

U.S. EPA CMOP Webinar

Abandoned Mine Methane as an Energy Source

October 3, 2019



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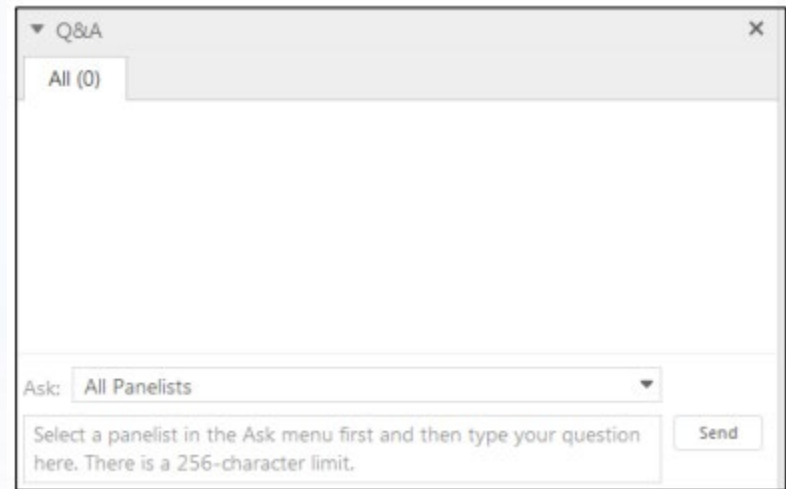
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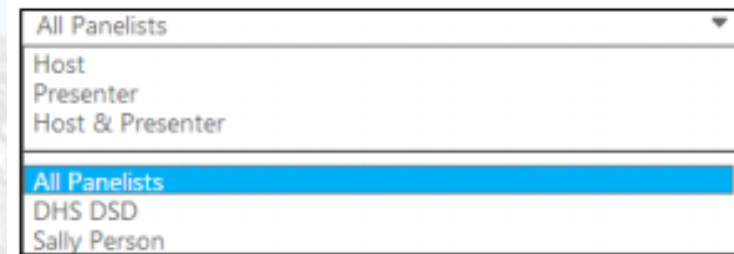
Q&A

All (0)

Ask: All Panelists

Select a panelist in the Ask menu first and then type your question here. There is a 256-character limit.

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Agenda

- Agenda
 - Valerie Askinazi, U.S. EPA Coalbed Methane Outreach Program (CMOP)
 - Michael Cote, Ruby Canyon Engineering
 - Evan Vessels, Vessels Carbon Solutions
- Question and Answer

Overview of the Coalbed Methane Outreach Program (CMOP)



Valerie Askinazi

**U.S. Environmental Protection Agency
Coalbed Methane Outreach Program**



**Coalbed Methane Outreach Program Webinar
October 3, 2019**

U.S. EPA's Coalbed Methane Outreach Program (CMOP)



- Our Focus

- Greenhouse gas emission reduction opportunities: coal mine methane (CMM) rather than coalbed methane (CBM)

- Our Mission

- Work with private sector to cost-effectively reduce CMM emissions through recovery and use projects

- Our Activities

- Identify profitable opportunities for CMM recovery
- Identify and help overcome market, regulatory, and technical barriers
- Offer technical and analytic support where appropriate
- Conduct direct outreach to coal mines



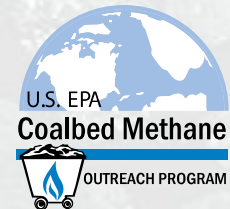
CMOP Accomplishments



- Roughly 80% of methane from U.S. coal mine degasification systems is recovered and used today, compared to ~25% in 1993¹
- From 1994 to 2017, cumulative emissions reductions are more than 199 MMTCO₂E.

Updated Resources in 2019 (accessible at: www.epa.gov):

- CMM Finance Guide
- CMM Recovery at Active and Abandoned U.S. Coal Mines: Current Projects and Potential Opportunities
- Coal Mine Methane Developments in the United States
- Identifying Opportunities for Methane Recovery at U.S. Coal Mines: Profiles of Selected Gassy Underground Coal Mines (2002-2016)
- Financial and Regulatory Incentives for CMM Emissions Reduction Project Development
- State Renewable Energy Programs
- Ventilation Air Methane (VAM) Utilization Technologies



¹U.S. Greenhouse Gas Inventory, 2017. "Degasification systems' include pre-mine drainage and gob wells).

MMTCO₂E = Million Metric Tons of Carbon Dioxide



Sources of Coal Mine Methane (CMM)



Ventilation Air Methane (VAM)

CMM is removed via ventilation systems which use fans to dilute the methane to safe levels by circulating fresh air through the mine. VAM is the largest source of methane emissions from underground coal mines.



Surface Mine Methane (SMM)

SMM is methane released by surface or open-pit/open-cast mining activities as the mined coal is broken, mined and transported, and is commonly emitted to the atmosphere.



Abandoned Mine Methane (AMM)

Coal mines that are temporarily or permanently closed can still produce significant methane emissions from diffuse vents, fissures, or boreholes.



Drainage System Methane

Degasification systems at underground mines may include vertical and/or horizontal wells to recover methane in advance of mining (known as "pre-mine drainage") or after mining.

Opportunities for Recovery and Use of Methane from U.S. Abandoned Underground Coal Mines



Michael Coté
Ruby Canyon Engineering, Inc.



