MEGTEC VAM processing

September 2012

Richard Mattus

MEGTEC VAM STATUS 2012

MEGTEC VAM status achieved by 2012				
Type of installations	**Number of plants**	**Number of RTO units**	**Approx total processing capacity in Nm3/h**	**Year of installation (Locations)**
Demo / pilot	4	4	80,000	1994, 2001, 2007, 2009 (UK, Australia, USA)
Commercial;				
- Completed	3	11	700,000	2007, 2008, 2011 (Australia, China)
- Under completion	1	2	200,000	2012 (China)

Total of MEGTEC VAM plant operation experience	~14 years
Total of MEGTEC VAM RTO unit operation experience	> 30 years

In full operation by April 2007 – the world's first VAM Power Plant:

WestVAMP at the West Cliff mine of Illawarra Coal, BHP Billiton

MEGTEC VAM Power Plant technology

WestVAMP at BHP Billiton in Australia

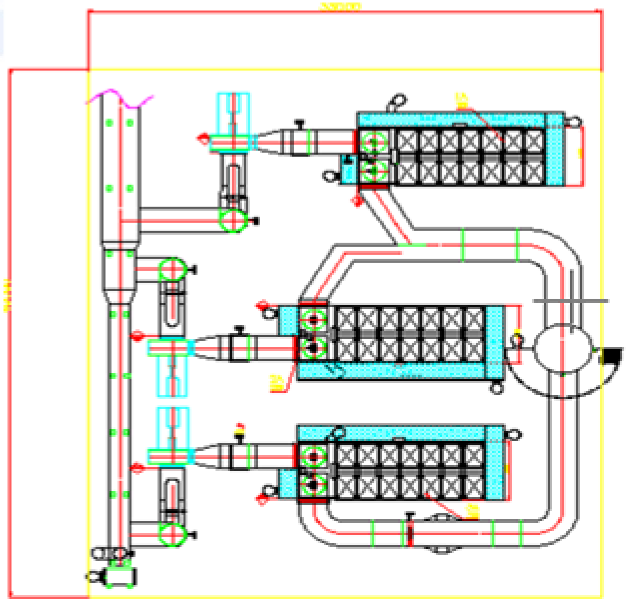
By 1st Q 2012 WestVAMP had generated;

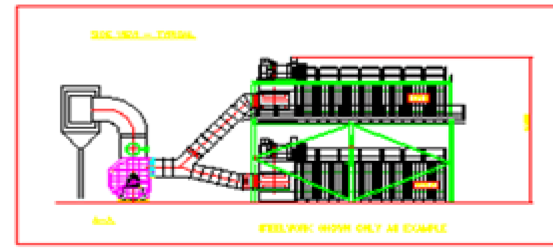
>165,000 MWh of electricity

>1 million carbon credits (CO_{2e} as NGAC's).

MEGTEC VAM in China 2011

at the Da Tong mine, ChonQing Province, China





- Installed at the DaTong coal mine, ChongQing Province
- Supplied by MEGTEC
- Investor is a joint venture owned by:
  - Shenzhen Dongjiang Environmental Renewable Energy Co Ltd
  - SongZao Coal & Electricity Co Ltd
  - AES Corp (US-based global power generation company)

MEGTEC VAM in China 2011

at the Da Tong mine, ChonQing Province, China

World's largest VAM abatement plant in operation
in the ChongQing Province of China since mid 2011.

MEGTEC VAM in China 2011

at the Da Tong mine, ChonQing Province, China

- ❖ 6 Vocsidizer units mounted on two levels
- ❖ Processing capacity is 375,000 Nm3/h of ventilation air
- ❖ Includes hot water generation for local use

MEGTEC VAM in China 2008

ZhengZhou Coal Mining Group, Henan Province

System capacity: 62 500 Nm3/h

VAM concentration: 0.3% - 0.7 %

Actual often <0.3%

The installation includes VAM abatement

and energy recovery in the form of hot water for local use.

MEGTEC VAM in China 2008

ZhengZhou Coal Mining Group, Henan Province

System capacity: 62 500 Nm3/h

VAM concentration: 0.3% - 0.7 %

Actual often <0.3%

The installation includes VAM abatement

and energy recovery in the form of hot water for local use.

The globally first project to be awarded VAM-based CER's

(Kyoto related Carbon Credits).

MEGTEC VAM in China 2012

Duerping mine, Shanxi Province, with Sindicatum

One Megtec 2-Can Regenerative Thermal Oxidizer (“RTO”) units with a capacity of 2,100 Nm3/min

One 1,200 Nm3/min capacity CH4MIN Regenerative Catalytic Oxidizer (“RCO”) built by Megtec.

- The first commercial deployment of the CH4MIN catalytic technology.
- The project is expected to generate 2 million CERs over its life.
- Completion planned for 2nd half 2012.

MEGTEC

MEGTEC VAM demo installations
September 2012

- Demos

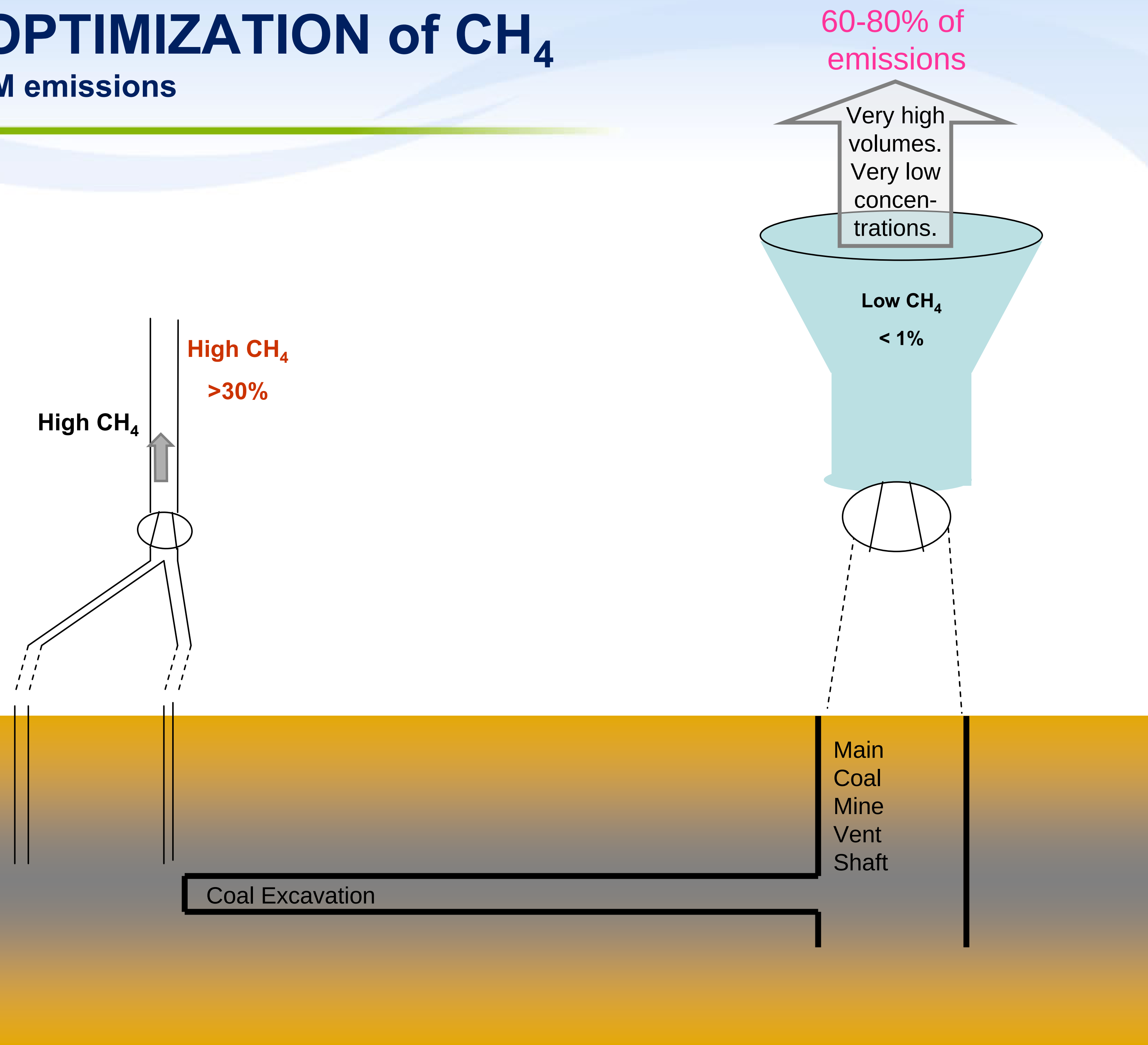
MEGTEC Commercial VAM installations
September 2012

