A Technical Overview of VAM Mitigation Technology Platforms

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OUTLINE

- Background
- VAM abatement technology status
- Technology gaps / issues
- Future R&D needs
- Conclusions

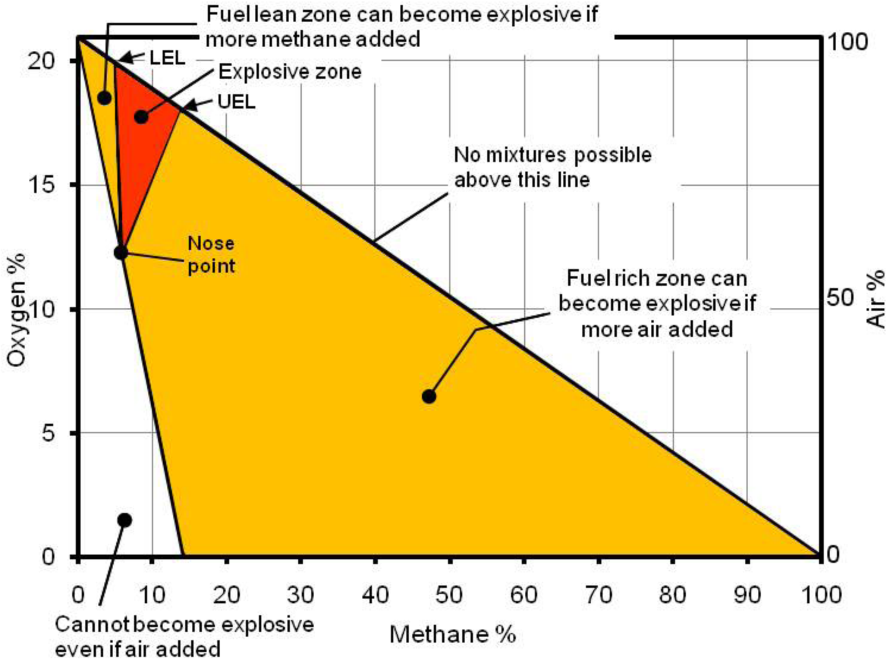
BACKGROUND

- Coal accounts for 25% of global primary energy, supplies 40% of global electricity and meets about 70% of the energy demand of the steel/aluminium industry.

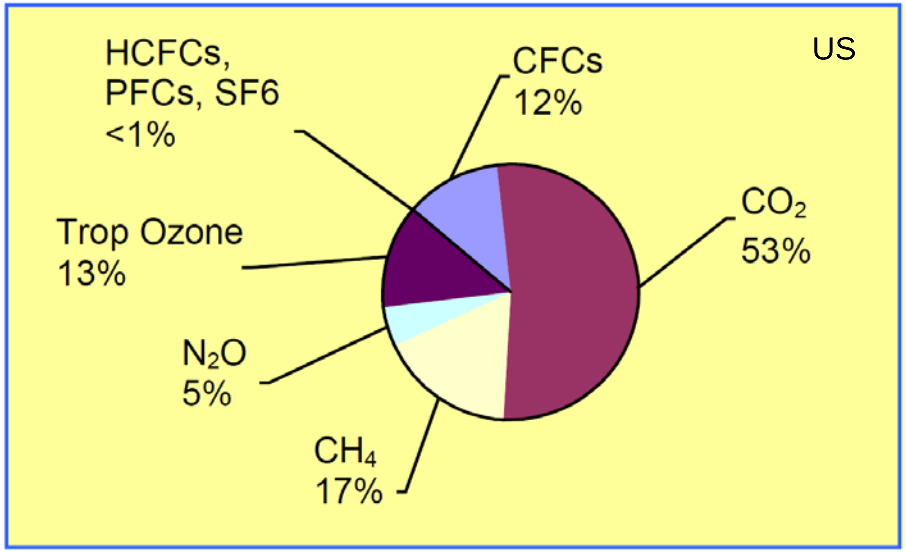
- Coal is also the leading fuel in meeting the projected growth in the energy demand (93% by 2030) of emerging economies such as China and India (IEA 2009).

- Continued dependence on coal, however, requires coal production from deeper and more gassy coal seams as shallow reserves are being exhausted in many parts of the world.

