Quantifying Resources, Reservoir Testing, Feasibility Study, Gas Production Strategies, AMM Utilization Options

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Capture and Use of Abandon Mine Methane and Mine Reclamation and Revitalization of Post Mining Areas
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Quantifying AMM resources

Gas Resource

Area thickness x residual gas content after mining

Gas Reserve

Technically & economically recoverable resources

- Develop estimate based on data
  - Mine plans
  - Geological logs
  - Water inflow data
  - In situ gas measurements

Source: EPA, Advanced Resources International, REI Drilling
AMM reserves

- Mean desorbable remaining gas content in UK = 25-50% of original virgin gas content
  - 35% is a reasonable default
- Longwall mines more attractive AMM resource than board-and-pillar mines
  - Sealed goaf (gob)
  - Zone of influence: 160-200m above and 40-70m below
- 1 AMM project can produce gas from multiple worked seams
- Mine flooding can severely impact volumes of AMM reserves

Source: Creedy, D. P., and K. Garner, 2002 & UNECE AMM Best Practice Guidance, 2020
Understand existing water levels and rate of flooding

- **Mine already flooded**
  - Cannot produce gas without dewatering
  - Pumping is not economic
  - Environmental implications

- **Mine partially flooded; water levels stabilized**
  - May have gas production capacity
  - Districts isolated by flooding can impact effectiveness of vacuum

- **Mine flooding after closure and water table rising**
  - Compresses gas and can lead to short-lived high production rates
  - Eventually mine floods and gas production ends
Producing gas from abandoned mines

- Boreholes are drilled into the workings, intersecting roadways which provide pathway for gas flow underground
- CH$_4$ desorbs from coal seams entering goaf areas
- Reservoir pressure may be sufficient at the beginning to produce gas
- Eventually vacuum pumps will be required to draw gas to the surface
- May require dewatering, dust removal and gas conditioning
Forecasting AMM production

- Follows a decline curve
- Starting point is methane emissions at closure
- Measure gas flow rates to support production forecasts
  - Drill test well(s) and produce gas over a specified period of time
  - Take measurements from a vent pipe with or without vacuum
- History matching improves accuracy

Source: UNECE AMM Best Practice Guidance from Coté (2003, 2018)
AMM project feasibility

- Recoverable reserves
- Gas resources
- Surface activity
- Adjacent operations
- Site access
- Mine plan
- Mine operating history
- Alternative fuels
- Legal framework
- Project Capex/Opex
- Market access
- Offtake agreements

Photo Source: UNECE AMM Best Practice Guidance
Gas production strategies

- Extract as much CMM as possible before closure
- Maximize extraction in early years after closure and sealing
- Produce AMM to match specific user demand

Optimizing AMM

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Benefit</th>
<th>Risk</th>
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<tbody>
<tr>
<td>Produce at less than maximum rate</td>
<td>Extend life</td>
<td>Lose reserves to flooding or other issue</td>
</tr>
<tr>
<td>Produce to satisfy peak demand</td>
<td>High peak tariffs</td>
<td>Tariffs may change potentially stranding reserves</td>
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<tr>
<td>Mix AMM with natural gas or CMM</td>
<td>Reduce costs/improve market access</td>
<td>Dependent on uses where lower gas quality is acceptable</td>
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<tr>
<td>Portable package systems for power gen</td>
<td>Flexibility</td>
<td>Sites need to be ready when time to move</td>
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AMM utilization

- Reduce risk of surface gas emissions
- Power Generation & CHP
- Opportunities for industrial park development
- Pipeline or town gas sales
- Local employment and job training
- Flaring

**GHG Emission Reductions**

**Energy Recovery**

**Public health & safety**

**Economic development**
Summary: Key features of a promising AMM project mine

- Extensive area of interconnected abandoned workings
- Large coal volume in unmined seams de-stressed by under and overworking
- Use of longwall total caving methods of extraction
- Significant residual methane in the unmined coal seams
- Minimal water ingress and ability to reduce water ingress
- Mine layout which encourages flow of water to lowest workings with little or no ponding in main roadways
Summary: Key features of a promising AMM project mine (cont.)

- Minimum number of mine entries
- An unfilled shaft or drift from which gas can be extracted or a suitable site for drilling a gas extraction borehole
- Good records of historic treatment of mine shafts
- No connections to shallow outcrop workings
- Surface access for infrastructure and development
- Local market for gas or small-scale power generation and high energy prices.
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