‘Gas Capture Maximisation’ approach for avoiding methane emissions in ventilation air

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Presentation Outline

• Introduction
• Fugitive emissions from underground coal mining
• Ventilation strategies for VAM mitigation
• Current gas drainage scenario and challenges
• Gas capture maximisation strategies
• GHG friendly mine scenario
• Conclusions
Introduction

• Australian coal industry – highly gassy mining conditions
  – Coal seams gas contents ranges from < 1.0 m$^3$/t to about 18 m$^3$/t
  – Specific gas emissions (SGE) up to 20 m$^3$/t of coal production (to 35 m$^3$/t)
  – Goaf gas emissions generally from 300 l/s to 3,000 l/s (even to 8,000 l/s)

• Complex mining conditions
  – Thick and multiple coal seams (& strata gas)
  – Depths approaching 600m, low permeability, structures, ..etc
  – Mines in remote areas, surface/environmental constraints, ..etc

• Coal seams are also prone to spontaneous combustion
  – Complicates goaf gas drainage issue (requires balancing/optimisation)
Fugitive emissions from UG coal mining

- UG fugitive emissions ~16 to 17 Mt CO$_2$-e (Total ~28 Mt)
- Total VAM around 30 m$^3$/s CH$_4$ (13 to 14 Mt CO$_2$-e)
- Total drained gas ~ 20 m$^3$/s CH$_4$
  - Drained gas ~ around 40% of total (20 m$^3$/s out of total 50 m$^3$/s)
  - 75% of pre-drained gas used for Power generation and in Flares

Gas emission rates and relationships

- CO$_2$-e and methane (CH$_4$) flow rates
  - 1 m$^3$/s CH$_4$ ~ 0.45 Mt/y CO$_2$-e (10 Mt CO$_2$-e ~ 22 m$^3$/s)
- CH$_4$ emissions and carbon charge
  - At A$23/t CO$_2$-e, 1 m$^3$/s (1,000 l/s) emissions ~ $10 M/year
Coal mine fugitive emissions intensity

- For example, gassy underground mine producing 5 Mt with intensity of 0.3 – total emissions around 1.5 Mt of CO₂-e, which equates to $35 M/yr (at cost of @$23/t)
- From this emissions intensity figure, we can see that
  - CO₂-e charge for a number of UG mines will be > $10 M/yr (for some mines over $25 M/yr)
  - Other mines will also face significant carbon charges
- Need to reduce fugitive emissions significantly from UG coal mines
Ventilation Air Methane (VAM) – in Australia

- Total VAM emissions - over 30 m³/s (out of total 50 m³/s from UG mines)
- As most of the drained gas is utilised/flared, VAM emissions represents 80-85% of the total fugitive emissions from UG mines
- Low CH₄% in VAM presents a challenge for utilisation or mitigation

VAM mitigation – Ventilation Options

- Example: LW mine 330 m³/s @ 0.55% CH₄ = 0.8 Mt CO₂-e
- To minimise these emissions, options include:
  - Mitigating the entire main ventilation VAM with > 0.3% CH₄
  - Ventilation modification and targeting only part of vent system at higher CH₄%
- LW airflow is typically around 30% of mine ventilation, but may contain up to 70% of the gas reporting to main ventilation VAM
VAM mitigation – Ventilation options (1)

- Total VAM ~ 0.8 Mt CO₂-e
- VAM charge $20M/Y
- Total VAM mitigation – not feasible
- LW 70 m³/s at 1.5% CH4
  - VAM mitigation $10M
  - Remaining carbon charge $7M
- Other VAM mitigation options

Targeting LW return/bleeder for VAM mitigation optimisation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Main Shaft m³/s</th>
<th>Main Ex Shaft CH4 %</th>
<th>VAM Shaft(s) m³/s</th>
<th>Capex $M</th>
<th>CO2-e Charge $M/year</th>
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<tr>
<td>No VAM destruction</td>
<td>331</td>
<td>0.53</td>
<td>0</td>
<td>0</td>
<td>19.56</td>
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<tr>
<td>Tailgate only</td>
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<td>0.26</td>
<td>70</td>
<td>9.735</td>
<td>7.757</td>
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<td>Taigate and lead gate</td>
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<td>0.22</td>
<td>135</td>
<td>18.882</td>
<td>4.103</td>
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<tr>
<td>Taigate and both gates</td>
<td>146</td>
<td>0.11</td>
<td>185</td>
<td>26.265</td>
<td>1.855</td>
</tr>
</tbody>
</table>