- Demos
- **Commercial**

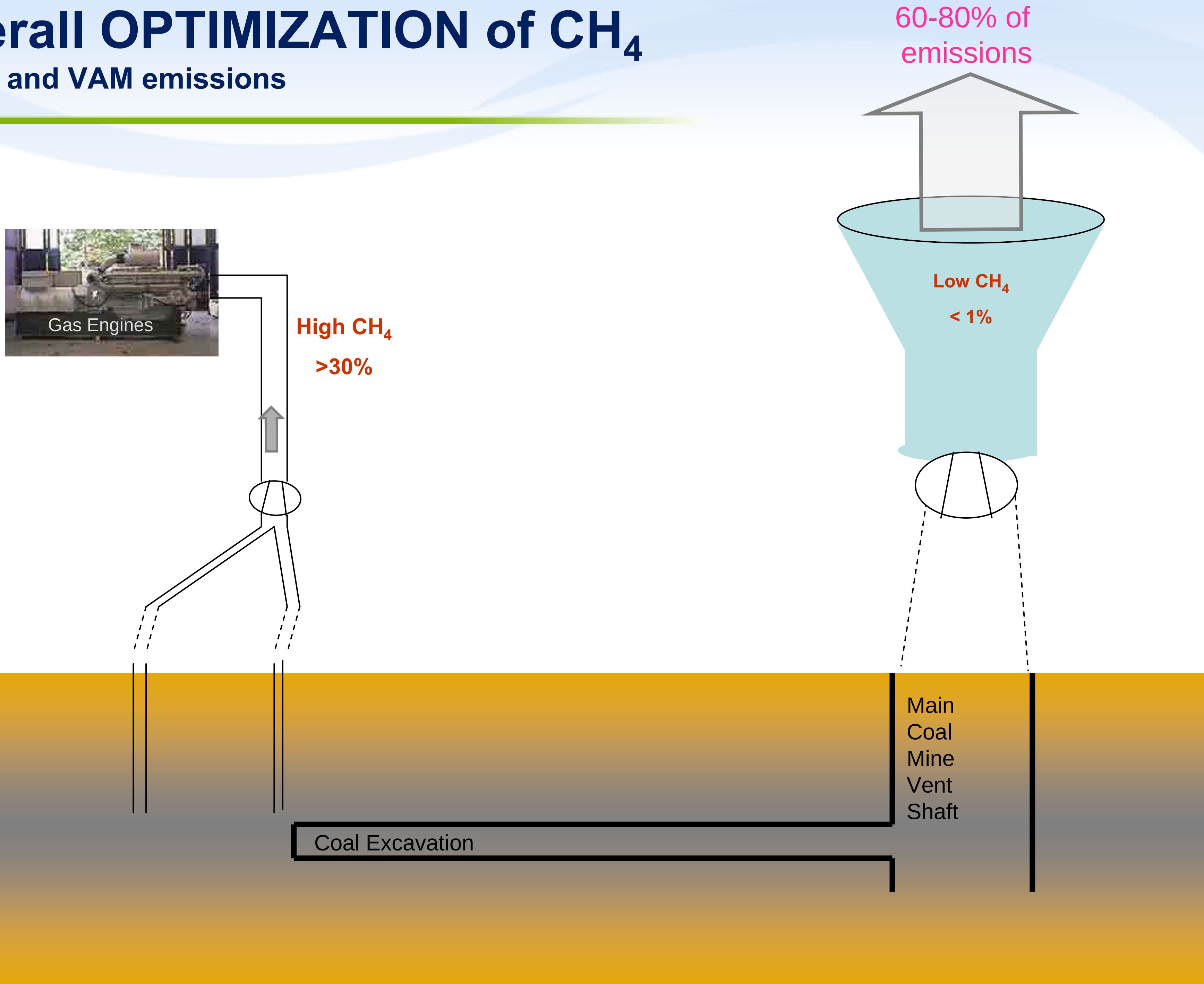
MEGTEC Commercial VAM installations
September 2012