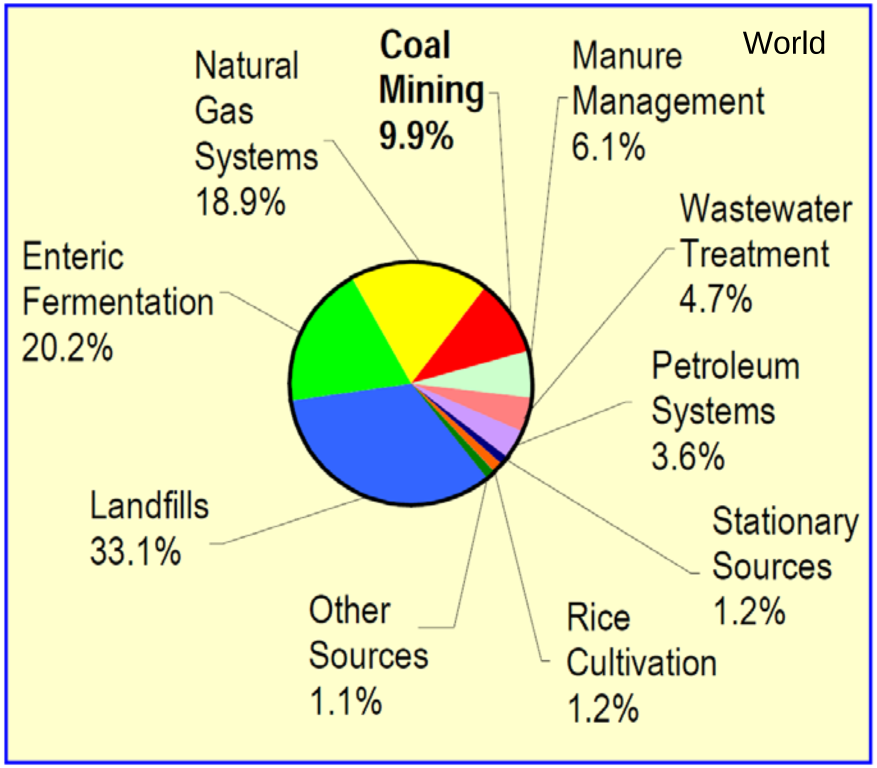
- In this context coal mine methane (CMM) poses a range of safety and environmental challenges.
- LEL (5%), UEL (15%), GWP (25 over 100 years)

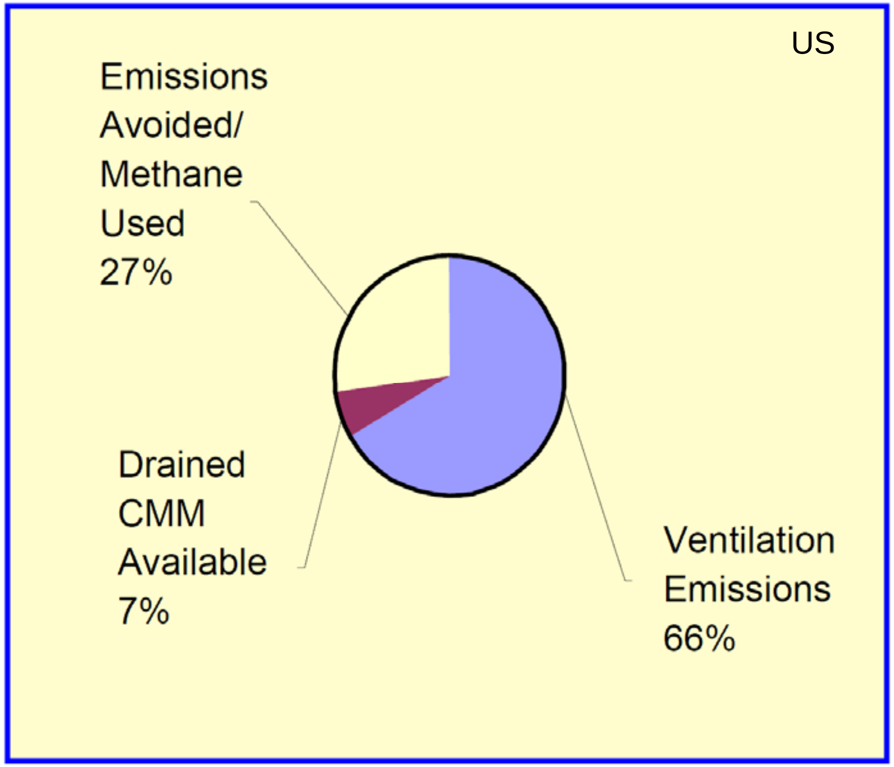


Source: ECE ENERGY SERIES No.31



Source: USEPA, EPA 430-R-03-002, 2003





Source: USEPA, EPA 430-R-03-002, 2003

Country	VAM ($MtCO_2e$)	%World
China	90.0	40
US	33.8	15
Ukraine	33.8	15
Australia	11.3	5
Russia	11.3	5
Total	**225**	**80**

