Workshop on Best Practices in Coal Mine Methane Capture and Utilization
Bogotá, Colombia

Estimating CMM Resources and Converting them to Reserves

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Outline

• Background
• Resource Estimation and Classification Schemes
• Classification Schemes and Methods of Resource Estimation
• Principles of CMM Resources Estimation
• Conclusions
Background
The future of methane management is innovation in policy, business and technology deployment

- For the purposes of this presentation, coal associated methane, referred to as coal bed methane (CBM), coal mine methane (CMM), surface mine methane (SMM), ventilation air methane (VAM), abandoned mine methane (AMM), at various stages of methane liberation during the coal mining cycle offer significant potential to aid in achieving lower carbon environment in Colombia.

- Colombia is poised to make innovative advances in policy development, creating adaptive business models, and technology
Value of coal associated gas reserves are not recognized as corporate assets

• Other unconventional energy resources such as CBM and some SMM are booked as assets on corporate balance sheets, but CMM, VAM, AMM are not
• The Group of Experts on CMM and the Expert Group on Resource Classification will work together to create a customized classification scheme under the United Nations Framework Classification.
• It will provide clear and consistent specifications, guidelines, and best practices so that these resources are exploited transparently and sustainably in a socially acceptable manner
• Adoption of the classification system will help in produce meaningful statistics that will allow the use of these resources to be monitored and valued appropriately
Input Considerations for Resource Assessments

• CMM
  – SMM integrates knowledge gained from coal resource exploration and coal mine development; generally requires experience in region to reliably forecast resource and producibility and is reliant on coal mine timing.
  – AMM utilizes historical information regarding size and extent of mining and the void created, methane emission during active mining, and time since closure to estimate potential resource. Forecasting is unreliable without AMM gas production reliability.
  – VAM resources largely determined by volume of ventilation air and exposure of coal in mine workings; safety considerations establish limits on methane and ventilation air.
Resources Classifications

- Resources classifications should:
  - Facilitate and organize exploration and development information and data so that the magnitude of a potentially valuable resource is reliably reported
  - Capture the uncertainty of the discovery and the potential for commercial development
  - May incorporate legally defined categories

- Resources classifications are used to assess the relative value of the resource base
- The basis on which resources are publicly reported may be strictly regulated
What External Factors Can/Should be Considered When Estimating and Reporting Resources and Reserves?

- economic
- environmental
- market
- legal
- political
- social
Classification Schemes and Methods of Resource Estimation
McKelvey (1972) Diagram Implies Relative Commercial Potential of Resources By Mapping Uncertainty

<table>
<thead>
<tr>
<th>Cumulative Production</th>
<th>IDENTIFIED RESOURCES</th>
<th>UNDISCOVERED RESOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demonstrated</td>
<td>Inferred</td>
</tr>
<tr>
<td></td>
<td>Measured</td>
<td>Indicated</td>
</tr>
<tr>
<td>ECONOMIC</td>
<td>Reserves</td>
<td>Inferred Reserves</td>
</tr>
<tr>
<td>MARGINALY ECONOMIC</td>
<td>Marginal Reserves</td>
<td>Inferred Marginal Reserves</td>
</tr>
<tr>
<td>SUB-ECONOMIC</td>
<td>Demonstrated Subeconomic Resources</td>
<td>Inferred Subeconomic Resources</td>
</tr>
<tr>
<td>Other Occurrences</td>
<td>Includes nonconventional and low-grade materials</td>
<td></td>
</tr>
</tbody>
</table>
Converting Resources to Reserves — What Determines the Commercial Potential?