Overall OPTIMIZATION of CH_4

- CMM and VAM emissions

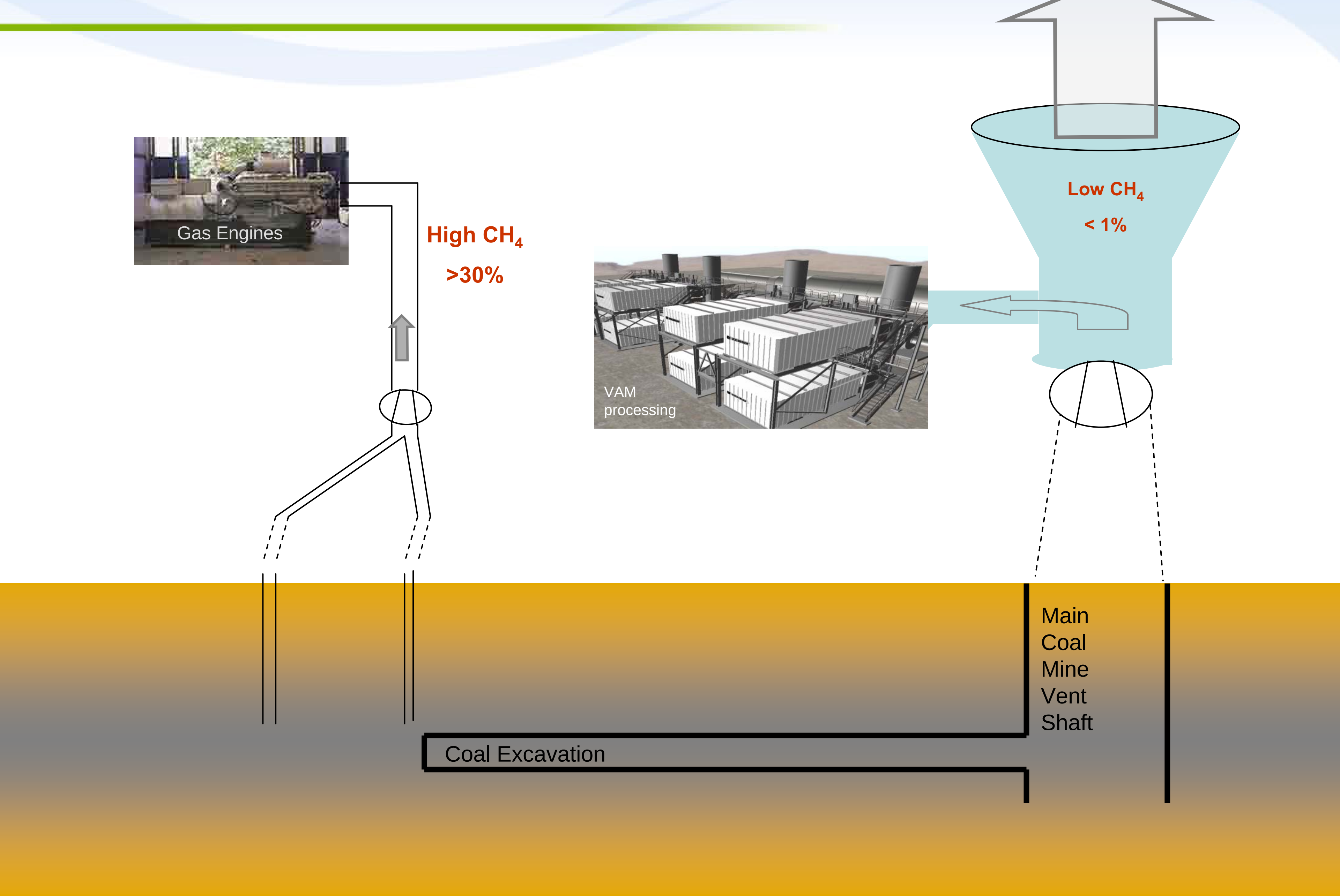


Overall OPTIMIZATION of CH_4
- CMM and VAM emissions



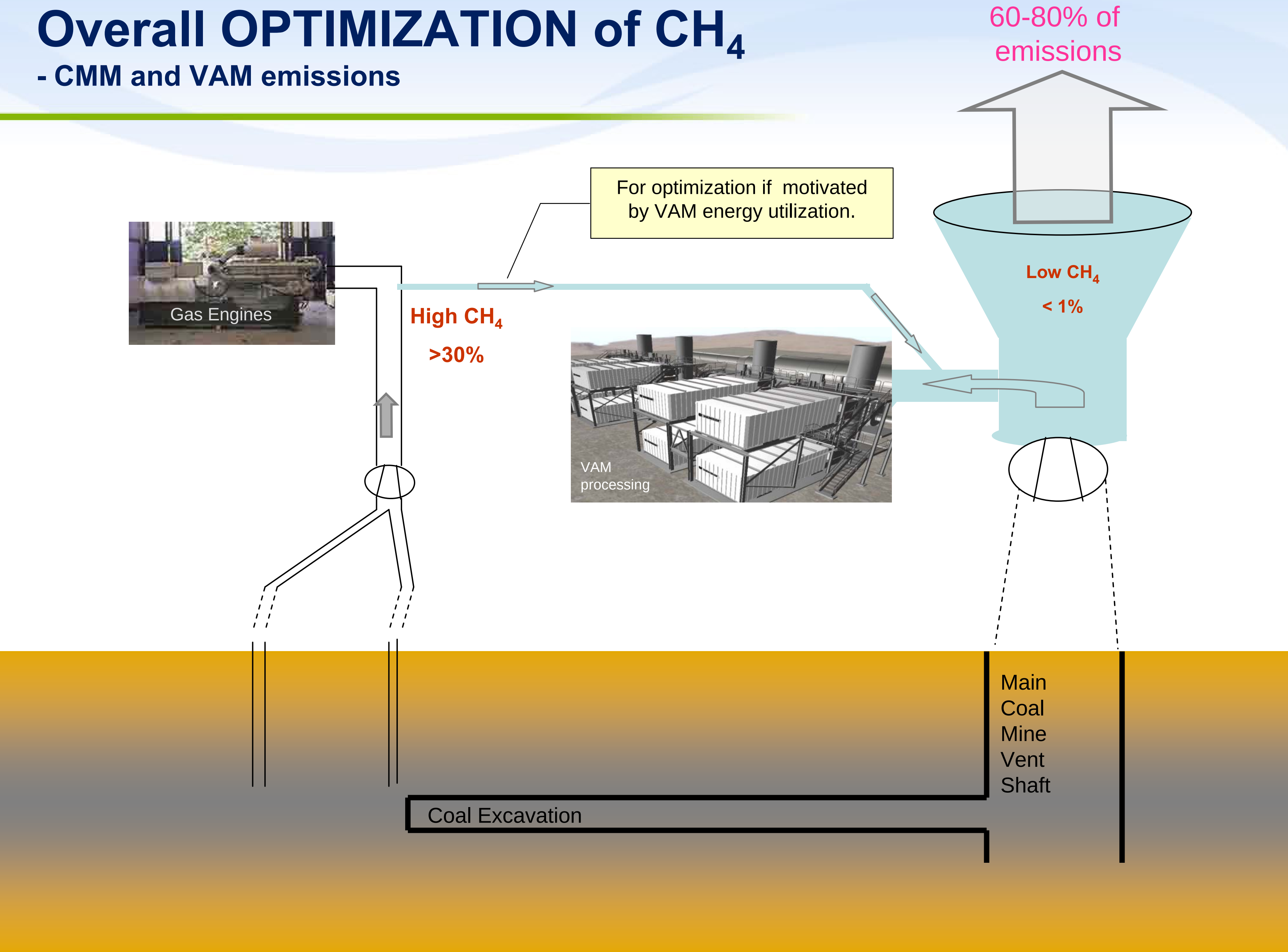
Overall OPTIMIZATION of CH_4

- CMM and VAM emissions



Overall OPTIMIZATION of CH_4

- CMM and VAM emissions



MEGTEC – global leader in Industrial Emission Control

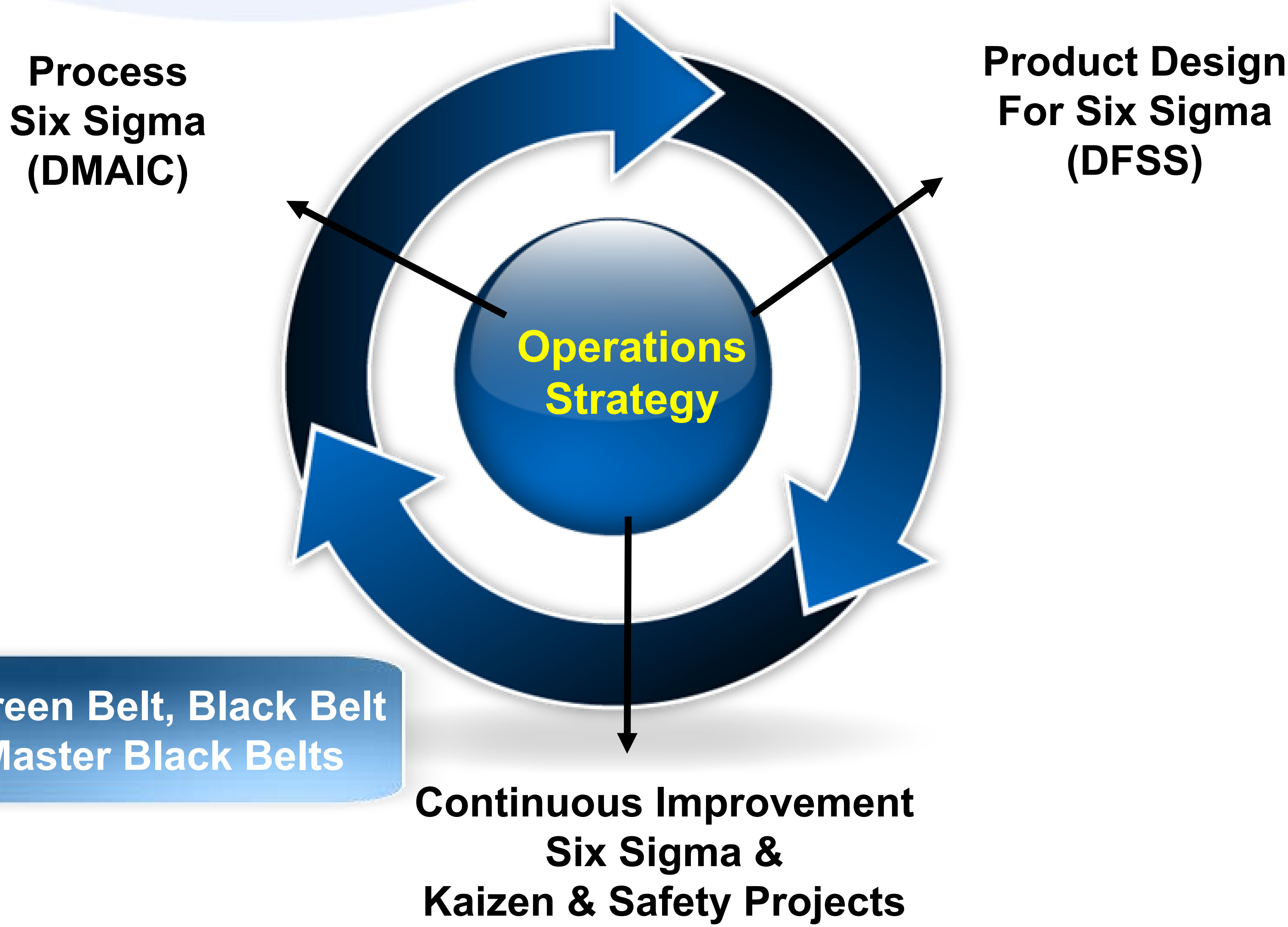
Industry Applications

- ✓ Battery Separators
- ✓ Extrusion Laminates
- ✓ Flexible Packaging
- ✓ Foil Laminates
- ✓ LCD Screens
- ✓ Medical Products
- ✓ Membrane Manufacturing
- ✓ Metal Coil Coating
- ✓ Photovoltaic Cells
- ✓ PSA Label Stock
- ✓ Rechargeable Battery Foils
- ✓ Solar Films

- ✓ Bakery & Food
- ✓ Biofuels Production
- ✓ Biogas Generation
- ✓ Chemical Processes
- ✓ **Coal Mines**
- ✓ Electronics
- ✓ Fiberglass Processes
