: 5174 Highway 133
Phone Number: (970) 929-5015
Mailing Address: P.O. Box 591 | Somerset , CO | 81434

GENERAL INFORMATION
Number of Employees at Mine: 384
Mining Method: Longwall
Year of Initial Production: 1982
Primary Coal Use: Steam
Life Expectancy: 2020
BTUs/lb of Coal Produced: 11,700
Depth to Seam (ft): 0 – 2,300
Seam Thickness (ft): B:8-16, E:7-15, F:6-8

PRODUCTION, VENTILATION, AND DRAINAGE DATA

| | 2011 | 2012 | 2013 |
|---|---|---|---|
| Coal Production (short tons/year): | 5,896,402 | 6,852,136 | 5,826,798 |
| Estimated Total Methane Liberated (million cf/year): | 2,747 | 2,491 | 2,347 |
| Emission from Ventilation Systems: | 2,060 | 1,483 | 1,605 |
| Estimated Methane Drained: | 687 | 1,008 | 742 |
| Estimated Specific Emissions (cf/ton): | 466 | 364 | 403 |
| Methane Used (million cf/year): | 0 | 28 | 88 |

Estimated Current Drainage Efficiency: 32%
Drainage System Used: Horizontal & Vertical Gob Boreholes with Pumps

POWER GENERATION POTENTIAL
Utility Electric Supplier: Delta-Montrose Electric Association
Nearest Transmission Line: On site
Parent Corporation of Utility: Touchstone Energy Cooperatives

| | MW | GWH/YEAR |
|---|---|---|
| Mine electricity demand 2006 | 37.4 | 144.3 |
| Generating capacity assuming 50% CH4 Recovery Efficiency: | 4.5 | 35.5 |

## ELK CREEK MINE

Mine Status: Temporarily Idled
Drainage System: Yes
Use Project: Flare/generator/heater

GEOGRAPHIC DATA
Basin: Uinta
State: CO
Coalbed: D Seam
County:Gunnison

CORPORATE INFORMATION
Current Operator: Oxbow Mining LLC
Parent Company Website: www.oxbow.com
Owner/Parent Company: Oxbow Carbon & Materials Inc.
Previous Owner(s): None
Previous or Alternative Name of Mine: None

MINE ADDRESS
Physical Address: 3737 Highway 133
Phone Number: (970) 929-5122
Mailing Address: P.O. Box 5535 | Somerset, CO | 81434

GENERAL INFORMATION
Number of Employees at Mine: 11
Mining Method: Longwall
Year of Initial Production: 2002
Primary Coal Use: Steam
Life Expectancy: 2014
BTUs/lb of Coal Produced: 12,128
Depth to Seam (ft): 200 – 1,200
Seam Thickness (ft): D:6-19, D2:14

PRODUCTION, VENTILATION, AND DRAINAGE DATA

| | 2011 | 2012 | 2013 |
|---|---|---|---|
| Coal Production (short tons/year): | 3,007,833 | 2,958,014 | 436,381 |
| Estimated Total Methane Liberated (million cf/year): | 5,852 | 4,182 | 544 |
| Emission from Ventilation Systems: | 3,687 | 3,217 | 179 |
| Estimated Methane Drained: | 2,165 | 965 | 365 |
| Estimated Specific Emissions (cf/ton): | 1,946 | 1,414 | 1,247 |
| Methane Used (million cf/year): | 0 | 17 | 360 |

Estimated Current Drainage Efficiency: 67%
Drainage System Used: Vertical Gob Boreholes with Pumps

POWER GENERATION POTENTIAL
Utility Electric Supplier: Delta-Montrose Electric Association
Nearest Transmission Line: One site
Parent Corporation of Utility: Touchstone Energy Cooperatives

| | MW | GWh/year |
|---|---|---|
| Mine electricity demand 2013 | 31.9 | 123.1 |
| Generating capacity assuming 100% CH4 Recovery Efficiency: | 4.4 | 34.7 |

## BOWIE NO. 2

Mine Status: Recently Idled
Drainage System: Yes
Use Project: No

GEOGRAPHIC DATA
Central Rockies
B & D Seams
State: CO
County: Delta

CORPORATE INFORMATION
Current Operator: Bowie Resources LLC
Owner/Parent Company: Bowie Resources Partners LLC
Previous Owner(s): Bowie Resources Limited
Parent Company Website: www.bowieresources.com
Previous or Alternative Name of Mine: None