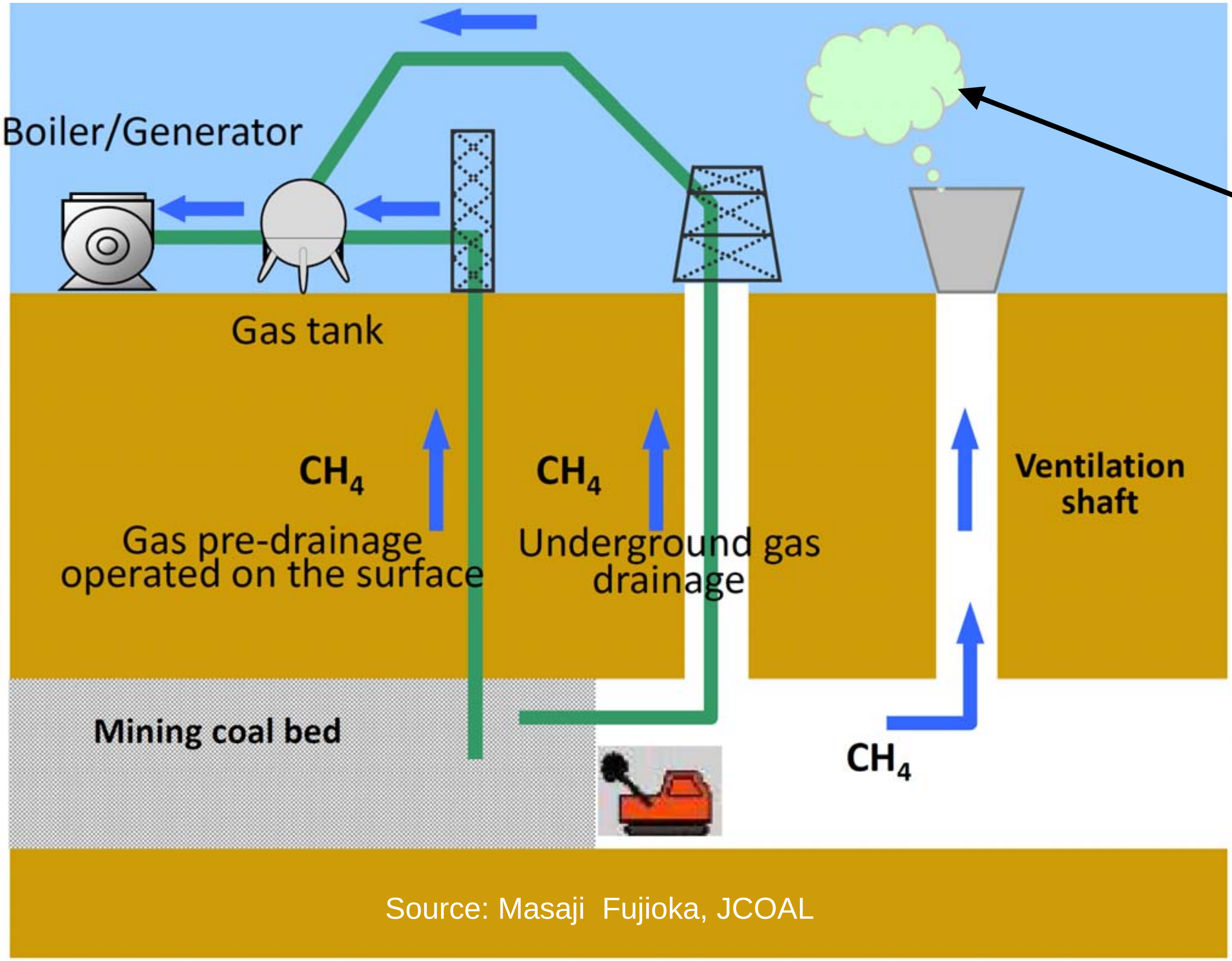
Source: USEPA, EPA 430-R-03-002, 2003

- Capturing and using VAM is challenging because:
    - ➢ Large airflows (47 - 470 m^3/s)
- ➢ Low concentrations: range 0.1–1.0% (often 0.3–0.5%)
- Variable, both flow and concentration