- ✓ Flexible Packaging
- ✓ Gas & Diesel Engines
- ✓ Landfills
- ✓ Odour Market
- ✓ Pharmaceutical
- ✓ Wood Products

- ✓ Commercial Printing
- ✓ Semi-commercial Printing
- ✓ Newspaper Printing
- ✓ Digital Printing
- ✓ Insert Printing
- ✓ Direct Mail
- ✓ Book Printing
- ✓ Label Printing
- ✓ Flexible Packaging
- ✓ Carton Packaging

Operational Excellence



200+ Green Belt, Black Belt and Master Black Belts

Innovation - 100+ Patents

Environment, Climate & Energy

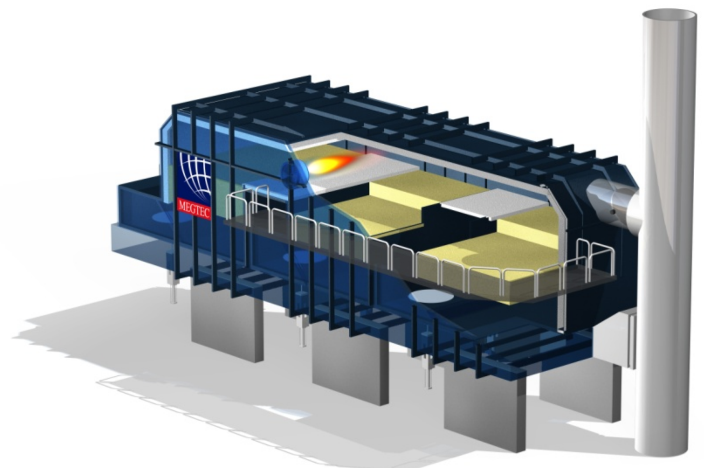
Environment, Climate & Energy

- ✓ Regenerative Thermal Oxidizers (RTO)
- ✓ Recuperative Thermal Oxidizers
- ✓ Catalytic Oxidizers

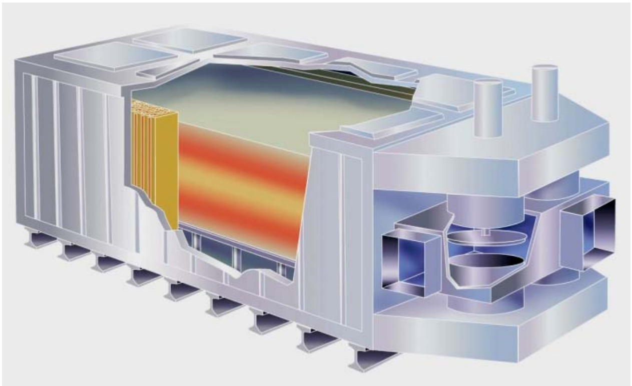
- ✓ Solvent Recovery Systems
- ✓ Distillation Systems

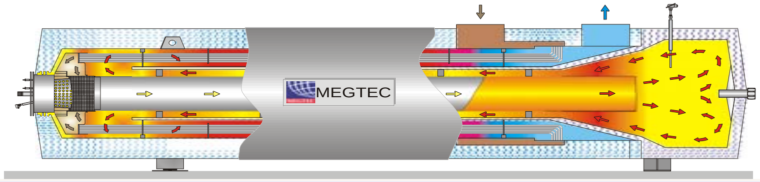
- ✓ Heat Recovery Systems
- ✓ Bioscrubbers / Bioreactors