MINE ADDRESS
Physical Address: 43659 Bowie Rd
Mailing Address: None | Paonia, CO | 81428
Phone Number: (970) 527-7786

GENERAL INFORMATION
Number of Employees at Mine: 207
Year of Initial Production: 1997
Life Expectancy: unknown
Depth to Seam (ft): 450 – 2,000
Mining Method: Longwall
Primary Coal Use: Steam
BTUs/lb of Coal Produced:12,128
Seam Thickness (ft): 12 – 20

PRODUCTION, VENTILATION, AND DRAINAGE DATA

| | 2011 | 2012 | 2013 |
|---|---|---|---|
| Coal Production (short tons/year): | 2,235,055 | 3,430,291 | 3,320,696 |
| Estimated Total Methane Liberated (million cf/year): | 725 | 736 | 667 |
| Emission from Ventilation Systems: | 457 | 642 | 527 |
| Estimated Methane Drained: | 268 | 94 | 140 |
| Estimated Specific Emissions (cf/ton): | 324 | 215 | 201 |
| Methane Used (million cf/year): | 0 | 0 | 0 |

Estimated Current Drainage Efficiency: 21%
Drainage System Used: Vertical Gob Boreholes with Pumps

POWER GENERATION POTENTIAL
Utility Electric Supplier: Delta-Montrose Electric Association
Parent Corporation of Utility: Touchstone Energy Cooperatives
Nearest Transmission Line: One site

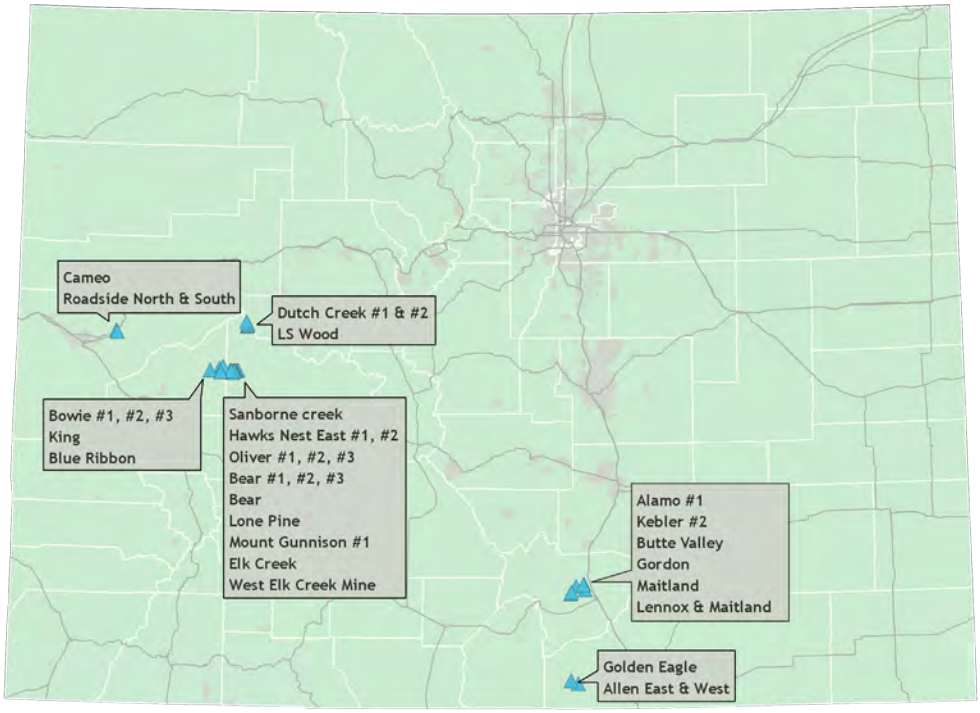
| | MW | GWh/year |
|---|---|---|
| Mine electricity demand 2006 | 27.5 | 106.1 |
| Generating capacity assuming 50% CH4 Recovery Efficiency: | 1 | 7.9 |