Coalbed Methane Outreach Program Webinar
October 3, 2019

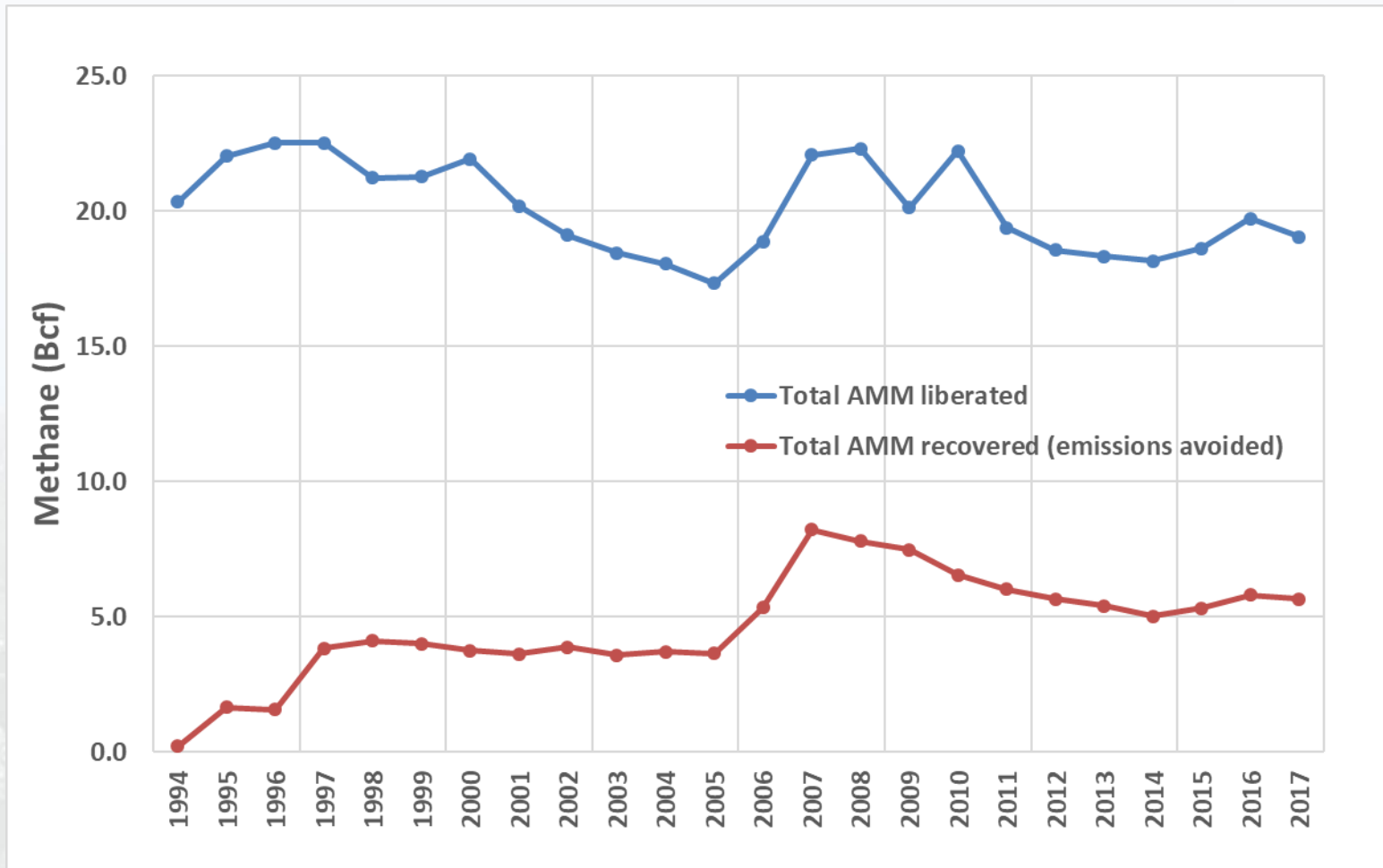
Key Messages

- AMM can be a valuable source of energy
- There are currently opportunities for AMM project development in the US
- AMM recovery is a growing sector as more gassy mines are abandoned
 - Recently abandoned gassy mines: Emerald Mine (Pennsylvania), Bowie #2 Mine (Colorado), New Future Mine (Illinois), West Ridge Mine (Utah)
 - Other new AMM projects are currently listed in California Air Resources Board (CARB)
- Pre-project assessments and ongoing AMM production evaluations are key to projects' long-term economic viability

Abandoned Mine Methane (AMM)

- An abandoned coal mine can be a large reservoir of methane and source of fugitive emissions
- Abandoned mine gas has favorable characteristics
 - Generally contains 40-80% methane
 - Few wells needed if mine is sealed well
- Abandoned mines are often nearby active underground mines and coal mine methane (CMM) projects
 - Advantages to combining AMM and CMM projects
- Data needs for AMM resource assessment
- History of active mine emissions and coal production
 - Degree of sealing and flooding
 - Date of abandonment

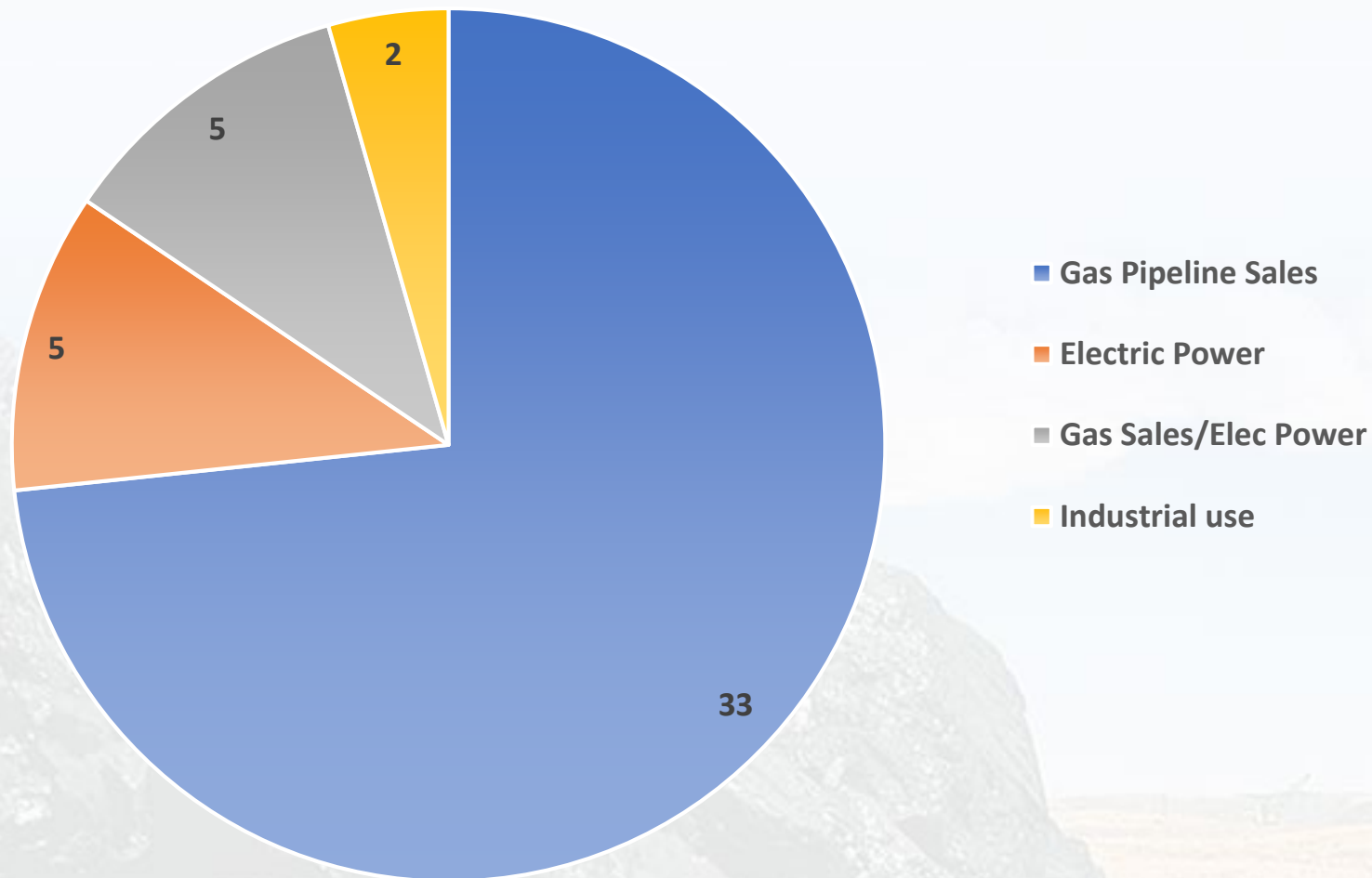
U.S. AMM Emissions 1994-2017



Number of Gassy Abandoned Coal Mines in the U.S.

- About 10,000 abandoned underground (UG) mines
- 500+ gassy coal mines emitting about 18 Bcf/yr
- 6 Bcf/yr recovered from 45 mines (20 projects)
- 6 Bcf/yr potential from top 100 candidate mines
- 6 Bcf/yr may be uneconomic to recover

