Maximizing Value of Abandoned Mine Methane

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Michael Coté, President
Presentation Outline

- Introduction
- Preparing Underground Workings
- Evaluating AMM Resource
- Estimating Reserves
- Mine Aggregation
- Conclusions
AMM Pros and Cons

- AMM flows decline over time
- No mine ventilation air to compete with
- AMM infrastructure smaller than CMM
- AMM gas ownership issues
- Sealing integrity of mine vents & pipes
- No mining company involvement
- High and consistent quality
Actual AMM Production vs. Decline Curve Model Forecast

Default Decline Curve
Preparing Coal Mines for AMM Projects

AMM Recovery - Sooner is Better!
- AMM Emissions Forecast Using Decline Curve Estimate

Active Mine Emissions = 100,000 M³/Day

<table>
<thead>
<tr>
<th>TIME</th>
<th>Emissions (million M³/yr)</th>
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<tbody>
<tr>
<td>First 5 years</td>
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<tr>
<td>Next 13 years</td>
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<tr>
<td>First 10 years</td>
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<td>Next 27 years</td>
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<td>First 20 years</td>
<td></td>
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<td>Next 58 years</td>
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Preparing Underground Workings at Active Mines

- Installing gas piping underground
- Accessing sealed mining districts
- Using the mine roadways as conduit for methane flow
- Verify integrity of surface seals to prevent atmospheric air intrusion
Installing Underground Pipes to Access Sealed Areas
Installing Underground Pipes to Access Sealed Areas
Accessing Sealed Areas Using Mine Roadways
Accessing Sealed Areas Using Mine Roadways
Evaluating AMM Resources

- **Pressure Testing**
  - Estimate the void volume using mine maps and coal production records.
  - Continuously monitor the static pressure of a borehole/well and barometric pressure.

- **Flow Testing & Pressure Buildup**
  - Continuously monitor gas flow rate, methane content and upstream pressure.
  - Shut-in well, let pressure stabilize at a predetermined volume recovered.
  - Compare actual P to expected P from void model.
Evaluating AMM Resources

Photo courtesy of Perennial Energy
Estimating Reserves

- **Analyzing Results**
  - A comparison of the *pressure change* vs *gas volume recovered* will provide an indication of the methane volume in contact with the wellbore
  - Repeat procedure for additional wells (if applicable)
  - Test data can be compared to a generic decline curve that was used in the original resource assessment
Estimating Reserves

- **Forecasting Production**
  - Initial Forecast - Recalibrate model to conform to flow test results
  - Follow-up Forecast - Apply a best fit decline function to the actual production data
  - Project decline function into future years
  - Repeat model recalibration every one or two years
Estimating Reserves

![Graph: Project Actual Production and Matched Decline Curve](image)
Aggregating Abandoned Mines in the U.S.

- Total AMM Projects –
  - 19 AMM projects at 45 mines

- Aggregated Projects –
  - 3 AMM projects group 3-5 mines into a single project
  - 1 AMM project aggregates methane from 14 mines
  - 3 AMM projects are combined with existing CMM projects
Example AMM Project – Illinois, U.S.

- 14 mines
- 31 wells
- 70% CH₄
- 34,000 hectares
- 11 field stations
- 85 mM³/day
Technical Barriers

- Uncertainty in methane resource
- Geological conditions
- Water flooding
- Compartmentalization
- Adequate piping and seals upon closure
- Suction pressure
- Remote locations with limited access
Conclusions

- AMM projects offer a different set of opportunities and challenges
- Perform a proper resource evaluation to adequately size the project
- Preparing an active mine for methane extraction at the time of closure
- Important to update reserves model
Thank you!

Michael Coté, President
Tel: +1-970-241-9298 ext.11
Email: mcote@rubycanyoneng.com
Website: www.rubycanyoneng.com

Felicia Ruiz
Coalbed Methane Outreach Program
Tel: +1-202-343-9129
Email: ruiz.Felicia@epa.gov
Website: www.epa.gov/cmop