Best Practices for CMM Utilization – End Use Options

GMI Coal Mine Methane and Coalbed Methane Technical Workshop
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Clark Talkington, Advanced Resources International, Inc.
Presentation Outline

- Introduction to ARI
- Coal Mine Methane Sources
- Methane Drainage Use Technology Options
- Ventilation Air Methane (VAM) Use Technology Options
- Project Economics
- Developing a CMM Project
- Financing a CMM Project
- Conclusions
Advanced Resources International

- A consulting, research and development firm
- **Principal practice areas**
  - Coal mine methane (CMM)
  - Unconventional gas development (gas shales, coalbed methane and tight sands)
  - Enhanced oil recovery (EOR)
  - Carbon capture, utilization and storage (CCUS).
- **Experience in over 30 other countries**
Sources of Coal Mine Methane

- CMM = 8% of Global CH₄ Emissions
- CMM emissions are growing.
  - In 2014, CMM emissions totaled 621MMtCO₂e (44 BCM)*
  - By 2030, CMM emissions projected to increase to 784 MMTCO₂E (55 BCM)*

Share of Global CMM Emissions from Major Coal Mining Countries (Million tCO₂e)

Source: US EPA 2012
Integrated CMM Capture and Utilization at an Operating Mine

Methane Drainage Value Chain

**METHANE EXTRACTION AND RECOVERY**
- **Vertical Degasification Wells**
- **In Mine Well**
- **Gob Wells**

**GATHERING, COMPRESSION, AND PROCESSING**
- **Compression**
- **Dehydration**
- **Gas Processing**
- **Power/Heat Generation**
- **Sales Metering**

**High Quality Methane (95%+ CH)***

**Low/Medium Quality Methane (30% 70% CH)**

**METHANE TO MARKETS**
- **Regional and Export Gas Sales**
- **Power Generation**
- **Chemical Feedstock**
- **Methanol Production Plant**
- **Transportation Fuel**
- **Compressed Natural Gas Refueling Station**
# Methane Drainage Use and Destruction Technology Options

<table>
<thead>
<tr>
<th>Technology</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Natural Gas Pipeline Sales</td>
<td>• Economic where extensive gas pipeline network is accessible&lt;br&gt;• Requires consistently high gas quality to meet pipeline specifications.</td>
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<tr>
<td>Power Generation</td>
<td>• Most common use worldwide&lt;br&gt;• Used mostly in internal combustion (IC) engines but can be used in gas turbines.&lt;br&gt;• Modular configuration with small engines (500kW-3 MW) are most common</td>
</tr>
<tr>
<td>Vehicle Fuel – CNG/LNG</td>
<td>• Requires a very pure methane stream.&lt;br&gt;• Infrastructure necessary to move CNG/LNG to market or use on-site&lt;br&gt;• Expensive options but becoming more attractive</td>
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<tr>
<td>Boiler Fuel</td>
<td>• Very common&lt;br&gt;• Used to heat water or air for mine buildings (e.g. showers/space heating) and shaft heating.&lt;br&gt;• Not technologically complex and can use mine gas with 30% CH4 concentration.</td>
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<tr>
<td>Direct Heating</td>
<td>• Mine shaft heating in winter&lt;br&gt;• Industrial furnaces</td>
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<tr>
<td>Flaring</td>
<td>• Destruction-only technology. Can use mine gas with concentrations down to 30%.&lt;br&gt;• For stranded gas with no market, as an interim GHG destruction option, or to destroy excess GHGs in an integrated CMM project.</td>
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<tr>
<td>Other uses</td>
<td>• CMM has been used in methanol production, glass making, steel manufacturing, desalination plants, green houses, and coal drying.</td>
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</table>
Methane Drainage Key Points

- Technologies to use or destroy CMM are the same as those that use natural gas.

- End use is determined by many factors:
  - Gas quality (CH$_4$ %)
  - Gas quantity (4.2 m$^3$/min CH$_4$ = 1 MW)
  - Access to markets
  - Infrastructure
  - Financial position
  - Staff capacity
  - Mining company priorities
  - Government policy priorities
Methane Drainage Key Points

- Projects often include a portfolio of technologies to maximize gas use.