# Appendix B

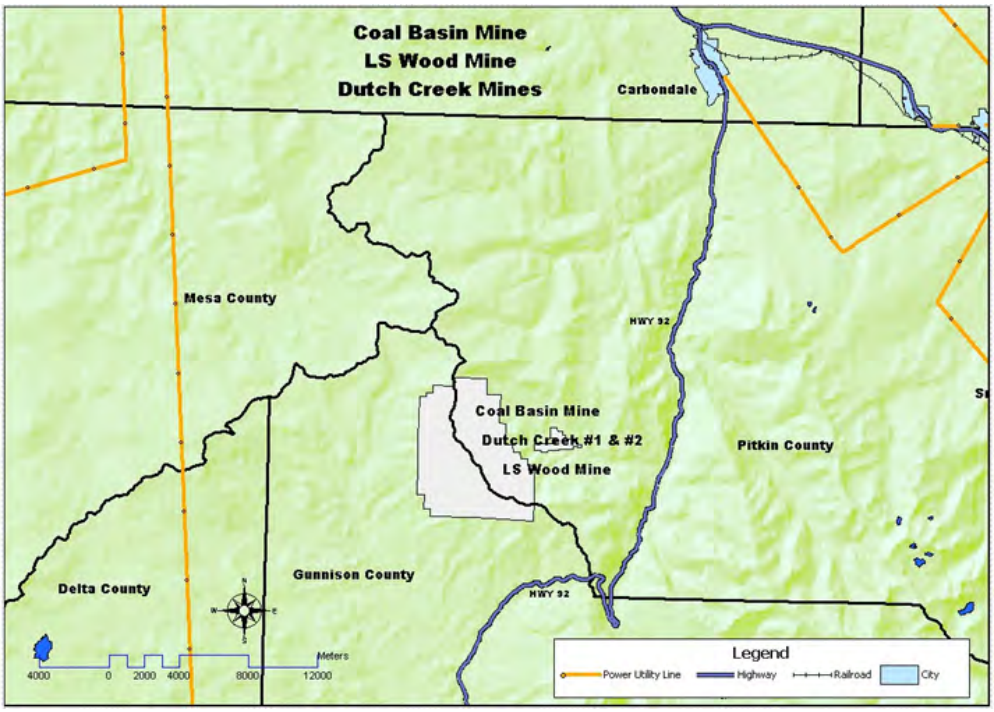
| Utility | Web Address | County | Mine |
|---|---|---|---|
| Grand Valley Power / Excel Energy | http://gvp.org/ http://www.xcelenergy.com/ | Mesa | Cameo, Roadside, North and South Portals |
| Holy Cross Electric / Excel Energy | https://www.holycross.com/ http://www.xcelenergy.com/ | Pitkin | Dutch Creek #1<br>Dutch Creek #2<br>LS Wood<br>Coal Basin |
| Delta Montrose Electric Association | http://www.dmea.com/ | Gunnison | Sanborn Creek Mine<br>Hawks Nest East<br>Somerset<br>Hawks Nest #1<br>Hawks Nest #3<br>Oliver #1 & 3<br>Oliver #2<br>Bear #1, 2, 3<br>Sanborn Creek Mine<br>Bear<br>Lone Pine<br>Mount Gunnison #1 |
| | | Delta | Bowie #1<br>King<br>Blue Ribbon Coal<br>Bowie #3 |
| | | Las Animas | Golden Eagle<br>Allen-East and West Portals |
| San Isabel Electric Association | http://www.siea.com/ | Huerfano | Maitland #1<br>Lennox and Maitland<br>Alamo No.1<br>Gordon<br>Kebler #2<br>Butte Valley |