Example: GHG Emission at a Typical Australian Gassy Mine

CH_4 Source	**Gas Flow Rate (m^3/y)**	**Average CH_4 Conc. (%)**	**CH_4 Flow Rate (m^3/y)**	**Heating Value (MJ/m^3)**	**Emissions ($MtCO_2e$)**
Drainage CMM	73.2×10^6	75.3	55.1×10^6	27.2	0.8
VAM (@ 210 m^3/s)	58.0×10^8	0.56	32.5×10^6	0.2	0.5
Total			87.6×10^6		1.3

VAM ABATEMENT TECHNOLOGY STATUS



Source: Masaji Fujioka, JCOAL

What are the VAM Mitigation options?

- Destruction
- Utilisation

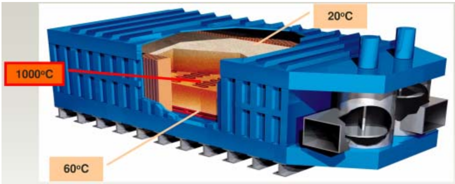
Underlying Technology	VAM Use		Process Type	
	Ancillary	Principal	Oxidation	Enrichment
Conventional Fossil Fuel-Fired Power Plants (Boilers, Kilns, Furnaces)	✓		✓	
Flares	✓		✓	
Gas Engines / Generators	✓		✓	
Thermal Oxidisers		✓	✓	
Catalytic Oxidisers		✓	✓	
REDOX Processes		✓	✓	
Gas Turbines		✓	✓	
Fuel Cells		✓	✓	
Adsorbents		✓		✓
Membranes		✓		✓
Mechanical Separators		✓		✓
Biological Convertors		✓	✓	
Others (e.g. Plasmas, Pyrolysis, PO, Gasification)		✓	✓	

Underlying Technology

- Conventional Fossil Fuel-Fired Power Plants
- Flares
- **Gas Engines / Generators**
- **Thermal Oxidisers**
- **Catalytic Oxidisers**
- **REDOX Processes**
- **Gas Turbines**
- Fuel Cells
- Adsorbents
- Membranes
- Mechanical Separators
- Biological Convertors
- Others (e.g. Plasmas, Pyrolysis, PO)

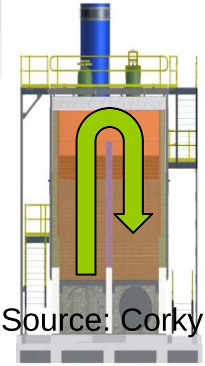
TFRR

VOCSIDIZER™



Source: MEGTEC

Corky's VAM-RAB



Source: Corky's

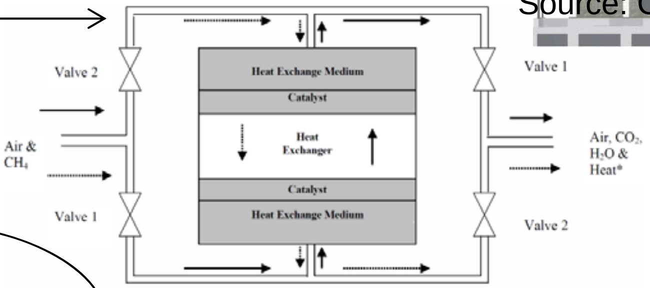
Porous Burners

CFRR

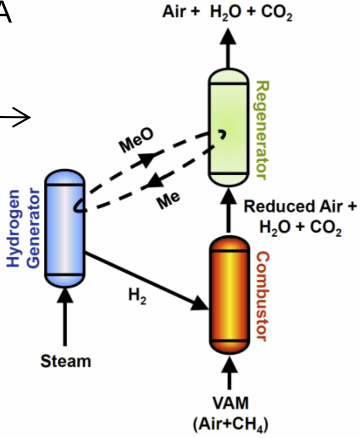
L.T. Cat. Convs.

L.T. Methanol Convs.

Chemical looping



Source: USEPA



Recuperative Lean G.T.