AMM Utilization at 45 U.S. Mines



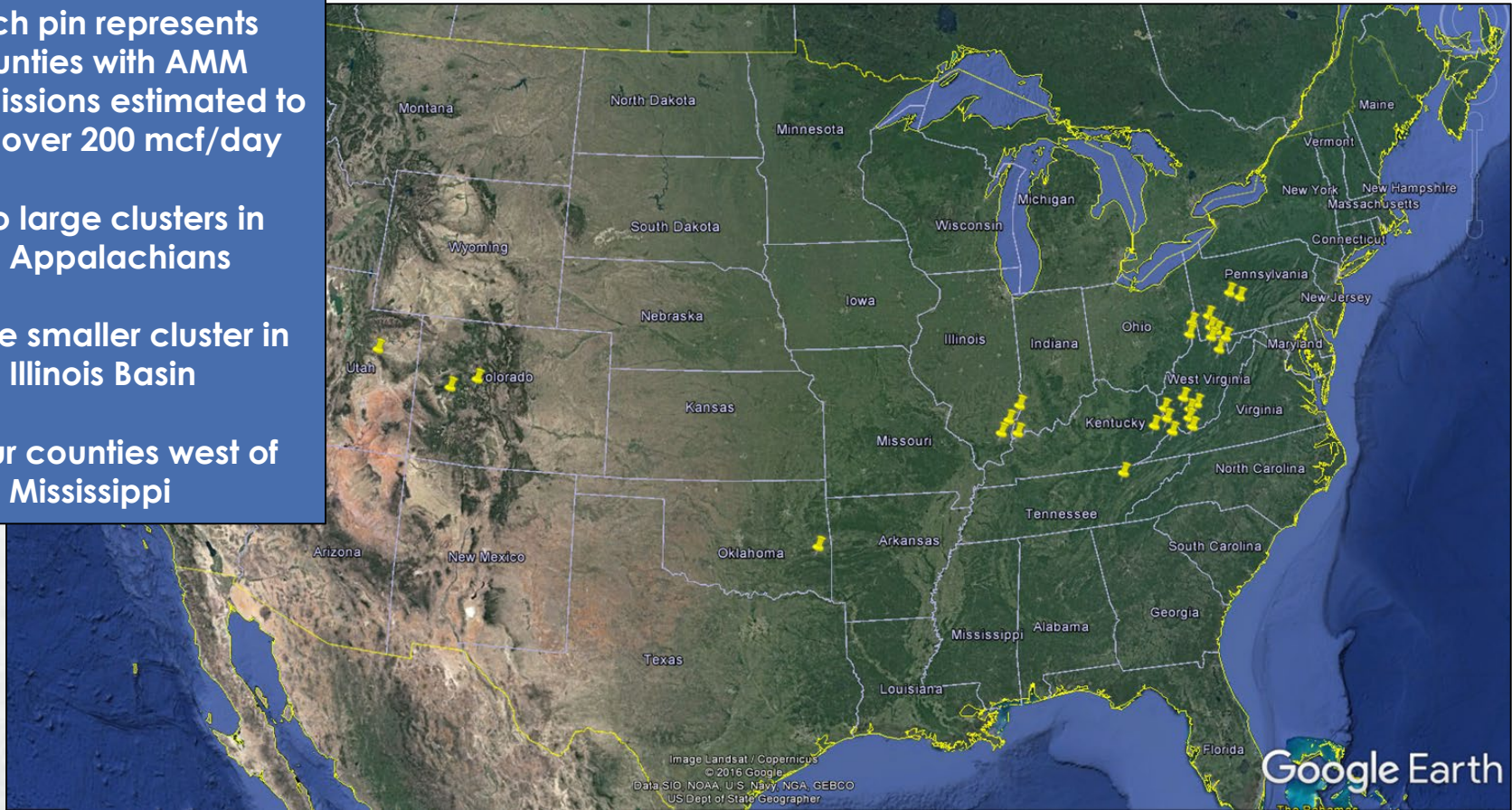
AMM Project Opportunities Map

Each pin represents counties with AMM emissions estimated to be over 200 mcf/day

Two large clusters in the Appalachians

One smaller cluster in the Illinois Basin

Four counties west of the Mississippi

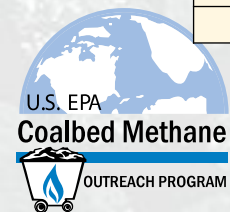


State and County Locations with AMM Resources

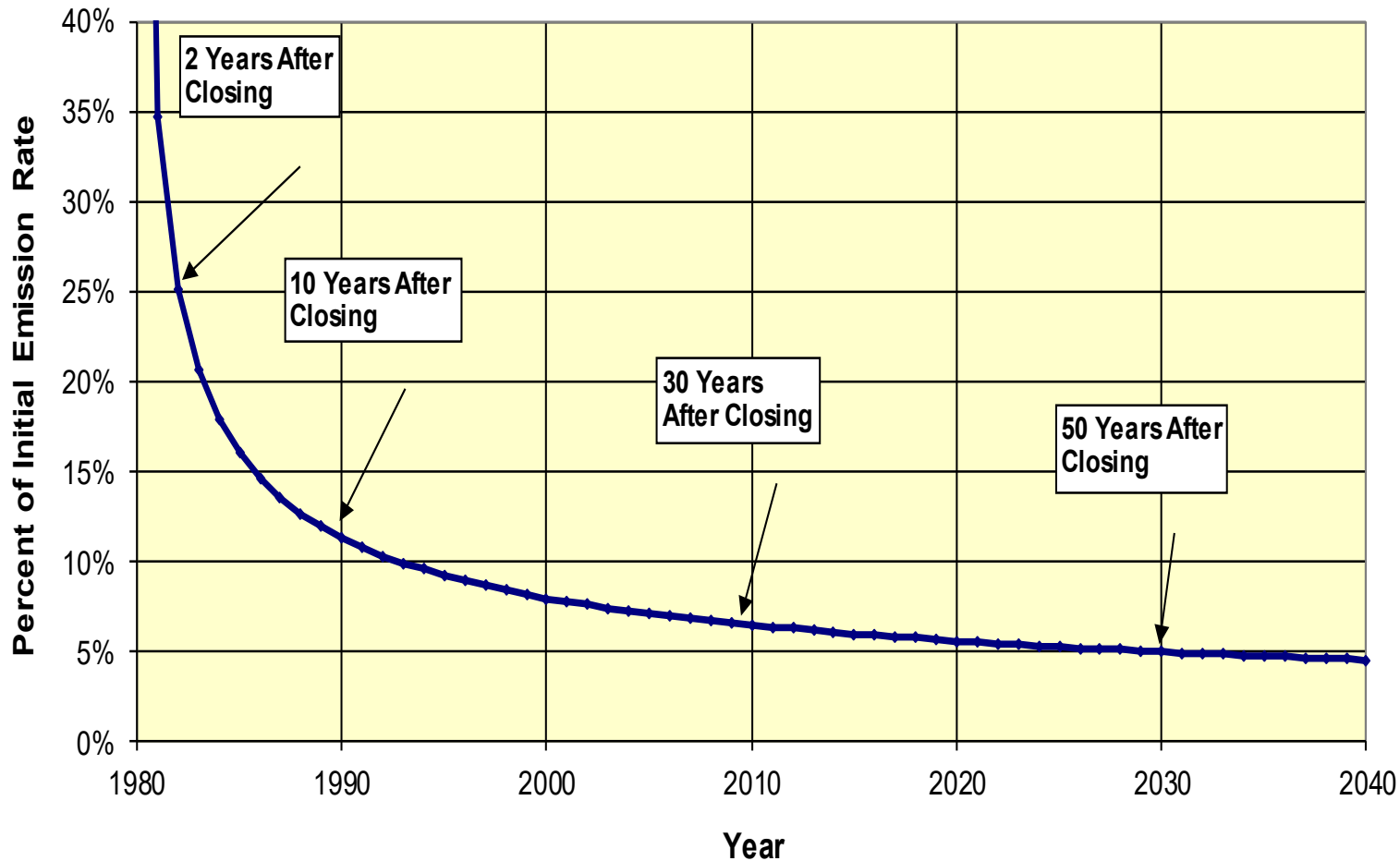
State	County	Number of Mines	Total Number of Mines	Methane (mmcf/yr)	Total Methane (mmcf/yr)
West Virginia	Raleigh	5	22	488	1,397
	McDowell	5		171	
	Wyoming	3		155	
	Boone	3		153	
	Barbour	2		146	
	Preston	1		117	
	Marion	2		90	
	Monongalia	1		77	
Pennsylvania	Washington	6	18	381	1,176
	Indiana	8		378	
	Cambria	2		228	
	Greene	2		189	
Kentucky	Pike	5	12	334	688
	Martin	3		124	
	Union	3		117	
	Knott	1		113	
CO	Pitkin	4	7	431	587
	Delta	3		155	
Virginia	Tazewell	2	6	204	506
	Dickenson	4		302	
IL	Saline	2	4	213	480
	Wabash	1		156	
	White	1		111	
UT	Carbon	5	5	346	346
OH	Belmont	1	2	88	176
	Monroe	1		88	
OK	Le Flore	2	2	142	142
TN	Rosedale	1	1	88	88
Totals			79		5,587

Coalbed Methane Outreach Program (2017) *Abandoned Coal Mine Methane Opportunities Database*. U.S. Environmental Protection Agency, Washington, DC USA.