MEGTEC equipment – in total gloabally over 4,000 have been installed



.. whereof over 800 Vocsidizers

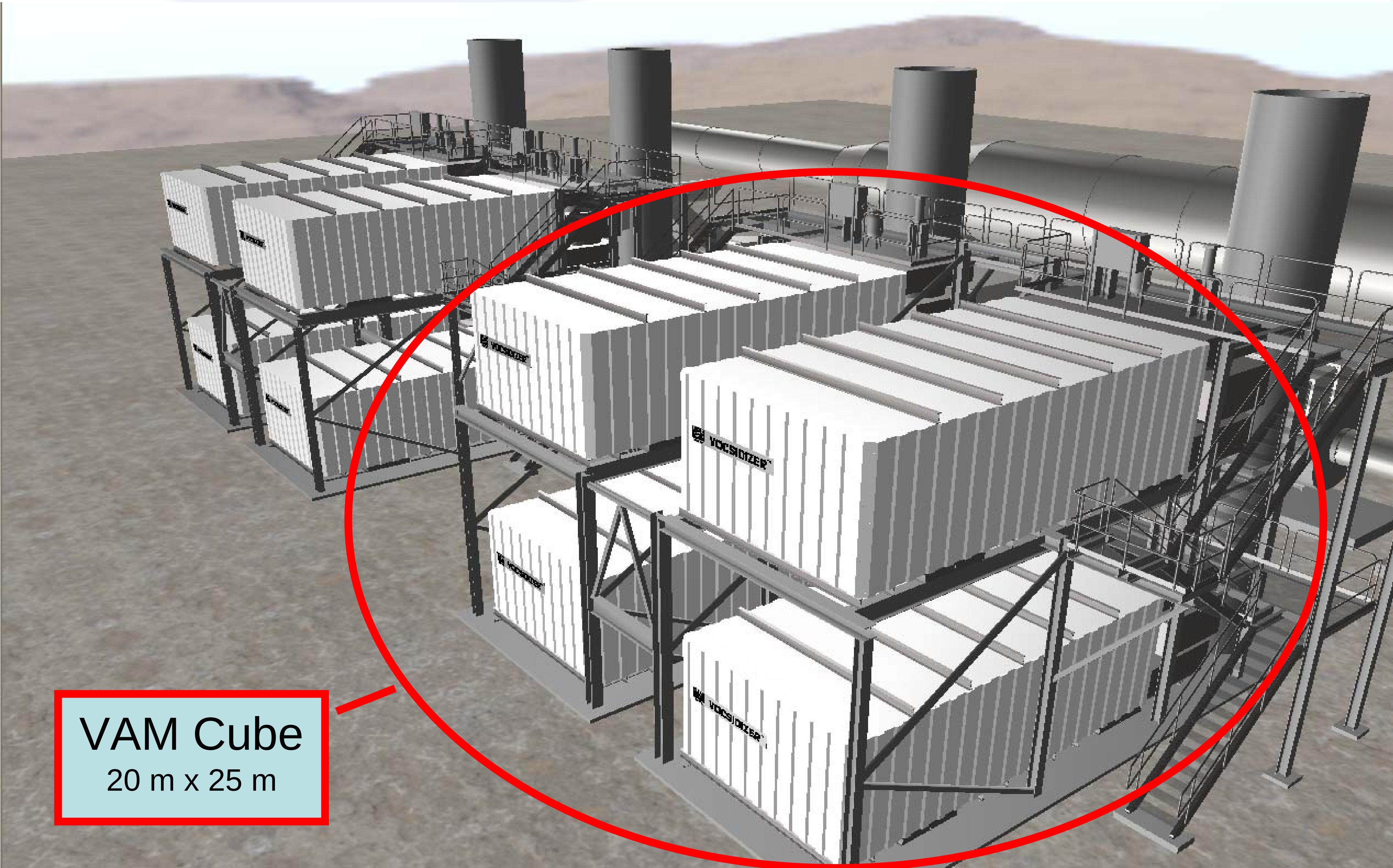




Regenerative Thermal Oxidizers

**Sizes ranging from
300 to 160 000 Nm3/h capacity,
single & multiple can designs**

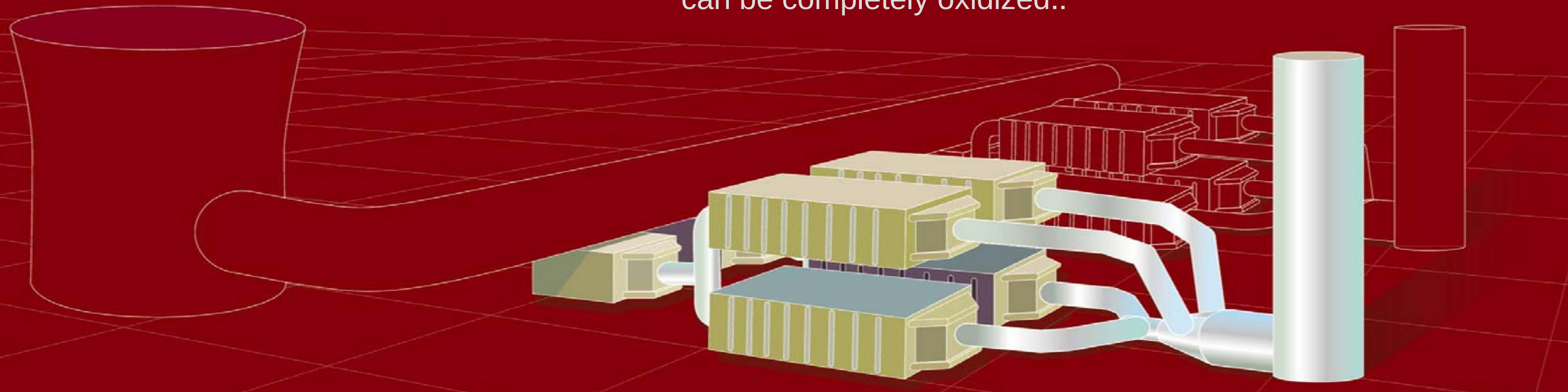
MEGTEC VAM processing concept is modular, based on VOCSIDIZERs, stacked in arrangements of VAM Cubes, each Cube processing 250,000 Nm3/h.