CSIRO Lean Catalytic G.T.

Supersonic G.T.

Kawasaki G.T.

Source: Masaji Fujioka, JCOAL

Technology Assessment

Conventional Fossil Fuel-Fired Power Plants (Boilers, Kilns, Furnaces)	
Key Features	* Uses VAM as combustion air; * No fundamental issue
Challenges	* Site specific engineering issues; * Requires close proximity; * No large-scale demo
Maturity	* High
Cost	* Low (if in close proximity)
Flares	
Key Features	* Uses VAM as combustion air; * No fundamental issue
Challenges	* Site specific eng issues; * Requires particulate removal; * No large-scale demo
Maturity	* High
Cost	* Low
Gas Engines / Generators	
Key Features	* Uses VAM as combustion air; * No fundamental issue
Challenges	* Site specific eng issues; * Sensitive to particulate matter; * Requires large amounts of primary fuel (drainage gas) to operate
Maturity	* High
Cost	* Medium to high

Thermal Oxidisers (TFRR)	
Key Features	* Uses a high thermal mass ceramic for recuperative thermal oxidation of VAM * Under ideal conditions is self sustaining for methane conc. > 0.1% * Practically though is self sustaining at methane conc. > 0.3-0.5% * Single and dual "CAN" configurations * Established track record in VOC destruction at scale similar to VAM
Challenges	* Lack of large-scale experience at high temperatures associated with VAM * Safety issues (see next section for details)
Maturity	* Medium to High
Cost	* High
Thermal Oxidisers (Porous Burners)	
Key Features	* Similar to a single CAN TFRR * Can process VAM with methane as low as 0.3%
Challenges	* Requires expensive nickel alloys to house/contain ceramic components
Maturity	* Low
Cost	* Very high
Catalytic Oxidisers (CFRR)	
Key Features	* Similar to a TFRR with ceramics coated with catalyst * Operate at lower temperatures than TFRR, hence, has lower energy footprint
Challenges	* Sensitive to particulate matter; * Sensitive to catalyst poisoning & deactivation * No large-scale demo yet
Maturity	* Still at R&D
Cost	* High

Catalytic Oxidisers (L.T. Convertors)	
Key Features	* Operate below the auto-ignition of methane (~530^{o}C) * Lower energy footprint than CFRR; * Can be configured for methanol production
Challenges	* Requires suitable, robust and cost effective catalysts
Maturity	* R&D
Cost	* Medium to High
REDOX (Chemical Looping)	
Key Features	* Uses metal oxides to generate H2 in a cyclic fashion * Co-feeds H2 to VAM combustor to lower the ignition temperature of the mixture * Not sensitive to fluctuations in methane concentration * Self-sustaining from methane concentrations of about 0.04%
Challenges	* Requires suitable, robust and cost effective metal oxides for prolonged operation * No large-scale demos yet
Maturity	* R&D
Cost	* Medium (Atmospheric operation; Relatively small unit operations)
Gas Turbines (Lean GT)	
Key Features	* Uses VAM as fuel rather than combustion air; * Efficiency (~30%) < gas engines
Challenges	* Requires methane concentration > 0.1% and, hence, a supplementary fuel * Leads to incomplete combustion (CO formation); * Sensitive to particles & dust * Causes cooling issues for methane conc. > 0.5%
Maturity	* R&D
Cost	* Medium to high