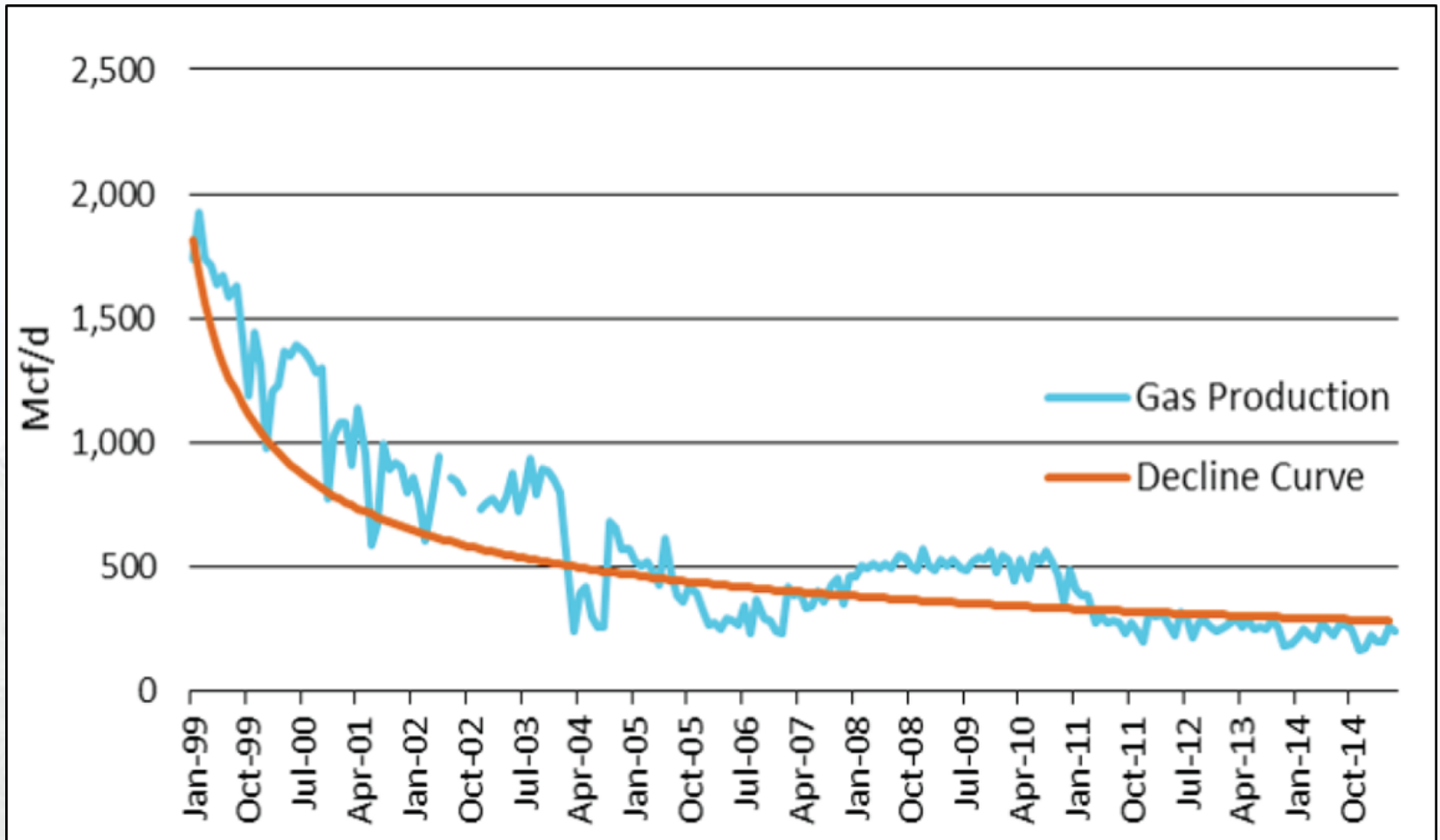
Mmcf = Million cubic feet



Declining AMM Emissions Rate

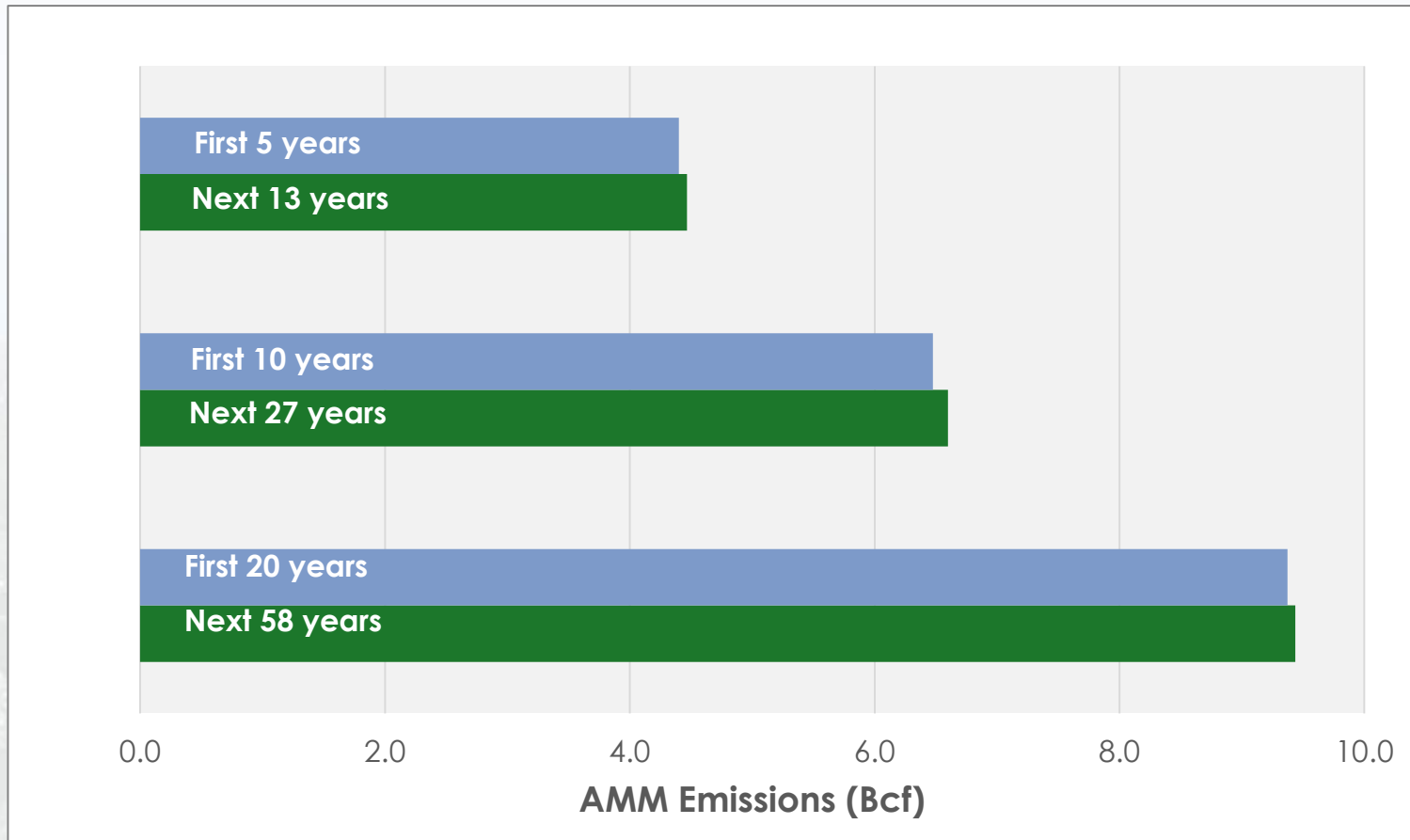


Long-Term AMM Production Example



AMM Recovery Best in the Years Immediately Following Mine Closure

Active Mine Emissions = 3.5 mmcf/d



AMM Development Incentives for U.S. Projects

- Compliance Offset Credits
 - California Air Resources Board
- Voluntary Offset Credits
 - Verra (Verified Carbon Standard)
 - American Carbon Registry (expected 12/31/2019)
- Renewable/Clean/Alternative Energy Credits
 - Pennsylvania, Ohio, Indiana, Colorado, Utah

