Developing a Diverse CMM Industry including VAM Utilisation

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Methane to Markets Ministerial Meeting, 15-17 November 2004
Coal mine methane emissions-1

- **Mine CH$_4$:**
  - In Australia: ~6% of GHG production

- **Coal-related methane emission sources:**

  ![Pie chart showing emission sources]
  - R & D focus
  - Underground ventilation 70%
  - Underground drainage 20%
  - Abandoned mines 1%
  - Surface handling 5%
  - Open cut mining 4%

  from IEA report
Mine methane emissions-2

**Underground**

✓ **PRE-DRAINAGE**
  - High CH₄ conc ~ 95%,
  - Relatively consistent flow.

✓ **POST-DRAINAGE**
  - Medium CH₄ conc ~ (>30%),
  - Rapid change in flow rate.

✓ **VENTILATION AIR**
  - Huge amount, 150~300m³/s
  - Variable CH₄ conc <1%.
  - Most difficult to use

Drained CMM available: ~23%

Emissions avoided/methane used: ~12%

Ventilation emissions: ~65%

Underground CMM liberation
(estimated based on mine-site data)
What can we do with the mine methane?

- Combustion
  - thermal oxidation
  - catalytic oxidation
- Purification to make pipeline gas
- Feedstock for chemicals
  - methanol
  - carbon black
## Map of potential technologies

### Mine Methane

<table>
<thead>
<tr>
<th>Mitigation</th>
<th>Use</th>
<th>Mitigation</th>
<th>Use</th>
<th>Use</th>
</tr>
</thead>
</table>

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*Note: The table above outlines potential technologies for mitigating methane emissions from mines. The technologies are categorized by concentration levels (Low, Medium-High) and the methods used for their application.*
Technologies for drainage gas

- *Purification: pipeline gas*
- *Power generation/cogeneration*
  - Reciprocating gas engine
  - Conventional gas turbine
  - Co-firing in power stations
  - Fuel cell power generation
    (electrochemical reaction)
- *Chemical feedstocks*
  - Methanol production
  - Carbon black production
Technologies for ventilation air methane

Ancillary uses
substituting the ventilation air for ambient air in combustion processes
Limited sites or small volumes used *not in case studies*

Principal uses
combustion of the methane in ventilation air as a primary fuel
• Thermal flow-reversal reactor (TFRR),
• Catalytic flow-reversal reactor (CFRR),
• Catalytic monolith reactor (CMR),
• Catalytic lean-burn gas turbine,
• Recuperative lean-burn gas turbine,
• Enriching process (?, *not in case studies*)
Technologies for ventilation air methane - 2

**Principal use technologies**

<table>
<thead>
<tr>
<th>CH₄ mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feature</td>
</tr>
<tr>
<td>Principles of operation</td>
</tr>
<tr>
<td>Catalyst</td>
</tr>
<tr>
<td>Auto-ignition temperature</td>
</tr>
<tr>
<td>Experience</td>
</tr>
<tr>
<td>Cycle period length</td>
</tr>
<tr>
<td>Minimum CH₄ concentration</td>
</tr>
<tr>
<td>Applicability</td>
</tr>
<tr>
<td>Possibility of recovering heat to generate power</td>
</tr>
<tr>
<td>Variability of CH₄ concentration</td>
</tr>
<tr>
<td>Plant size</td>
</tr>
<tr>
<td>Operation</td>
</tr>
<tr>
<td>Lifetime</td>
</tr>
<tr>
<td>NOₓ emission</td>
</tr>
<tr>
<td>CO emission</td>
</tr>
</tbody>
</table>

All need extra fuel added to VAM to generate power.
### Technologies for ventilation air methane - 3

#### CH₄ mitigation & utilisation

<table>
<thead>
<tr>
<th>Feature</th>
<th>EDL Recuperative Turbine</th>
<th>CSIRO Catalytic Turbine</th>
<th>Ingersol-Rand Catalytic Microturbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principles of operation</td>
<td>Air heater inside combustion chamber</td>
<td>Monolith reactor</td>
<td>Monolith reactor</td>
</tr>
<tr>
<td>Catalyst</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Auto-ignition temperature</td>
<td>700~1000°C</td>
<td>500°C</td>
<td>N/A</td>
</tr>
<tr>
<td>Experience</td>
<td>Pilot-scale trial</td>
<td>Bench-scale study on combustion</td>
<td>Conventional microturbine development</td>
</tr>
<tr>
<td>Cycle period length</td>
<td>Continuously</td>
<td>Continuously</td>
<td>Continuously</td>
</tr>
<tr>
<td>Minimum CH₄ concentration for operation</td>
<td>1.6%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Applicability</td>
<td>CH₄ mitigation and power generation and need additional fuel to increase CH₄ concentration</td>
<td>CH₄ mitigation and power generation and need additional fuel to increase CH₄ concentration</td>
<td>CH₄ mitigation and power generation and need additional fuel to increase CH₄ concentration</td>
</tr>
<tr>
<td>Possibility of recovering heat</td>
<td>Feasible (power generation)</td>
<td>Feasible (power generation)</td>
<td>Feasible (power generation)</td>
</tr>
<tr>
<td>Variability of CH₄ concentration</td>
<td>Constant</td>
<td>Constant</td>
<td>Constant</td>
</tr>
<tr>
<td>Operation</td>
<td>Simple and stable</td>
<td>Simple and stable</td>
<td>Simple and stable</td>
</tr>
<tr>
<td>Lifetime</td>
<td>May be shorter due to the high temperature combustion heat exchanger</td>
<td>&gt;8,000 hours for catalysts, and 20 years for a turbine.</td>
<td>N/A</td>
</tr>
<tr>
<td>NOₓ emission</td>
<td>N/A</td>
<td>Low (&lt;3ppm)</td>
<td>Low</td>
</tr>
<tr>
<td>CO emission</td>
<td>Low</td>
<td>Low (~0ppm)</td>
<td>Low</td>
</tr>
</tbody>
</table>
Technologies for ventilation air methane & drainage gas