![Graph showing Capex $M and CO2-e $M/year for different scenarios](image)
VAM mitigation – Ventilation options (2)

- LW bleeder gas up to 2% CH₄
- Gas from adjacent goafs
- Alternative ventilation layouts
- Peripheral/split vent systems
- Changes in mine design/layouts
- Safety issues to be considered

Bleeder ventilation of longwalls and goaf bleeders – VAM mitigation
VAM mitigation – Key points

- VAM is 60% of UG CMM emissions and represents 80-85% fugitive emissions
- VAM mitigation – still an issue and difficult to mitigate all VAM emissions

- Targeting only part of ventilation at higher CH₄%
- Modifying mine ventilation to increase CH₄% in VAM for mitigation
- Increasing gas capture and using some gas for VAM mitigation

- Increasing ‘mine gas capture’ to reduce total VAM emissions - best strategy

- Gas drainage strategies/options to reduce VAM/fugitive emissions
Current gas drainage scenario

• Total gas drained ~ 20 m$^3$/s CH$_4$ (and 3 m$^3$/s CO$_2$)
  – Pre-drainage gas ~ 12 m$^3$/s and goaf drainage ~ 11 m$^3$/s
  – Drained gas ~ 40% of total 50 m$^3$/s (VAM ~ 30 m$^3$/s CH4)

• Total 14 mines using gas drainage (pre-drainage and/or goaf drainage)

• Pre-drainage for outburst prevention – only in working seam

• Goaf drainage to control gas in longwall panels

• Gas drainage main objectives - Gas control and Outburst prevention – not necessarily ‘Gas Capture Maximisation’ at the moment
Typical gas drainage in mines

LW mines methane emissions and capture efficiency
Future challenges – in gas control

- Mines getting deeper – high gas & less perm
- Goaf gas drainage – surface restrictions
- Multiple seams mining – goaf drainage issue
- Thick seam extractions – more gas emissions
- Sponcom issues vs goaf gas drainage rates
- Remote mines (and less local demand) – issue for gas capture maximisation
- Safety issues – to capture CH$_4$ at < 30%

- Current CMM capture (both pre-drainage & goaf drainage) from all coal mines (around 12 to 14 mines) ~ 20 m$^3$/s = 20,000 l/s only
- In future, we get that much gas flow from just a few mines & more challenges
Gas drainage practices and approach

- Gas capture efficiency ~ 40% to 50% (highest 75%)
- Need to improve gas drainage efficiencies significantly
- Need to introduce additional gas drainage in mines - even if not necessary for statutory compliance purposes
  - For example, $10M/y to capture additional 1,000 l/s may be cost effective
- Current perceptions of ‘more gas drainage results in more goaf gas emissions’ need to change
- Need to change from current “Gas Control” approach to “Gas Capture Maximisation” approach
Gas Capture – UG goaf drainage in China & UK

- Gas drainage focus on near face active zone (in front and close behind)
- Note: Capture efficiency of 50% achieved even at low flow rates
- Purity is an issue – some times < 30% CH₄

Total gas drained = 110 l/s CH₄
Total in ventilation = 102 l/s CH₄
Efficiency = 50%
Gas Capture – Unconventional hole patterns

Return roadway
Longwall block and working seam
Intake roadway
Gas drainage boreholes
Gas drainage roadway in floor rock
Gas Capture – Alternative post-drainage strategies

- Surface MRD pre drainage hole used for goaf drainage
- Remote roof seam
- Close roof seam
- Immediate roof seam
- Close floor seam
- USA extension to floor seams
- High O2
- Main zone of gas emission
- Higher holes - mainly pre drainage effect but maintain integrity into goaf
- Closer holes prone to O2 ingress and cut off
- Superjacent drill galleries

30 to 50m
Up to 2.5km
0 to 300m
Gas Capture – Other techniques

- **Underground patterns +**
  - MRD – standard and reamed
  - Petroleum industry rig capabilities
  - Hydrofracture – multiple completion
  - Nitrogen flushing
  - Pre-drainage – 3 to 10 years ahead
Gas Capture Maximisation (Pre-drainage)

- SIS holes highly successful – but, WS only & 1 – 2 years ahead
  - SIS holes to be used for drainage of upper seams
  - SIS drainage to be implemented 3 – 10 years ahead