PURE VAM ABATEMENT – OR CONVERTING

COAL MINE VENTILATION AIR METHANE INTO USEFUL ENERGY

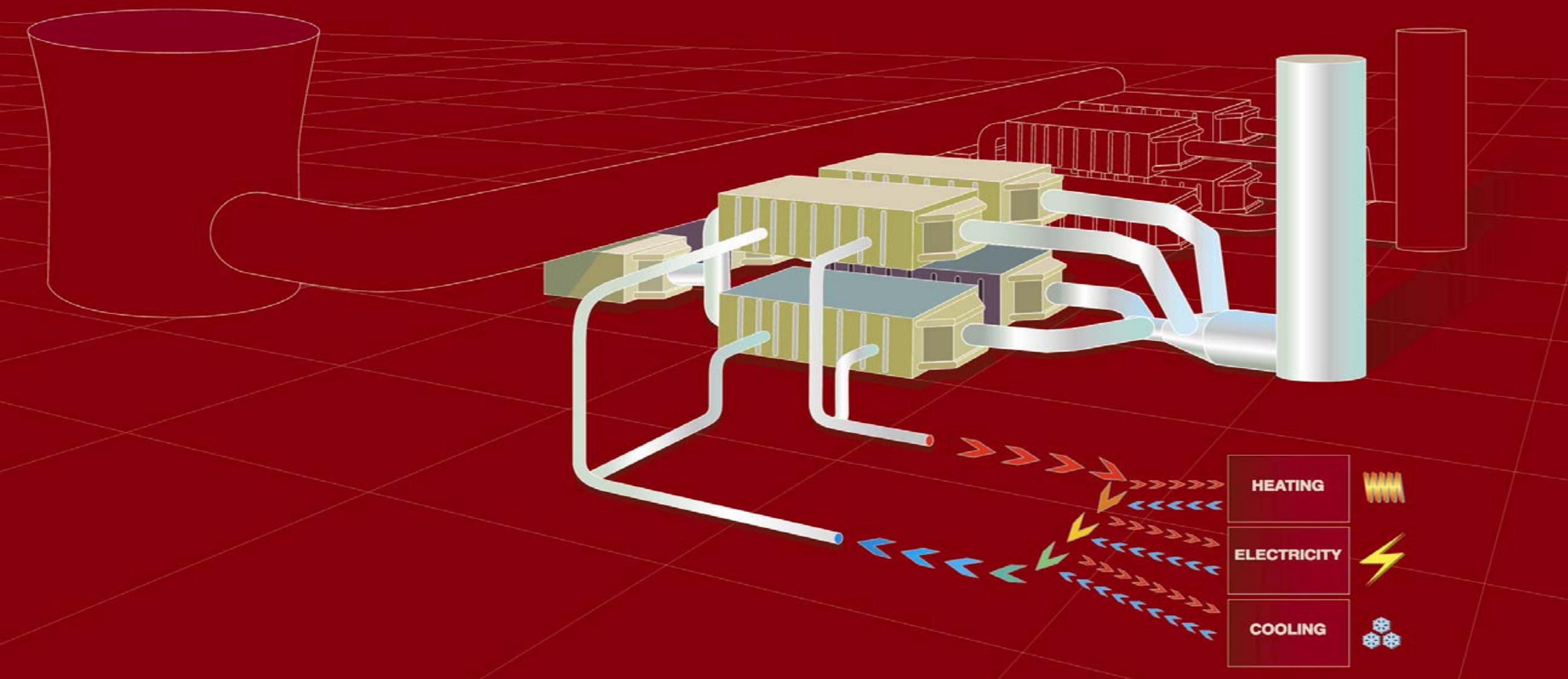
In the VOCSIDIZER,
the methane in ventilation air
can be completely oxidized..



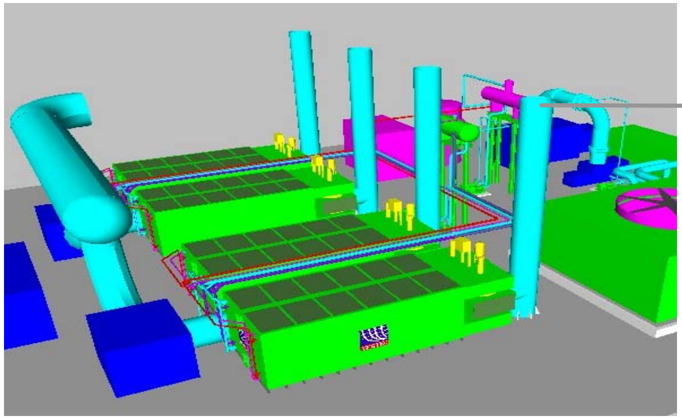
PURE VAM ABATEMENT – OR CONVERTING

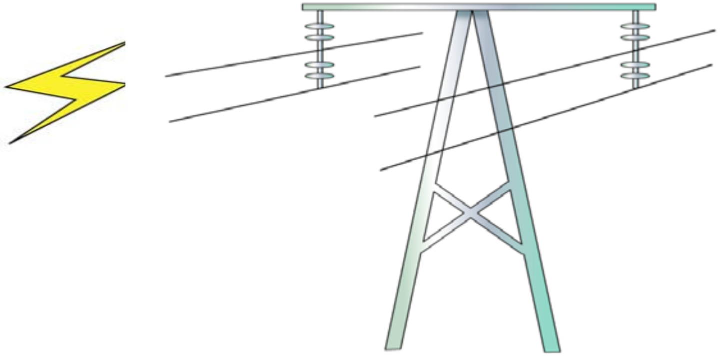
COAL MINE VENTILATION AIR METHANE INTO USEFUL ENERGY

.. and converted to useful energy.



VOCSIDIZER technology for VAM Energy Recovery





0.2 % methane needed to maintain oxidation.
Energy of concentrations above 0.2 % can be recovered.

Example:

800 000 m³/h

1 % CH_4

→ *72 MW(th)* → *21 MW(el)*

(at 30% efficiency)

Example:

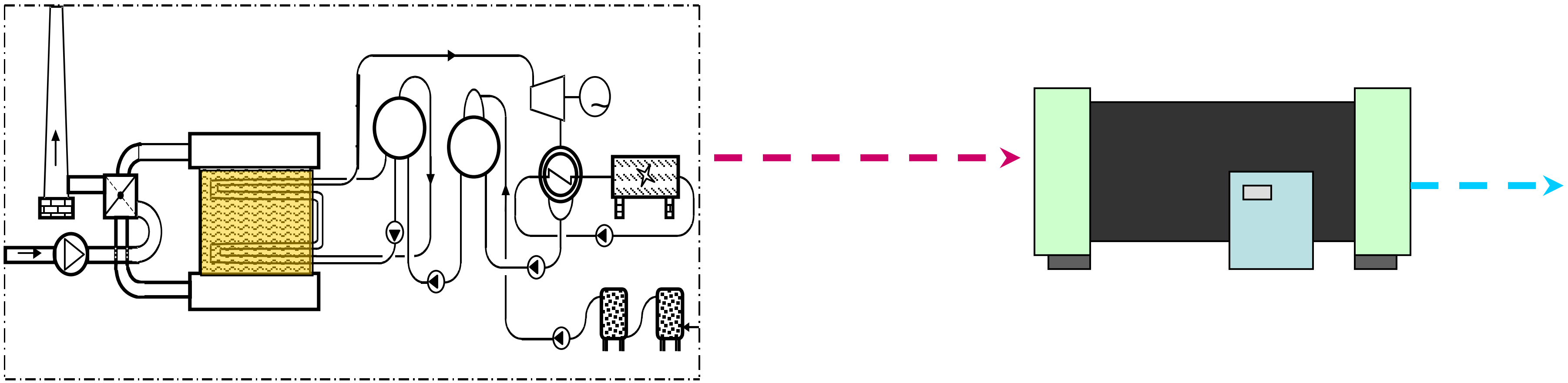
800 000 m³/h

0.6 % CH_4

→ *36 MW(th)* → *10 MW(el)*

(at 30% efficiency)