Technical Barriers to AMM Development

- Uncertainty in methane resource
- Difficult geological conditions
- Water flooding
- Compartmentalization limiting methane flow
- Adequate piping and seals upon closure
- Suction pressure
- Remote locations with limited access to power

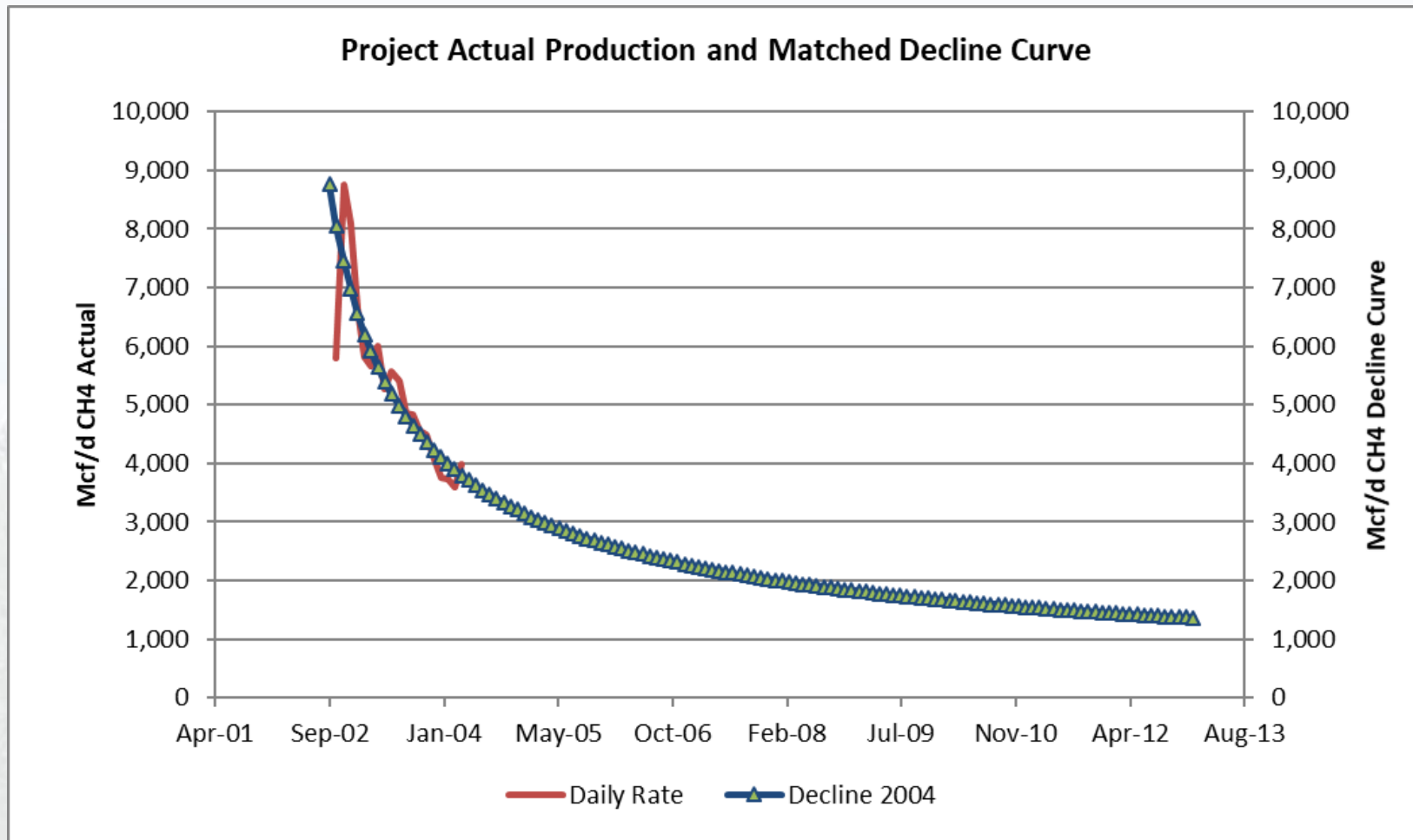
Evaluating AMM Gas Resources

Important to understand how each AMM resource will perform

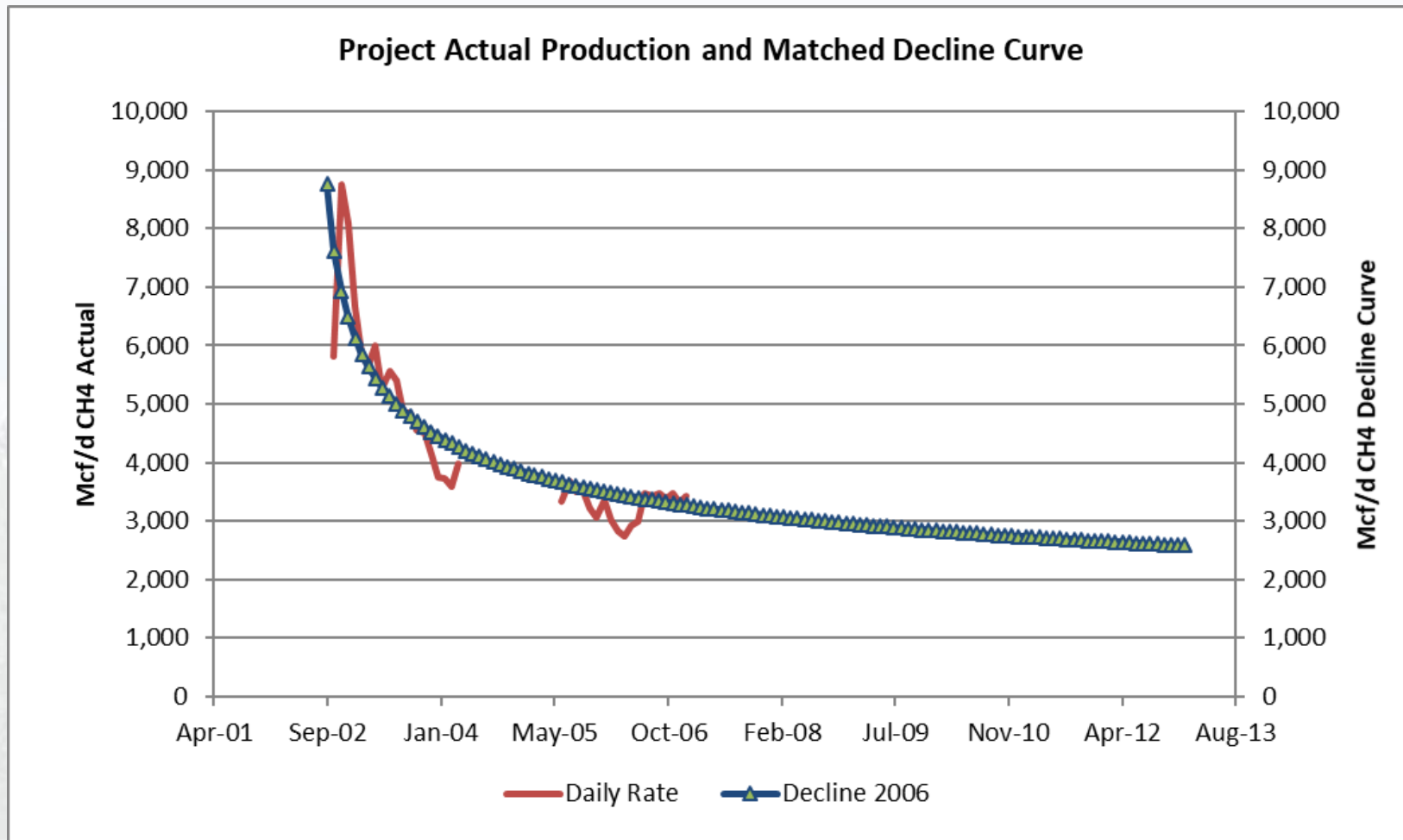


Photo courtesy of Perennial Energy

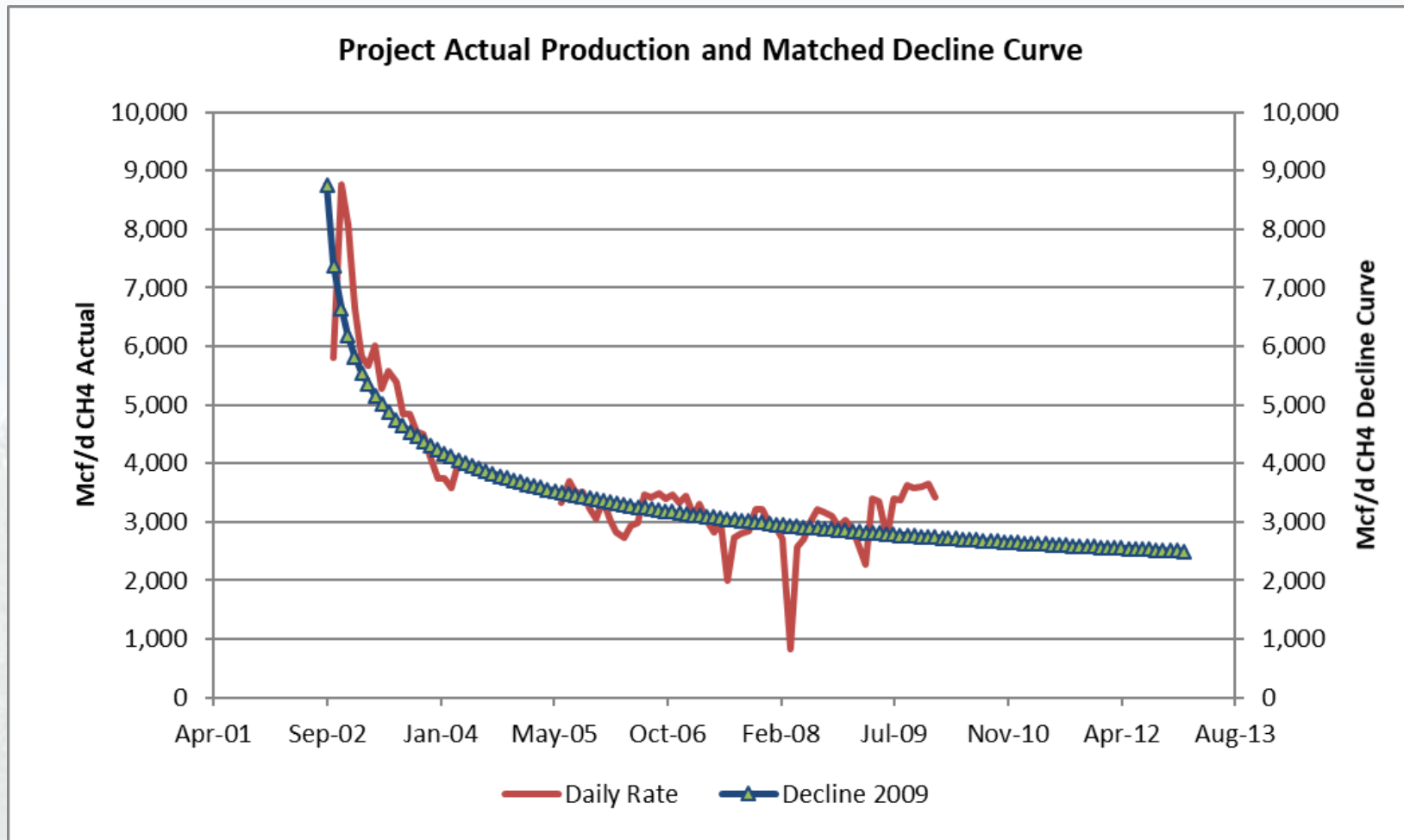
Forecasting AMM Gas Resources



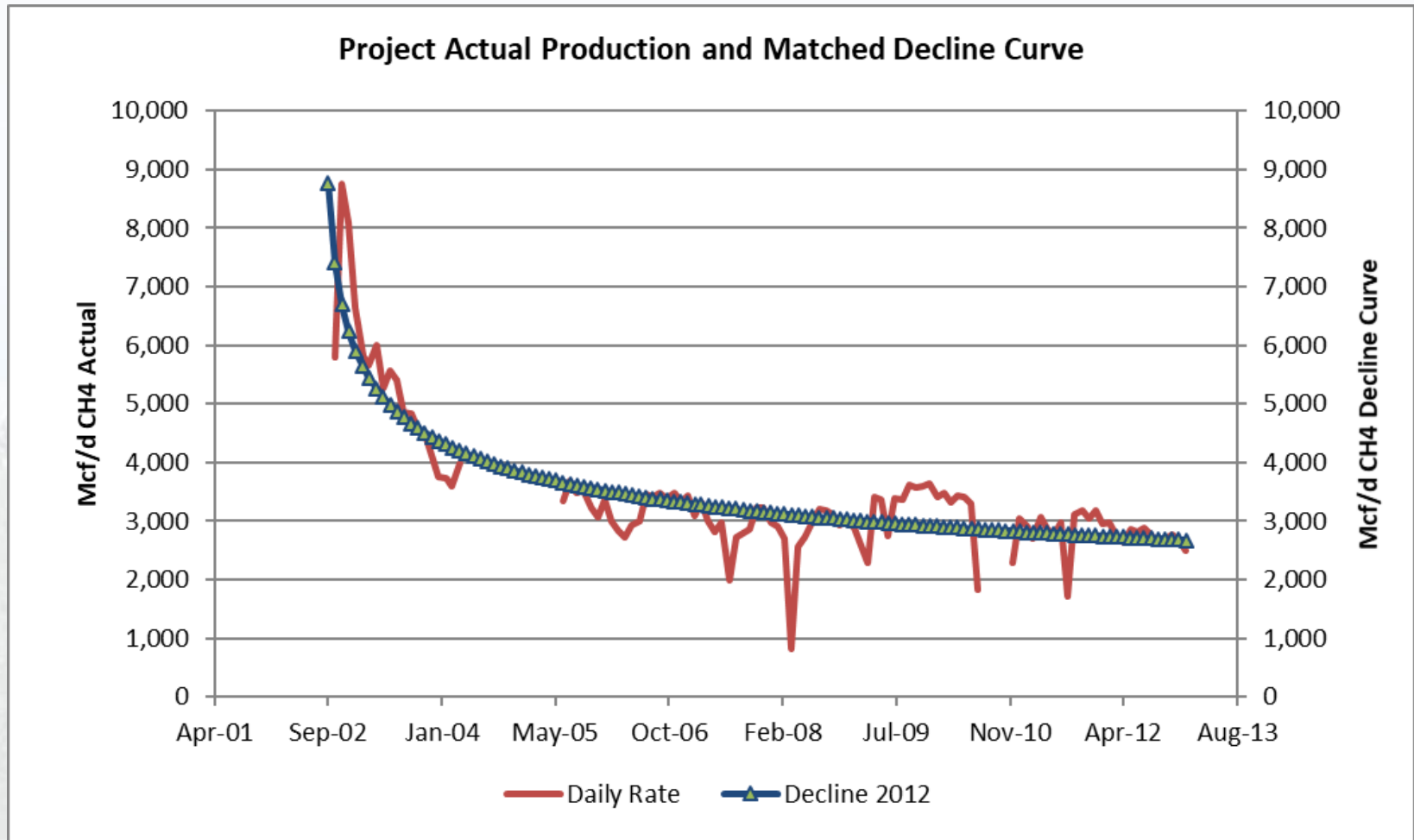
Forecasting AMM Gas Resources



Forecasting AMM Gas Resources



Forecasting AMM Gas Resources



Comparing AMM Projects to CMM Projects

- **Size and Scale of Projects**

- AMM projects tend to be 10-25% the size of CMM projects at the same mine, but abandoned mines can be aggregated into a single larger project.

- **Utilization Technologies**

- AMM projects are able to use medium-quality gas technologies such as boilers, heaters, reciprocating engines for electric power, and flares/combustors.

- **Coal Mine Involvement**

- AMM projects are simplified by not having the mine control all methane extraction activities based on safety considerations.

- **Gas Ownership**