- Gas drainage to be carried out, wherever feasible
  - when capturing additional 100’s l/s gas costs < CO₂-e charge. For example, capturing additional 1,000 l/s with $10M/y is feasible

- Additional UG gas pre-drainage (-OR- reduced hole spacing)
- Hydrofrac/stimulation to improve drainage rates & efficiency
- Extensive CBM operations ahead of mining
Gas Capture Maximisation (Post-drainage)

• Goaf gas drainage to be increased from 40% to 80%
  – Deep goaf gas drainage strategies to be implemented, even if not immediately effecting LW return gas levels
  – Gas drainage from overlying and underlying seams

• Both surface and UG goaf gas drainage strategies
• Goaf gas drainage even in low to medium gassy mines
• Trying to achieve 0.3-0.4% CH₄ in LW return (rather than <1%)
• Mine design/vent changes – to maximise gas capture
• Gas capture maximisation practices not widely used
• Increased gas capture – reduces VAM & fugitive emissions
Gas Capture Maximisation – Potential Strategies (1)

- **Very low gas emission mines** \((GRS < 30 \text{ m}^3/\text{m}^2, WS \text{ gas} < 3 \text{ m}^3/\text{t})\)
  - Conventional pre-drainage may not be feasible
  - Consider sealed area goaf drainage, if significant

- **Low gas emission mines** \((30 < GRS < 50 \text{ m}^3/\text{m}^2, 3 < WS < 5 \text{ m}^3/\text{t})\)
  - Viability of stimulated pre-drainage to be considered
  - Consider goaf drainage of active and sealed areas

- **Medium gas emission mines** \((50 < GRS < 80 \text{ m}^3/\text{m}^2, WS < 7 \text{ m}^3/\text{t})\)
  - Consider pre-drainage of both working and other seams
  - Goaf drainage of active and sealed areas required
  - VAM mitigation with or without split ventilation
Gas Capture Maximisation – Potential Strategies (2)

• High gas emission mines ($80 < \text{GRS} < 110 \text{ m}^3/\text{m}^2$, $WS > \text{outburst}$)
  – Pre-drainage required – and consider increased intensity
  – Pre-drainage of non-working seams too
  – Goaf and sealed area drainage required - and increased efficiency
  – VAM mitigation required for part or all (with or without split vent)
  – Additional gas capture strategies to be considered

• Very high gas emission mines ($\text{GRS} > 110 \text{ m}^3/\text{m}^2$, $WS > \text{outburst}$)
  – All of above +
  – Gas reservoir stimulation techniques
  – Pre-drainage of any interburden/roof gas reservoir strata
GHG Friendly Mine – Ideal Scenario

- Gas drainage – not just for ‘gas control’, but for ‘gas capture’
- Mine/Vent design – allows max gas capture & minimises VAM
- Increased pre-drainage of all coal seams (even when not required)
- Pre-drainage 3 to 10 years ahead
- Active/sealed/deep goaf drainage (even when not required)
- Goaf gas capture – even at low flow rates with low CH₄
- Introducing alternative strategies to increase gas capture
- All captured gas is used for power generation or flared
**GHG Friendly Mine – Ideal Scenario** (2)

- Avoiding methane emissions in ventilation air

**Gas Reservoir Size m³/m²**

LW gas emissions in m³/s at 3.0Mtpy – ideal gas capture scenario
Gas Capture Maximisation – Research Requirements

- Improved gas reservoir characterisation & Q3 determination
- Gas content measurement of all seams after LW retreat
- Gas capture maximisation strategies
- Mine design/layout optimisation for increased gas capture
- Vent design changes for optimum VAM mitigation
- Gas capture in low gassy mines & safe systems for low CH$_4$% drainage
- Gas reservoir stimulation techniques
- Accurate measurement of air flows and fugitive emissions
Conclusions

• Fugitive emissions > 27 Mt CO₂-e (impact on UG mines is large)
• Current gas drainage practice – for outburst and gas control
• VAM 30 m³/s out of 50 m³/s from UG mines (~80-85% fugitive emissions)
• The concept of VAM mitigation alone should be the main focus, as 85% fugitive emissions are VAM – requires a change in approach
• Scope to reduce VAM significantly, through improved gas capture
• Requires a fundamental shift in our approach (from “Gas Control” to “Gas Capture Maximisation”) - to achieve “near zero emissions”
Thank you

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