- Increases due to improvement in technology
- Increases due to lowered production costs or increased sales price
Joint Ore Reserves Committee Mineral Resources Classification

- **ECONOMIC**
  - Current JORC Reserves
    - Proved
    - Probable
  - Current JORC Resources
    - Measured
    - Indicated
    - Unless assessed by GA as subeconomic

- **SUBECONOMIC**
  - JORC Measured and Indicated resources assessed by Geoscience Australia to be subeconomic
  - (Includes historic resources)

- **SUBMARGINAL**
  - JORC Inferred Resources
    - (Includes historic resource)
The Petroleum Resources Management System (SPE, WPC, AAPG)
Approaches to Estimating CBM and CMM Resources

**CBM**

- Commonly a volumetric calculation for resources:
  - Multiply mass of coal (tonnes) by gas content (cubic meters of methane per ton of coal) = volume of gas in place (equivalent to OGIP or PIIP)
  - Two accepted approaches to calculate estimate:
    - Use low, high, and mid range single values for all parameters; result is a resource estimate ranging from low to high forecasts
    - Stochastic estimate using probability functions developed for each parameter yielding a probabilistic forecast of resources
    - May also include sophisticated reservoir simulation using proprietary or commercial available software.

- Reserves estimates are dependent on understanding historical production and economics and governed by reserve classification schemes approved by government entities
Approaches to Estimating CBM and CMM Resources (2)

**CMM**

- Commonly a volumetric calculation for pre-mine (CMM and SMM) drainage:
  - multiply mass of coal (tonnes) by gas content (cubic meters of methane per ton of coal) = volume of gas in place (equivalent to OGIP or PIIP)
  - Two accepted approaches to calculate estimate:
    - Use low, high, and mid range single values for all parameters; result is a resource estimate ranging from low to high forecasts
    - Stochastic estimate using probability functions developed for each parameter yielding a probabilistic forecast of resources
    - May include reservoir simulation

- Estimates of energy resources that will be recovered from post mine drainage of CMM and VAM are dependent on analysis of historical data documenting volume/mass of production and the rates at which coal and gas were produced.

- AMM resources may be estimated by various approaches, but reserves estimation is wholly dependent on testing and establishing stable (but declining) production; it is complicated, and the focus of work that the UNECE GoE on CMM and GMI are conducting.
Example of VAM data and energy resource calculations

Datong Coal Mine

Total Supplemental CH₄, 2007 - 2008: 29,303,251 m³

Optimum Abatement System Operating Concentration

Daily CH₄ Concentration

Drained CH₄ Required to Supplement VAM

Shihao Coal Mine North Fan

Total Supplemental CH₄, 2007 – 2008: 30,251,267 m³

Optimum Abatement System Operating Concentration

Drained CH₄ Required to Supplement VAM

Missing Data

* Total does not include period of missing data.
Example of correlation of VAM concentration to rate of coal production

Shihao Mine Coal Production & Shihao North and South 2 Ventilation Shafts Percent CH$_4$ in VAM

- South 2 Fan
- North Fan
- Coal Production

Date:

29-Nov-06  18-Jan-07  9-Mar-07  28-Apr-07  17-Jun-07  6-Aug-07  25-Sep-07  14-Nov-07  3-Jan-08  22-Feb-08

Coal Production:

0  20,000  40,000  60,000  80,000  100,000  120,000

CH$_4$ Concentration in VAM:

0.00%  0.10%  0.20%  0.30%  0.40%  0.50%  0.60%  0.70%  0.80%
Drained and vented gas correlated to coal production
Coal and Gas Resources and the Coal Mining Life Cycle

Coal Mining Life Cycle

- **Mine Planning**
  - Undeveloped Coal Reserves
  - Gas Resources Evaluated and Production Plan Adopted
  - Exploration

- **Active Mining**
  - Developed Coal Reserves
  - Gas Produced and Sold During Mining
  - Pre-mine and Gob Drainage

- **Mine Closed**
  - Depleted Coal Reserves
  - Enhanced CH₄ Recovery and CO₂ Sequestration
  - Post-mining Gas Production

Gas Production Life Cycle

Pilcher, 2013
Comprehensive extraction lifecycle

Accurate and transparent management of energy & materials throughout the lifecycle
How the UNFC uses economic, social and knowledge of occurrence to classify the resource
Conclusions

- Principles of resource and reserve calculation schemes must be understood and consensus reached among regulatory agencies in order to establish reasonable policy that:
  - encourages commerce
  - protect the environment
  - protect the rights of the mineral owner
  - protects investors
  - provides energy security to society

- As a community, we need to adopt an approach to CMM resource and reserve estimation that ensures the above listed principles
Gracias!

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