# Appendix C

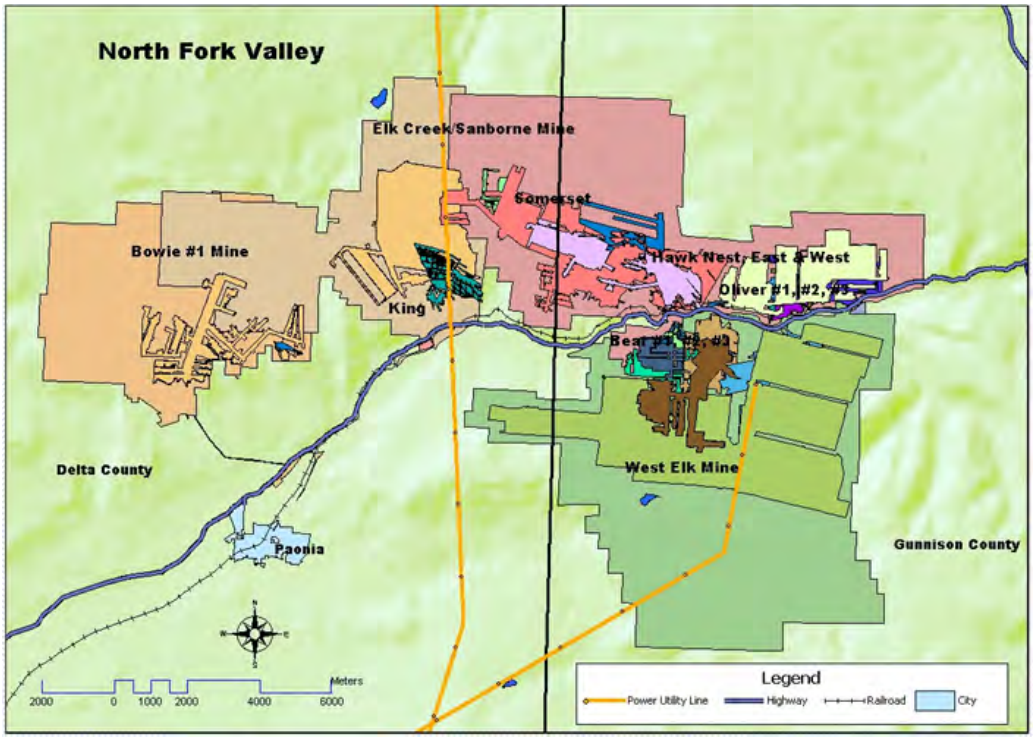
**Colorado's Active and Abandoned Coal Mines with Methane Recovery Opportunities**