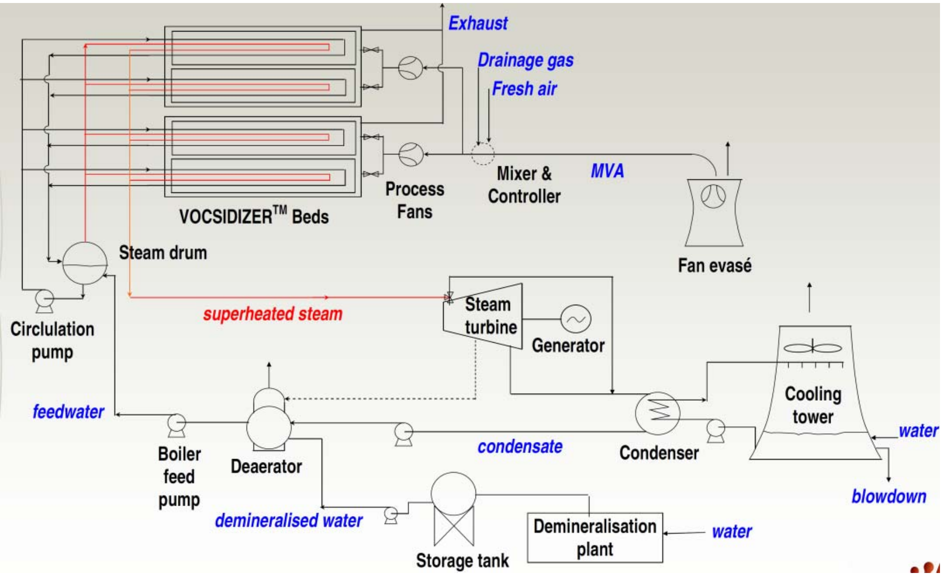
Gas Turbines (Catalytic Lean GT)	
Key Features	* Adds a catalytic convertor to conventional GT to lower the demand for supplementary fuel; * Efficiency of ~30%; * CSIRO and Kawasaki variants
Challenges	* Performance degradation for methane concentration < 0.8% * Sensitive to particles, dust and catalyst poisoning / deactivation
Maturity	* R&D
Cost	* Medium to High
Fuel Cells	
Key Features	* Modular; * High Efficiency; * Direct VAM to electricity
Challenges	* Sensitive to impurities particularly oxygen in anodic reactions * Have not been used in conjunction with large volumetric gas flows
Maturity	* R&D
Cost	* High (does not benefit from economy of scale because of modular structure)
Adsorbents	
Key Features	* Enriches VAM to 1% so that a thermal oxidizer can be used for destruction of VAM
Challenges	* Poor efficiency due to low surface areas available for methane separation * Poor selectivity for CH4; * High energy footprint in regen step (PSA, VPSA and TSA) * Adsorbents are sensitive to high temperatures
Maturity	* R&D (mature in the context of oil/gas industry where methane concentration > 50%)
Cost	* High

Membranes	
Key Features	* Modular * Higher efficiency than adsorbent * Smaller than adsorbent based systems * Proven track record in the oil/gas and process industries for gas separation
Challenges	* Low selectivity for methane separation * Concerns over high temperature operations
Maturity	* R&D
Cost	* High (does not benefit from economy of scale because of modular structure)
Bio-Convertors	
Key Features	* Oxidative conversion of methane to methanol using enzymes * Low temperature reaction, hence, small energy footprint
Challenges	* Slow reaction rates * Requires complex reactors * Leads to oversize (large) unit operations * High operational costs (requires nutrients) * Organisms must be kept under restrict operational conditions
Maturity	* R&D
Cost	* Very High

Australian Experience

Only a few pilot and demonstration VAM abatement projects. The most significant being:

- WestVAMP (BHP)
- Xstrata (Blackfield South)
- Centennial Coal, Corky’s and NSW Gov (Mandalong)
- Corky’s pilot-plant (Bloomfield)
- A single VOCSIDIZER™ unit (Appin)




WestVAMP plant; Source: Booth (BHP); 2008

- All plants to date in Australia have had design construction and/or operational issues and with the exception of WestVAMP (20% VAM) none have been approved to operate directly coupled to a mine ventilation fan.
- There seems to be also a disjoint between process engineers who have design/run VAM mitigation units and mining personnel; something that Newcastle University and its partners are helping to resolve.
- The mining industry is already exposed to an often crippling and expensive set of environmental regulations. VAM mitigation increases the exposure and thereby cost.
- The mining industry has a massive safety culture that has developed for good reason.
- This culture demands technology providers to design and deploy systems which do not increase risk at mine sites.

TECHNOLOGY GAPS / ISSUES

- VAM abatement systems present specific challenges on an operating gassy coal mine site, particularly in terms of safety.

- No VAM abatement technologies will ever be implemented in Australia if not safe.

However, there is no consistent, applicable and accepted safety standard. This is for design, construction and operation

- Pricing / cost implications

- Key hazards are:

1. Disruption to mine air flow
2. Blow-back, fire and explosion events
3. Dust and particulate matter leading to:
   - Reduced air flow (clogging)
   - Formation of hot spots
   - Sintering, corrosion and abrasion

- Need for engineering assessment and numerical modelling.

- Cost-effective heat recovery (Granex or other technologies).