- AMM projects may need gas leases that were not required as part of the active mine operations

- **Permits**

- AMM projects can be complicated by the need to apply for new (or separate the existing) licenses or permits.

AMM Development Summary

- AMM projects offer a different set of opportunities and challenges
- Preparing an active mine for methane extraction at the time of closure can prove beneficial
- Perform a proper gas resource evaluation to adequately size project equipment
- Important to update reserves model based on flow tests or methane production

Contact Information

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Mine Methane Capture to Carbon Offsets, Lessons Learned



Evan Vessels
Vessels Carbon Solutions



Coalbed Methane Outreach Program Webinar
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Mine Methane Capture to Carbon Offsets, Lessons Learned

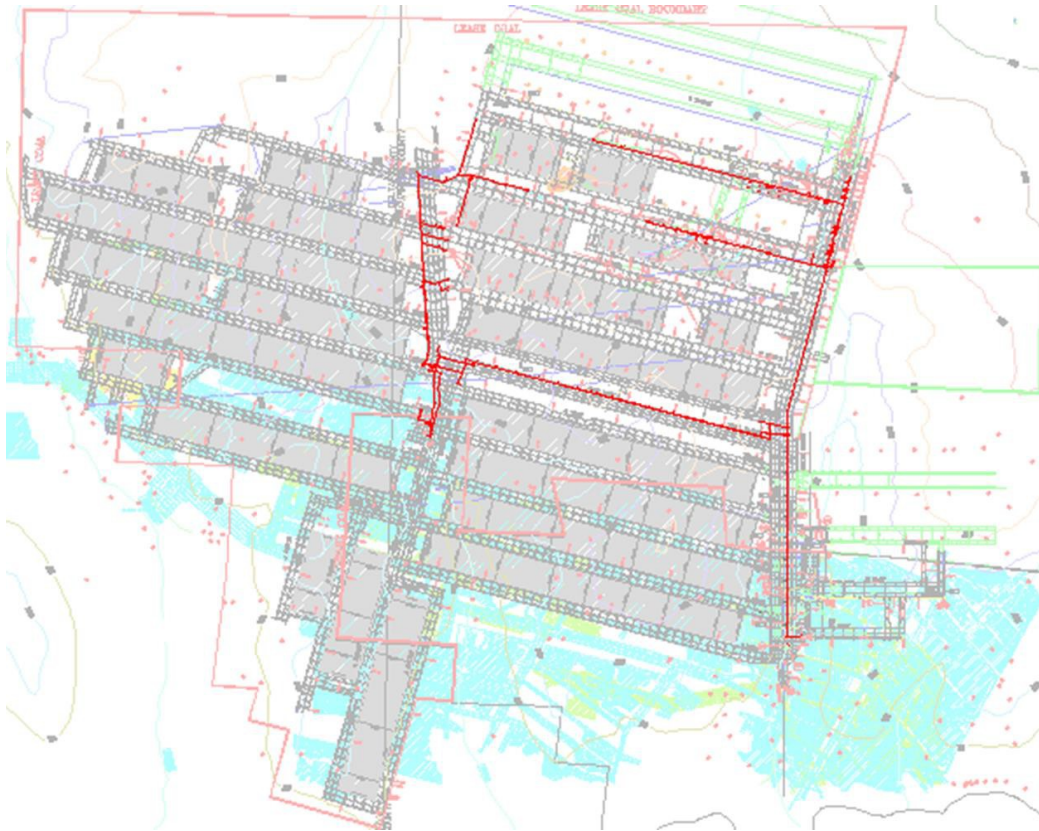
Evan Vessels, Manager
Business Development, Outreach
Vessels Carbon Solutions, Inc.

Prepared for
CMOP Webinar 10.03.19

Elk Creek Mine D seam - Somerset Coal Field Colorado



Mined \approx
5,000,000 tons
per year



Elk Creek Methane Drainage System, D Seam

Methane
drainage from
horizontal degas
holes behind
seals