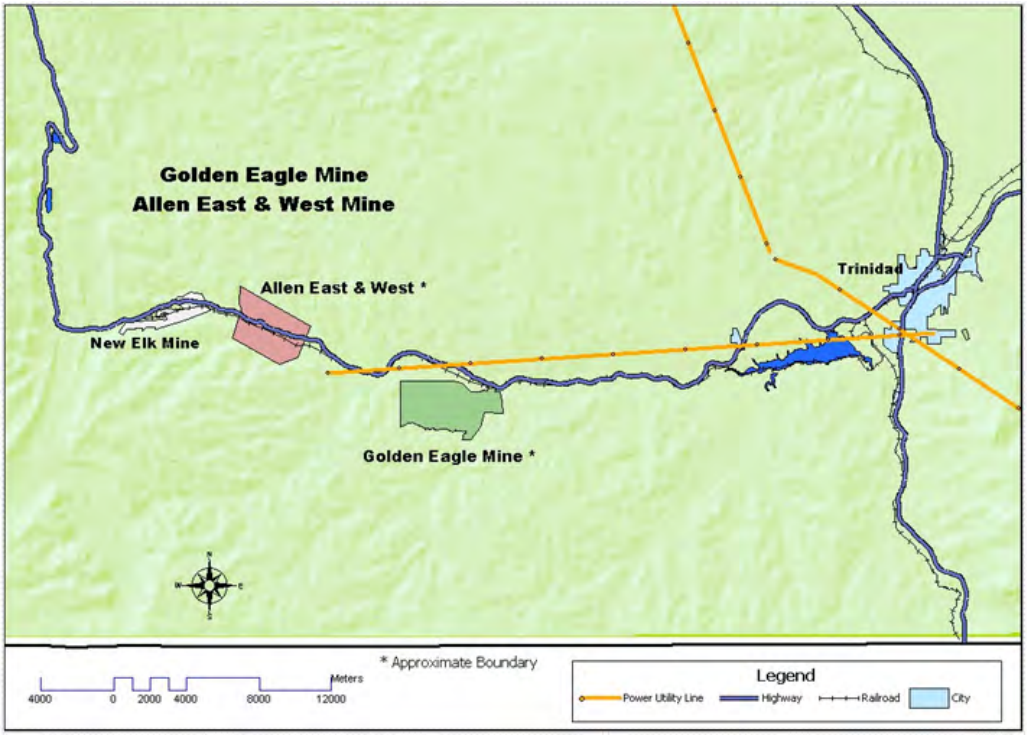

**Group A – Carbondale – Redstone Area**



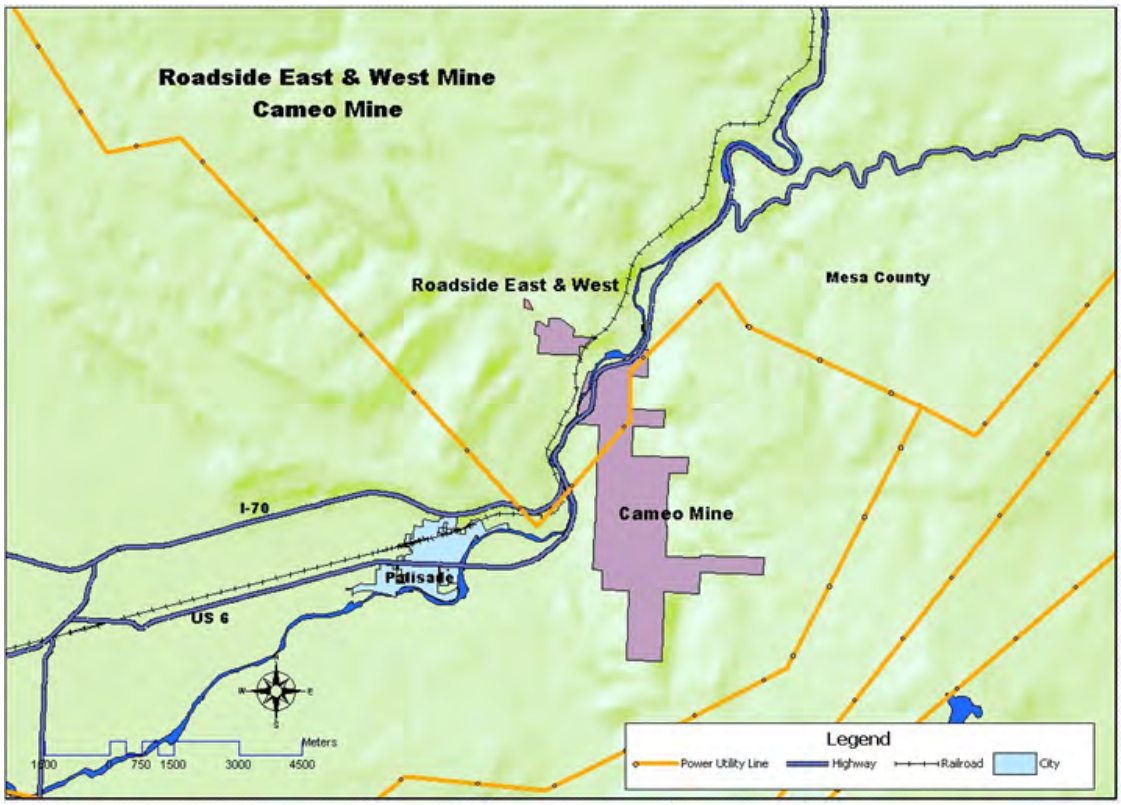
**Group B, D, E – Somerset**



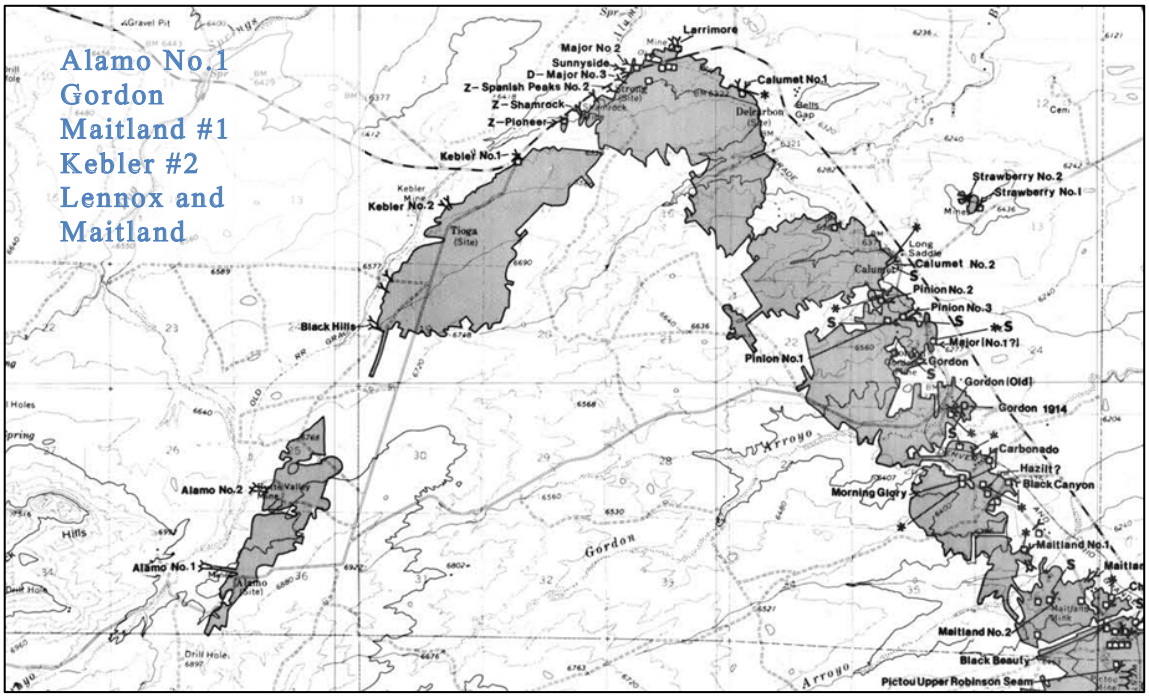

**Group C – Trinidad**



**Group F – Book Cliff – Cameo**




**Group G – Walsenburg**



# Appendix D

| Mine Name | Status | CMM 3-yr average for active AMM 10-yr average for abandoned | | | VAM active only | | |
|---|---|---|---|---|---|---|---|
| | | MCF/day | MW potential | MW Feasibility | MCF/ day | MW potential | MW Feasibility |
| West Elk Mine | Active | 2,226 | 10.5 | 5.2 | 4,702 | 17.4 | 3.49 |
| Elk Creek Mine | Active (idled) | 2,504 | 11.8 | 5.9 | 6,468 | 24.0 | 4.79 |
| Bowie No 2 Mine | Active (idled) | 459 | 2.2 | 1.1 | 1,485 | 5.5 | 1.10 |
| McClane Canyon Mine | Active | N/A | 0 | 0 | 286 | 1.1 | 0.21 |
| Foidel Creek Mine | Active | N/A | 0 | 0 | 123 | 0.5 | 0.09 |
| Deserado Mine | Active | N/A | 0 | 0 | 103 | 0.4 | 0.08 |
| Dutch Creek #1 | Abandoned | 517 | 2.3 | 1.38 | | | |
| Dutch Creek #2 | Abandoned | 419 | 1.9 | 1.14 | Feasible recovery estimates | | |
| LS Wood | Abandoned | 230 | 1.0 | 0.60 | Drainage | VAM | Abandoned |
| Coal Basin | Abandoned | 143 | 0.6 | 0.36 | 50% | 20% | 60% |