- Issues surrounding environmental approvals are becoming more complex and this adds to the time to develop and reduces NPV of projects, in many cases dramatically.

- The key environmental issues are:
  - Power use;
  - Noise;
  - Visual amenity;
  - Footprint and its impact on biodiversity and archaeology.

FUTURE R&D NEEDS

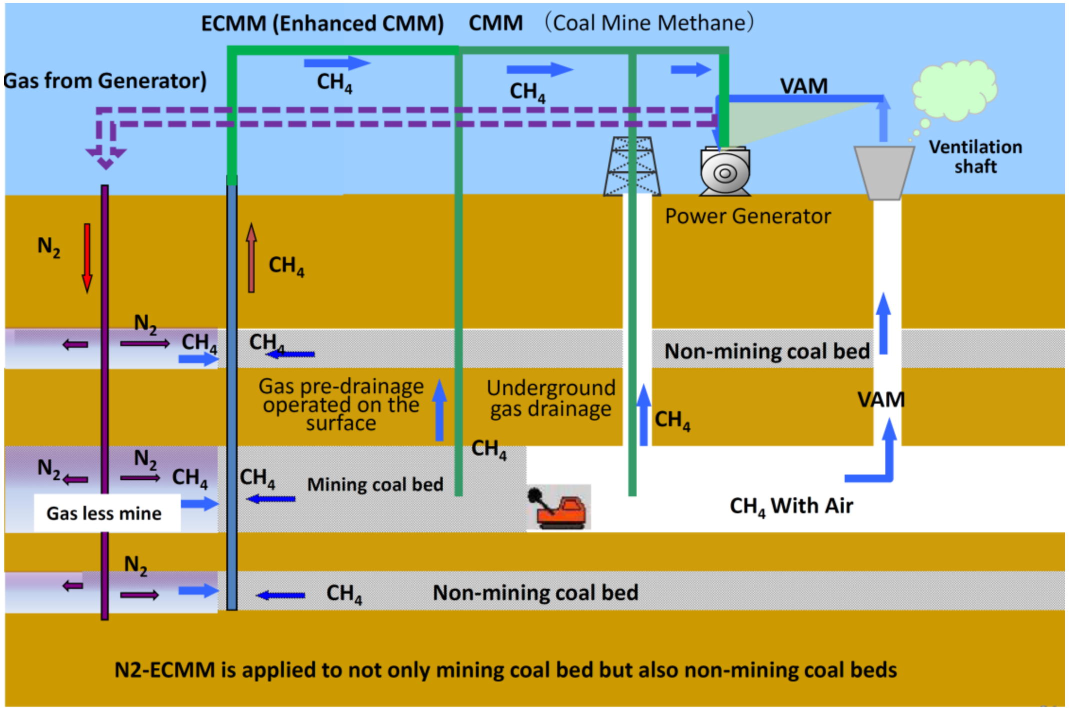
- Given the full effects of the carbon price will be felt by industry within 5 years and new projects and expansions are already factoring a carbon price, the urgency for R&D solutions to the VAM issue is critical to the future prosperity of the underground coal industry.

- To have large-scale plants operating at Australian coal mines within 5 years we need to roll out and complete some key R&D tasks within the next 3 years.

- The safe implementation of thermal oxidisers appears to be the greatest near-term challenge for industry and an important R&D undertaking.

- In this context, monitoring, fire/explosion control measures, VAM capture duct and integration are areas where further research is warranted and urgently needed (this is the focus of UoN and its partners).
- This should help in establishing safety standards for the industry.
- In terms of energy footprint, cost, and environmental impact next-gen technologies (e.g. chemical looping, membrane, catalytic oxidation) offer greater potentials than more conventional systems.
- The next-gen technologies may reach sufficient maturity within the next 5-10 years.
- They should be supported so that they can make the necessary transition from R&D to full commercialisation.

- Whilst there are limited VAM emission reduction or avoidance opportunities (e.g. more intensive gas drainage), these options have technical challenges, practical limitations and cost constraints.



Source: Masaji Fujioka, JCOAL

- Splitting the VAM into high and low streams may offer a new approach with different technologies applied to each stream.

CONCLUSIONS

The industry needs to take a holistic view that looks at:

- Safety
- Engineering
- Process integration
- Environmental approvals, policy and regulations
- Environmental constraints
- International trading and Regulation

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Questions

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