• Why is VAM an issue?

• Technologies for processing VAM
• Proven technologies so far
• Successful installations
• Guide lines for feasibility
Drainage gas

- Low volume
- High CH₄
- > 30%

Coal Excavation

Main Coal Mine Vent Shaft
Main Coal Mine Vent Shaft

Coal Excavation

Drainage gas

Low volume

High CH₄

> 30%

VAM, Ventilation Air Methane

Very high volume

Very low CH₄

< 1%
## TECHNOLOGIES FOR PROCESSING VAM

### CONDITIONS:

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TECHNOLOGIES FOR PROCESSING VAM

**CONDITIONS:**
Very large volumes of air with extremely low CH$_4$ content.

~1,000,000 Nm$^3$/hr

<$1\%$ to $<<1\%$

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1992 **Rio Conference**
- Agreement to establish the UN Framework Convention on Climate Change, UNFCCC

1997 **Kyoto Conference**
- Agreement to reduce emissions and to introduce mechanism of Carbon Credits
- Official launch of Kyoto related Carbon Credits

2007

2009 **Copenhagen Conference**
- Failure to extend Kyoto Protocol

2012

2015 **Paris Agreement**

2017

**CARBON CREDITS TRADING**
- EU ETS
- CARBON CREDITS TRADED

**VAM PROCESSING AND CARBON CREDITS**

1994
- UK trial at British Coal
- A few months

1997
- Australian trial at BHP
- A full year

2001

2007

2009

2015

**LARGE SIZE VAM INSTALLATION**
- Power plant, WestVAMP, Australia
- Abatement/hot water, China
- Abatement, JWR, US
- Abatement, McElroy, US
- LARGE SIZE VAM
- Power plant, GaoHe China
- Abatement, hot water, SongZao, China

**VAM PILOT**
- Abatement demo 1½ year
- CONSOL, US
COMMERCIAL SIZE VAM PROCESSING
IN OPERATION BY JUNE 2018

Closures of others due to:
- Moving of mining activities
- Failing values of carbon credits
RTO technology
- How does it work?
Like all VOC gases, methane oxidizes at 850-900°C to form water and CO₂.

And release Energy!
VOC Oxidation Rate

Oxidation Rate

Temperature

100° C
Single can RTO

**RTO FUNCTION:**
1. Heat center cross section of ceramic bed to 1000°C.
2. Pass ventilation air through, heating media, oxidizing all VAM in air passing the hot zone.
3. Change direction of flow, making hot zone remain in center bed section.

No catalyst operate at natural oxidizing temperature
Single can RTO
2 Can (or more) RTO

Main difference between the single can RTO and 2 can or multiple can RTO’s: Oxidation in a combustion chamber instead of in the ceramic bed.
RTO installations typically consists of multiple modular RTO units.
Min 0.2% CH₄ to keep oxidizing going.

If higher, the excess can be utilized.
CONVERTING ENERGY OF VAM INTO USEFUL ENERGY

.. as heating or cooling, or as electricity.
Indications of VAM project economics

- The project economics of a VAM processing installation will largely depend on;
  - Total costs for investment, operation and maintenance.
  - Average VAM concentration of the ventilation air being processed.
  - The value of reducing the emissions.
0.2 % methane needed to maintain oxidation.
Energy of concentrations above 0.2 % can be recovered.

**Example:**

800 000 m³/h
1 % CH₄

\[ \rightarrow 72 \text{ MW}(\text{th}) \rightarrow 21 \text{ MW}(\text{el}) \]
(at 30% efficiency)

**Example:**

800 000 m³/h
0.6 % CH₄

\[ \rightarrow 36 \text{ MW}(\text{th}) \rightarrow 10 \text{ MW}(\text{el}) \]
(at 30% efficiency)
Cogeneration of electricity and heating – plus cooling

Example:

\[ 800,000 \text{ m}^3/\text{h} \]
\[ 1\% \text{ methane} \]
\[ \rightarrow 72 \text{ MW(th)} \]
\[ \rightarrow 21 \text{ MW(el)} \]
\[ \rightarrow 19 \text{ MW(el)} + 38 \text{ MW(cool)} \]
Hot water from VAM (thermal energy)

- Heat straight from bed.
  - Water at 70 - 150°C
    - 3 MW for 0.3%
    - 11 MW for 0.6%
    - 18 MW for 0.9%

- For each 250 000 Nm3/h of ventilation air
  - 1 MW for 0.3%
  - 8 MW for 0.6%
  - 15 MW for 0.9%

- Secondary heat-exchanger.
  - Water at 70°C
    - 1 MW
  - Water at 150°C
    - 2 MW
Electricity from VAM (electrical energy)

For large size plants, conversion from thermal to electrical energy can be expected to be around 30%, and lower for smaller plants.