- When deciding what technology to use:
  - Power, flaring, boilers, and vacuum pumps require minimal gas treatment
  - LNG, CNG, and pipeline sales require expensive gas treatment

- In order to implement a successful methane drainage project:
  - Improve gas availability (gas quantity and quality) and maintain CH4 concentrations above the explosive range
  - Size plant properly- 80% of average gas flow
  - Flare gas when not used rather than venting
  - Regular maintenance and overhaul are required to keep the plant operating
Ventilation Air Methane (VAM) Technology Options

Range of Technologies have been identified
Only 2 have been used commercially

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<th>Regenerative Thermal Oxidation</th>
<th>Ancillary Use as Combustion Air</th>
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<tbody>
<tr>
<td>• Oxidizes VAM at 1000°C</td>
<td>• Successfully used in Australia at a 54 MW CMM power plant use 1 MW internal combustion engines</td>
</tr>
<tr>
<td>• Technology common in manufacturing operations to destroy very low concentrations of VOCs</td>
<td>• Improved efficiency of the gas engines</td>
</tr>
<tr>
<td>• Destruction only or energy recovery</td>
<td>• Resulted in some corrosion problems</td>
</tr>
<tr>
<td>• 1 VAM power project in Australia, and 1 under construction in China.</td>
<td></td>
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</table>

Duerping Mine (China)  
Marshall County Mine (USA)  
Jim Walter Resources Blue Creek #4 (USA)
VAM Technologies on the Horizon

- Regenerative Catalytic Oxidation
- Lean-burn turbines and microturbines
- Rotary Kilns
Ventilation Air Methane (VAM) Key Points

- Success of projects is almost entirely dependent on carbon markets
- Some potential for power generation, but it requires a consistent and high VAM concentration (1% CH₄)
  - One option is to enrich the VAM with supplemental drained gas
- CH₄% is critical – the higher the CH₄% the larger the emission reductions and the more carbon offsets that are generated.
- Proven technologies are available and in operation
- Other technologies close to commercialization
### Project Economics - Gas Drainage

Projects often include a portfolio of technologies to maximize gas use.

- **A CMM power project will typically include:**
  - Gas engines with generators
  - Flare
  - A passive vent
  - Possibly heat recovery

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<th>Technology</th>
<th>Capital Costs</th>
<th>Operating Costs</th>
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<tr>
<td>Flaring</td>
<td>$120,000 - $450,000 (290 - 1,089 mln Colombian Peso)</td>
<td>$10,000 - 20,000 per year (24 - 48 mln Colombian Peso)</td>
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<tr>
<td>Enclosed (ground flare)</td>
<td>$30,000-130,000 (72 – 314 mln Colombian Peso)</td>
<td>$5,000 -15,000 per year (12,106,250 – 36,318,750 Colombian Peso)</td>
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<tr>
<td>Open (candlestick flare)</td>
<td>$0.75 - 1.5 million per MW installed (1,815 – 3,631 mln Colombian Peso)</td>
<td>$0.015 - 0.03 per kWh (36.319 – 72.638 Colombian Peso)</td>
</tr>
<tr>
<td>Power generation</td>
<td>$2 - $4 million (4,842 – 9,685 mln Colombian Peso)</td>
<td>$400 - $600K per year (968 – 145 mln Colombian Peso)</td>
</tr>
<tr>
<td>Natural gas pipeline sales (assume gas conditioning)</td>
<td>$3 million per 1 MMcf/d processed (7,263 mln Colombian Peso)</td>
<td>$1.5 - $2 million per year (3,631 - 4,842 mln Colombian Peso)</td>
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**Project Economics - VAM**

### VAM Destruction and Use

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<th>Technology</th>
<th>Capex</th>
<th>Opex</th>
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<tr>
<td>Regenerative Thermal Oxidizer (RTO)</td>
<td>$50,000-$75,000 per m$^3$/s throughput installed (eg. 60 m$^3$/s unit = $3-4.5 million) (121 mln – 181 mln Colombian Peso)</td>
<td>60% of lifecycle project costs for a 10-year project (for 60 m$^3$/s unit, opex = $675,000/yr)</td>
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- VAM projects are capital intensive
- VAM projects can have high O&M costs
- Can generate significant revenue at attractive carbon prices due to high CH$_4$ throughput

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**Breakeven price of an example VAM project at different CH$_4$ concentrations**
Financing a CMM Project

- **Available funding**
  - Do it yourself- internally financed
  - Private Equity
  - Debt providers- commercial or investment banks
  - Targeted investment funds
  - Developer/ investors
  - Carbon credit buyers or buyers with focus on Corporate Social Responsibility

- **Critical to secure financing from 3rd parties**
  - Credible gas resource assessment and full feasibility study with financial analysis
  - Off- take agreements with credit- worthy partners

- **Secure carbon financing or other environmental finance in addition to internal financing and institutional finance**
Conclusions

- There is a long history of CMM capture and use worldwide and much experience to access.
- Recovery of CMM is largely from underground mines but there have been surface mine methane projects.
- Power generation, boiler fuel, gas pipeline sales, flaring and local distribution are the most common uses for gas drainage.
- VAM accounts for 70% of methane emissions from underground coal mines.
  - Any sustained effort to reduce Greenhouse Gas emissions from the coal sector must address VAM emissions.
  - Regenerative Thermal Oxidation is a commercially proven technology available currently in use.
  - Other technologies have been field tested and are close to commercialization.
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