| Sanborn Creek Mine | Abandoned | 770 | 3.4 | 2.04 | | | |
| Hawks Nest East | Abandoned | 86 | 0.4 | 0.24 | | | |
| Somerset | Abandoned | 71 | 0.3 | 0.18 | | | |
| Hawks Nest #1 | Abandoned | 58 | 0.3 | 0.18 | | | |
| Hawks Nest #3 | Abandoned | 55 | 0.2 | 0.12 | | | |
| Oliver #1 & 3 | Abandoned | 53 | 0.2 | 0.12 | | | |
| Oliver #2 | Abandoned | 50 | 0.2 | 0.12 | | | |
| Bear #1, 2, 3 | Abandoned | 42 | 0.2 | 0.12 | | | |
| Golden Eagle | Abandoned | 873 | 3.9 | 2.34 | | | |
| Allen-East and West Portals | Abandoned | 68 | 0.3 | 0.18 | | | |
| Bowie #3 | Abandoned | 163 | 0.7 | 0.42 | | | |
| Bowie #1 | Abandoned | 150 | 0.7 | 0.42 | | | |
| King | Abandoned | 84 | 0.4 | 0.24 | | | |
| Blue Ribbon Coal | Abandoned | 69 | 0.3 | 0.18 | | | |
| Bear | Abandoned | 68 | 0.3 | 0.18 | | | |
| Lone Pine | Abandoned | 55 | 0.2 | 0.12 | | | |
| Mount Gunnison #1 | Abandoned | 45 | 0.2 | 0.12 | | | |
| Cameo | Abandoned | 93 | 0.4 | 0.24 | | | |
| Roadside, No. & So. Portals | Abandoned | 71 | 0.3 | 0.18 | | | |
| Alamo No.1 | Abandoned | 49 | 0.2 | 0.12 | | | |
| Gordon | Abandoned | 24 | 0.1 | 0.06 | | | |
| Maitland #1 | Abandoned | 24 | 0.1 | 0.06 | | | |
| Kebler #2 | Abandoned | 23 | 0.1 | 0.06 | | | |

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