Cogeneration of electricity and heating – plus cooling



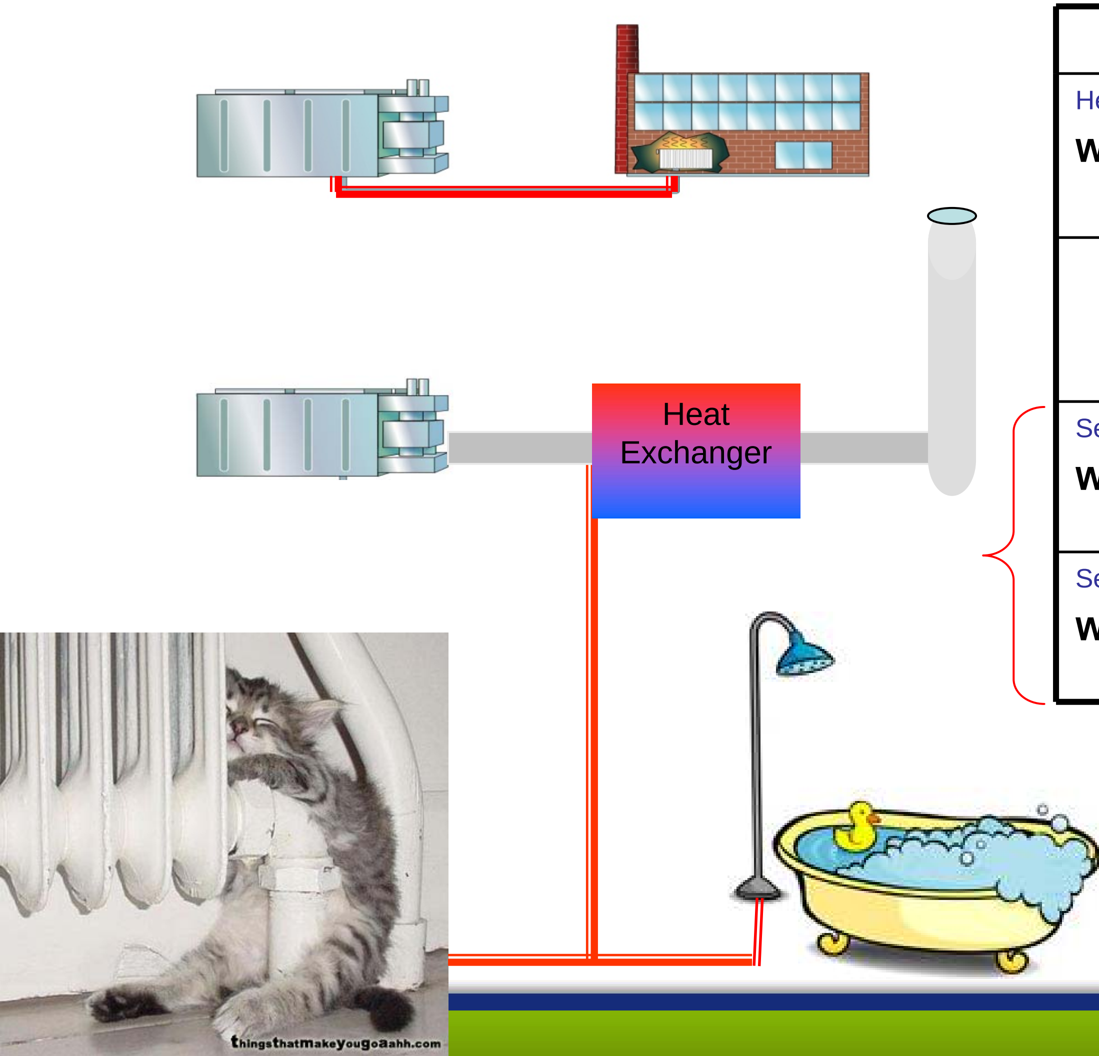
Cooling water from electricity generation drives absorption chiller

Example:

800 000 m3/h
1% methane → *72 MW(th)* → *21 MW(el)* → *19 MW(el) + 38 MW(cool)*

Hot water from VAM (thermal energy)

GUIDE LINES



	0.3%	0.6%	0.9%
Heat straight from bed. **Water at 70 - 150°C**	3 MW	11 MW	18 MW
--- *For each 250 000 Nm3/h of ventilation air* ---			
Secondary heat-exchanger. **Water at 70oC**	1 MW	8 MW	15 MW
Secondary heat-exchanger. **Water at 150oC**	-	2 MW	10 MW

Electricity from VAM Power Plant

GUIDE LINES

	0.3%	0.6%	0.9%
Heat straight from bed. **Water at 70 - 150^{oC}**	~~3 MW_{th} = ½ -1 MW_e~~	11 MW_{th} = 3 -4 MW_e	18 MW_{th} = 5 - 6 MW_e
--- *For each 250 000 Nm3/h of ventilation air* ---			

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

INDUSTRIAL SAFETY MANAGEMENT

Generally applied for securing potentially dangerous installations
in chemical process industries, in oil & gas industry,
in paper & pulp industry, in power industry etc
in Europe and elsewhere: **IEC 61511** *)

*) Since January 2010 recommended in the Machine Directive for all industrial systems

IEC 61511 is based on assessment and confirmation of
SIL (Safety Integrity Level) in design, implementation, operation and maintenance.

This is done by applying a number of established routines such as;
Hazard and Operability Analysis (HAZOP), Layer Of Protection Analysis, Risk Matrix, Risk Graph, etc.

INDUSTRIAL SAFETY MANAGEMENT

Consequence	
Type	C
H	F
E	D
F	E

Example

of SIL analysis acc to IEC 61511 of each potentially dangerous loop identified by HAZOP:

Avoidance probability		P
P_B	Avoidance conditions NOT fulfilled	1
P_A	All avoidance conditions ARE fulfilled	0

Exposure rate			F
F_D	Permanent	=1	2
F_C	Frequent	0.1-1	2
F_B	Occasionally	0.01-0.1	1
F_A	Rare	<0.01	0

Demand rate			W
W_9	Often	>1/y	9
W_8	Frequent	1/1-3 y	8
W_7	Likely	1/3-10 y	7
W_6	Probable	1/10-30 y	6
W_5	Occasional	1/30-100 y	5
W_4	Remote	1/100-300 y	4
W_3	Improbable	1/300-1,000 y	3
W_2	Incredible	1/1,000-10,000 y	2
W_1	Inconceivable	1/10,000-1,000,000 y	1

Consequence		Influence		Demand	Likelihood
Type	C	F	P	W	Sum
F	F	2	1		6
E	D	1	1	3	5
F	E				

	Likelihood sum (F+P+W)					
C	1-2	3-4	5-6	7-8	9-10	11-12
F	NR	IL 1	IL 2	IL 3	IL 4	NO
E	NR	NR	IL 1	IL 2	IL 3	IL 4
D	OK	NR	NR	IL 1	IL 2	IL 3
C	OK	OK	NR	NR	IL 1	IL 2
B	OK	OK	OK	NR	NR	IL 1
a	OK	OK	OK	OK	NR	NR

Consequence		Influence		Demand	Likelihood	Integrity	
Type	C	F	P	W	Sum	IL	SIL
H	F	2	1		6	2	2
E	D	1	1	3	5	0	
F	E					1	

Thereafter a LOPA *) is done to determine requirement for each component of the evaluated loop.