Elk Creek Coal Mine Methane Destruction and Utilization Project



Pipeline

Gas conditioning:
Remove water, filter
Cool
Pressurize

Control
buildings

- 3 MW (3,000 kilowatts) of electricity generation capacity, combusting > 600,000 scf of methane
- Enclosed combustion of up to 2,500,000 scf of methane
- Reliability: 95% operational availability
- Design flexibility: 20 – 90% methane gas concentration

scf = Standard cubic feet

Elk Creek Coal Mine Methane Destruction and Utilization

Project Registered with American Carbon Registry (CAR)

Listed with California Air Resources Board (ARB)

North Fork Energy LLC

Manager, Vessels Carbon Solutions Inc.

Equity owners:

OXBOW Mining LLC

Gunnison Energy Corporation

Vessels Carbon Solutions Inc.

3 MW LLC

Manager, Vessels Carbon Solutions Inc.

Equity owners:

Aspen Skiing Company

OXBOW Mining LLC

Gunnison Energy Corporation

Vessels Carbon Solutions Inc.



Thermal oxidizer constructed as accessory to generation project

- Implementation of California Cap & Trade program provides attractive economic return
- ≈770,000 offsets by 2019



Project completed within capital budget and performing above annual operational targets of 27,000 megawatt hours and associated renewable energy credits. Project has produced 303,000 offsets.