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<td>½ - 1 MW(_{e})</td>
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For each 250 000 Nm3/h of ventilation air
Calculations of CO$_2$e from VAM processing

Examples:
250 000 Nm3/h @ 0.9 % VAM comes to 240 000 tonnes of CO2e
125 000 Nm3/h @ 0.9 % VAM comes to 120 000 t CO2e
125 000 Nm3/h @ 0.3 % VAM comes to 40 000 t CO2e
VAM Project Financial Feasibility

VAM project economics indications

![Graph showing the relationship between IRR (%) and Carbon emission reduction value (EUR/ton) with three lines for different emission reduction percentages: 0.8%, 0.6%, and 0.4%.

- The green line represents 0.8%.
- The blue line represents 0.6%.
- The red line represents 0.4%.

横轴：碳排放减少价值（EUR/ton）
纵轴：IRR（%）
Examples:
• An emission reduction value of EUR 16/t CO$_2$e and a 0.8% VAM concentration would yield an IRR of approx 65% - i.e. an expected pay back of less than 2 years.
• A value of EUR 10/t CO2e and a 0.6% VAM concentration would yield an IRR of approx 20% - i.e. an expected pay back of around 5 years.
CONCLUSIONS for reasonable/good pay back:
• VAM concentrations should be min ½ percent
• Carbon emission reduction value (Carbon Credits/Carbon Tax etc) should be minimum EUR 10/t CO$_{2e}$
Kyoto Compliance Period
2008 - 2012

Carbon price overview EU

EUA price (€/t)
Carbon price overview EU

The initial price level of EUR 20-30 per ton CO2e was interrupted by economic recession and by introductory disturbances.

Lowered value primarily relating to:
- 2012 Kyoto end uncertainty
- Low industrial & energy production creating a major surplus of Carbon Credits flooding the market
Carbon price overview EU

Most of the compliance period saw a steady and balanced trend.

Kyoto Compliance Period
2008 - 2012
Carbon price overview EU

2018 EUA price: By June above € 15. Coming back to a balanced market situation?

Kyoto Compliance Period
2008 - 2012
Carbon price overview EU

Kyoto Compliance Period
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Kyoto Compliance Period
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FORECAST PUBLISHED IN FEBRUARY 2018
(EUA at €13 EUR)

EU carbon prices forecast to triple by 2030
EUR per metric ton, nominal

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Overall OPTIMIZATION of CH$_4$
- CMM and VAM emissions

**60-80% of emissions**

- Very high volumes.
- Very low concentrations.

Low CH$_4$

- < 1%

Coal Excavation

Main Coal Mine Vent Shaft

High CH$_4$

- >30%
Overall OPTIMIZATION of CH$_4$
- CMM and VAM emissions

Gas Engines

High CH$_4$
$>$30%

Main Coal Mine Vent Shaft

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Low CH$_4$
$<$ 1%
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VAM processing

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< 1%

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Main Coal Mine Vent Shaft

Coal Excavation
Overall OPTIMIZATION of CH$_4$
- CMM and VAM emissions

For optimization if motivated by VAM energy utilization.

Gas Engines

High CH$_4$
>30%

VAM processing

Low CH$_4$
< 1%

60-80% of emissions

Coal Excavation

Main Coal Mine Vent Shaft
VAM PROCESSING
• Experienced RTO suppliers can provide proven VAM processing solutions
• There will be more suppliers and more technical solutions to VAM processing

• For best feasibility of VAM projects, look for:
  o VAM concentrations of $\sim 0.5\%$ or more
  o Possibility to enrich the ventilation air (into VAM processing) to min $0.5\%$
  o Possibilities to utilize thermal energy close to ventilation shaft (cooling?)
  o Look for good value of reducing VAM emissions (Carbon Credits or similar)
• Optimize your overall emission strategy between processing of drainage gas and VAM