- No single technology provides an easy solution
- Combined units can give benefits

*Example*: 1% methane turbine and conventional gas engine power plant system can maximise the mitigation and utilisation of all of mine methane.
Case studies of two mines

Technical & economic assessment of the implementation of most of the above technologies into an Australian mine

Technical feasibility
• Range of technologies, 95% availability, maximum capacity

Economics
• determine major economic parameters: capital cost, operational cost, IRR, net present value, break-even cost
• basic case
  – plant lifetime: 25 years,
  – installation cost: 10% of equipment capital cost,
  – discount rate: 7.5%,
  – electricity price: AU$37/MW•hr,
  – natural gas price: $5.05/GJ,
  – no carbon credit.
Case study-Mine 1

CH₄ emissions at mine

Flow rate, m³/s

Post-drainage gas

Pre-drainage gas

Ventilation air

Flow rate

CH₄ concentration

Date, time
Case study-Mine 1

\( \text{CH}_4 \) emissions at mine

(Based on average values)
Vent air: 32,433,515 m\(^3\)/year, 32.8%
Drainage: 66,475,933 m\(^3\)/year, 67.2%

Mine ventilation methane is contained in 5.4 billion m\(^3\) of air
Case study-Mine 1

CH₄ at mine site

- Biggest CH₄ concentration variation rate: 0.01%/hour in vent air
- CH₄ in Ventilation air: min 0.2%, max 1.44%, average 0.56%
- CH₄ in drainage gas: average 79.2% for Pre, 71.8% for Post
- Pure CH₄ flow in drain gas: 2.11 m³/s
Case study-Mine 1

Operating status

Combined 1% methane turbine and gas engine power plant

Four 3MW<sub>e</sub> 1% CH<sub>4</sub> catalytic turbine units

Fourteen 1MW<sub>e</sub> gas engine units, ambient air as combustion air
Case study-Mine 1

Comparison of plant sizes and electricity production

- Gas Engine - Gas engine power plant
- Gas Turbine - Gas turbine power plant
- 1% Turbine - 1% CH₄ lean-burn turbine plant
- 1.6% Turbine - 1.6% CH₄ lean-burn turbine plant
- 1% & Engine - combined 1% CH₄ lean-burn turbine and gas engine power plant
- 1.6% & Engine - combined 1.6% CH₄ lean-burn turbine and gas engine power plant
Case study - Mine 1
Comparison of methane mitigation and utilisation

Percentage of ventilation air methane being mitigated/utilised, %

- TFFR
- CFRR
- CMR
- PSA
- Gas Engine
- 1% Turbine
- 1.6% Turbine
- 1% & Engine
- 1.6% & Engine

Percentage of drainage gas being mitigated/utilised, %

- Ventilation air
- Drainage gas
Case study-Mine 1

Amount of mitigated/utilised mine methane

<table>
<thead>
<tr>
<th>Method</th>
<th>Mitigated/utilised methane, m³</th>
<th>Mitigated CO₂-e, t</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFFR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFRR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas Engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas Turbine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% Turbine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6% Turbine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% Engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6% Engine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: The specific values are not provided in the image.*
Case study-Mine 2 (Typical gassy mine)

✓ ~64% CH₄ emitted with ventilation air
✓ Analysis summary of plant size and electricity production

Potential of the 1% CH₄ turbine for ventilation air methane at typical gassy mines!
Mine methane mitigation and policies
Applications in Australia

- National Greenhouse Strategy – framework
- National Carbon Accounting System – publishes data
- Greenhouse Abatement Program – provides capital
  - German Creek, Teralba, Bellambi mines (gas engines)
  - West Cliff (TFRR – MEGTEC)
- NSW Greenhouse Abatement Certificates NGAC
  - Credits are owned by owner of facility that does the mitigation example – Kiln with waste coal & mine methane
- National renewable scheme – mine wastes excluded although municipal waste methane included
Current research projects in CSIRO

- Characterisation and cleaning of mine ventilation air flows (Shi Su),
- Technical and economic issues on mine methane mitigation and utilisation (Shi Su),
- Development of a small pilot-scale demonstration unit of 1% CH$_4$ catalytic turbine (Shi Su),
- International networking on greenhouse gas (CH$_4$) mitigation (Shi Su),
- Coal mine greenhouse gas measurement – Australian practice (John Carras),
- Monitoring methane emissions from open cut mining (John Carras).
In CLOSING

Before a successful deployment of any technology, the following important issues need to be resolved:

- *is the technology proven?*
- *no decrease in mine safety and compliance with all regulatory standards,*
- *profitable economics using the methane energy and carbon reduction revenues,*
- *who owns ventilation air methane/CMM,*
- *units have to be portable.*