Reciprocating Engine Generator Set



- 1,500 horse power engines each consume 230 MMbtu/d
- Each generator nominal 1.1 MW of power at 4,160 volts
- 1,800 revolutions per minute
- Computer controlled fast-acting butterfly valve on gas inlet
- Engine control units, monitors and synchronizes frequency and voltage to match local electricity cooperative Delta Montrose Electric Association's high-voltage distribution

Elk Creek vacuum pumps of methane drainage system



- 200 horse power (HP) variable frequency drive (VFD) control
- VFD 8 Stage Lamson
- 75,208 vacuum pumps 3,000 cubic feet per minute per unit
- Gas exits at 190° F
- Methane concentration of 30 - 90%

Surface Methane Gathering Pipeline



- 20-inch diameter steel pipe connected to base of prior vent stack
- Preferentially conveys gas to methane destruction facilities
- Provides initial convection cooling

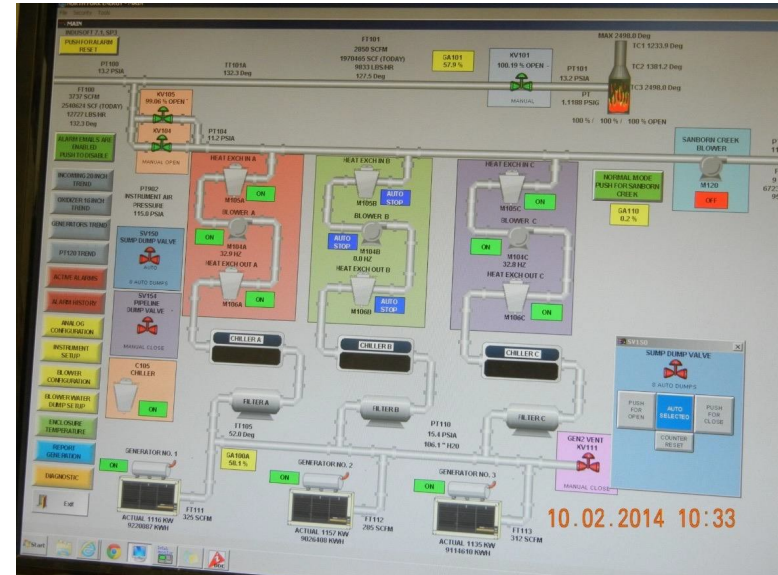
Methane Distribution

Treating for water reduction and filtering,
Cooling and pressurizing.



- Delivery to 3 MW site by 20 inch diameter steel pipe
- Fail-safe valve system
- Gas measurement and monitoring
- Option of delivery to oxidizer or electric generators or both

MCC & SCADA Buildings



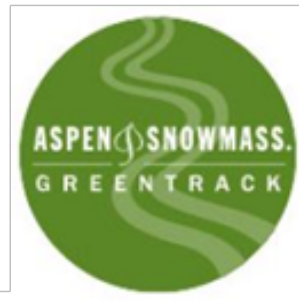
Control screen for customized operational software

- Monitors gas streams and controls gas conditioning skid as well as provides central control of electricity generator sets and thermal oxidizer
- Provides for unattended operations and remote control from PDA (iPad, iPhone)
- Monitors methane concentrations and volumes and records results
- Meets ARB Standards to record methane destruction
- Registered under CAR and listed with ARB

Current methane production is far below the estimated volume of emissions

- We are currently unable to increase suction on the mine to increase gas flow to our destruction facility
- High concentrations of methane have been detected seeping out of old mine portals
- Oxygen has been detected in the gas stream where there should not be oxygen
 - Free flowing oxygen will bond with coal in a short period of time to become carbon dioxide (CO₂)
- International best practice for CMM capture includes resealing mine portals
- We have identified 20 mine portals across the mine area we would like to reseal

Project scoping and partnering.



Project Proponents

- Del Worley, Chief Executive Officer - Holy Cross Energy
- Randy Udall – energy advisor to Holy Cross Energy

- James T. Cooper, President - OXBOW Mining LLC
- Brad Robinson, President – Gunnison Energy Corporation
- Mike Ludlow, Executive Vice President – OXBOW Mining LLC

- Mike Kaplan, President – Aspen Skiing Company
- Matt Jones, Chief Financial Officer – Aspen Skiing Company
- Auden Schendler, Vice President Sustainability - Aspen Skiing Company

- Tom Vessels, President - Vessels Carbon Solutions
- Julian Huzyk, Chief Operating Officer – Vessels Carbon Solutions

Getting into an active mine is very difficult, and addressing the concerns of the mine operator at the outset is key

- How will mine methane capture (MMC) impact the mining?
- Commitment to not interfere with mining
- Volatile Organic Compounds (VOCs) which are regulated get destroyed along with the methane.
- Mining company does not have to invest.
- Vessels Carbon Solutions creates a new cash flow stream for the mine.

What Worked

Local support and likeminded partnerships:

- The local environmental community constantly advocated for CMM capture and destruction
- Holy Cross Energy were willing to pay a premium over standard grid electricity to support a project that generated electricity with zero carbon emission
- Aspen ski company wanted to reduce there carbon foot print to zero and so invested 90% of the cost of the project. Their footprint is far below zero.
- Jim Cooper (Mine Operator and President) thought the emissions of methane from the Elk Creek Mine were extremely unfortunate. He championed our project and persuaded corporate management to let him do a deal with us

Cap and Trade

- Cap and Trade is the bread and butter of our success
- It puts a price point on direct greenhouse gas (GHG) reductions
- Enormous regulatory burden is made up for by the fact that it is profitable

What Didn't

Renewable Portfolio Standard (RPS):

- In many states, MMC is part of a state renewable energy program. Colorado and Pennsylvania are 2 such states
- In Colorado, the RPS mandates 20% of power generation comes from renewable sources for rural electric associations. Only 3 MW of renewable energy generation comes from MMC
- Due to the high cost of electricity generation from MMC, electricity from MMC destruction is not cost-competitive with wind and solar.
- In Pennsylvania the renewable energy generation was an afterthought due to the fact that we were generating electricity for ourselves onsite, and later discovered that we could get Renewable Energy Credits for it
- Selling the renewable electricity has not been profitable; only the destruction of excess gas by flaring has made mine methane capture possible
- Renewable energy might be defined by KWHs of energy generated and not by carbon emissions reductions.

What Didn't (continued)

Regulation

- There are no regulations in any state we have operated in that has a framework for methane reduction. We are not permitted to seal abandoned mine shafts
- We are not permitted to capture and destroy additional methane from Bureau of Land Management (BLM) land
- The BLM has indicated that if a state level regulatory body is willing to permit a methane mitigation project, they will consider allowing the operation on their land

Mine methane capture protocol

2,600 scf of methane emission
reduction = 1 ARBOC

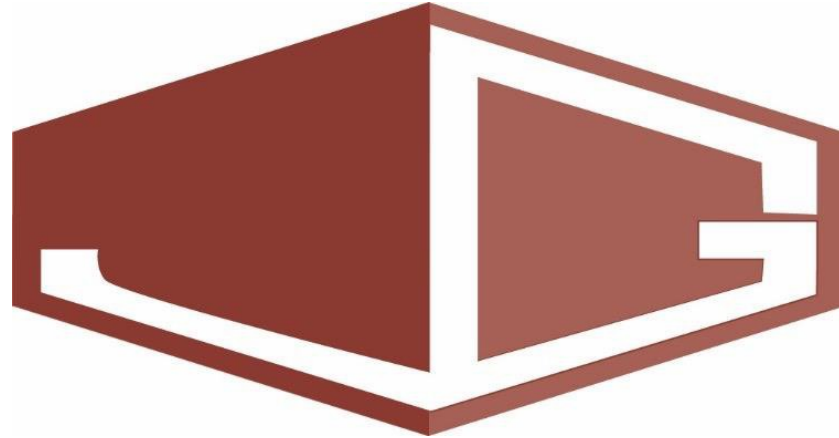
Gas measurement must be every 15
minutes or less continually

Verification and issuances of
ARBOC's can take up to six months

Invalidation risk is significant

California + Quebec Carbon Emission Cap and Trade system

- <http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm>
- Western Climate Initiative, Inc.
<http://wci-inc.org/>
- California, British Columbia, Manitoba, and Quebec are working closely to harmonize carbon reduction programs.



Vessels Carbon Solutions

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Question and Answer Session



To learn more about CMOP, visit:

www.epa.gov/cmop

To connect with CMOP, visit:

www.epa.gov/cmop/forms/contact-us-about-coal-methane-outreach-program

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