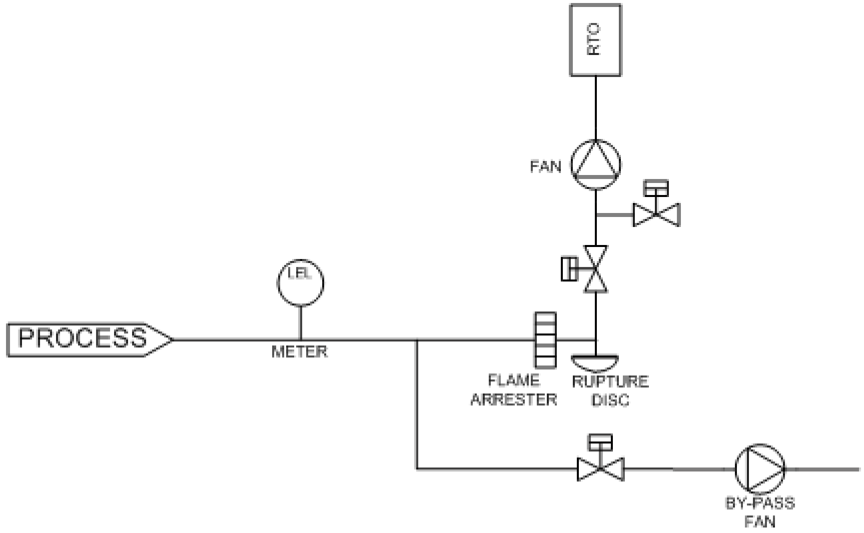
*) Layer Of Protection Analysis

INDUSTRIAL SAFETY MANAGEMENT

- KEY SAFETY ITEMS OF 3 EMISSION CONTROLL CASES

1/ Chemical industry example of solution at an international **paint producer**, where process air comes from paint mixing with possible high solvent concentrations.

- Single measurement of incoming concentrations
- Bypass with separate fan when too high concentrations are detected
- Single block shut off valve for incoming process air when in bypass mode
- Rupture disc
- Flame arrester
- Etc

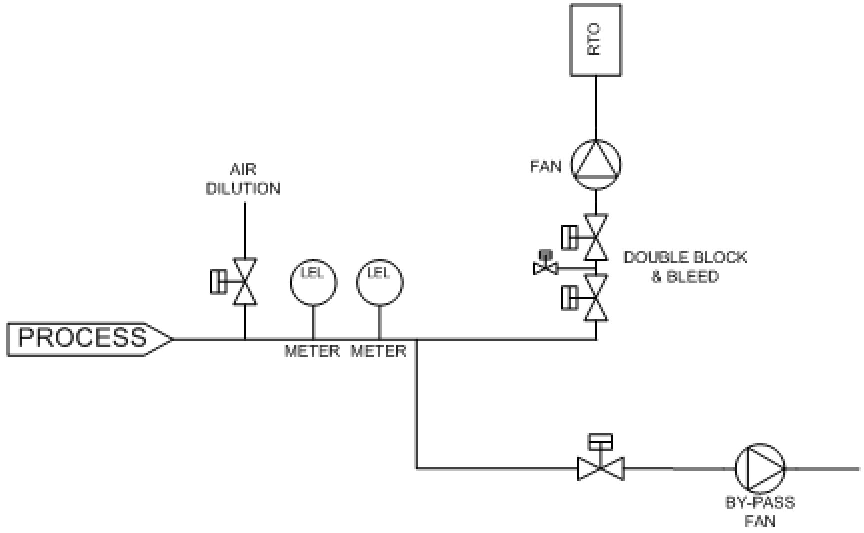


INDUSTRIAL SAFETY MANAGEMENT

- KEY SAFETY ITEMS OF 3 EMISSION CONTROLL CASES

2/ Methane example of solution for processing slip from **biogas upgrading** system, where incoming methane concentration is likely to occasionally exceed accepted levels.

- Double measuring of incoming process air (to obtain min SIL 2)
- Dilution with fresh air when methane concentration >1%
- Bypass with separate fan when methane concentration is too high to dilute to safe level
- Double block-and-bleed shut of valve for incoming process air when in bypass mode
- Etc

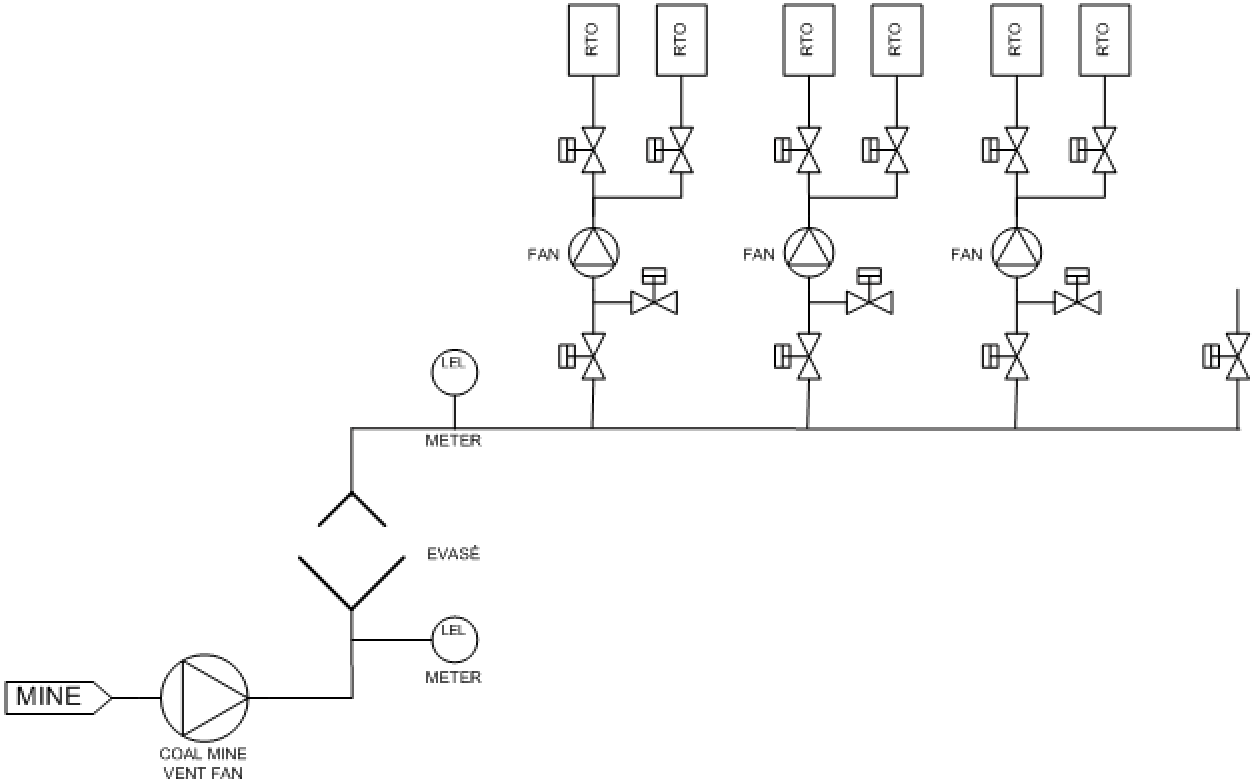


INDUSTRIAL SAFETY MANAGEMENT

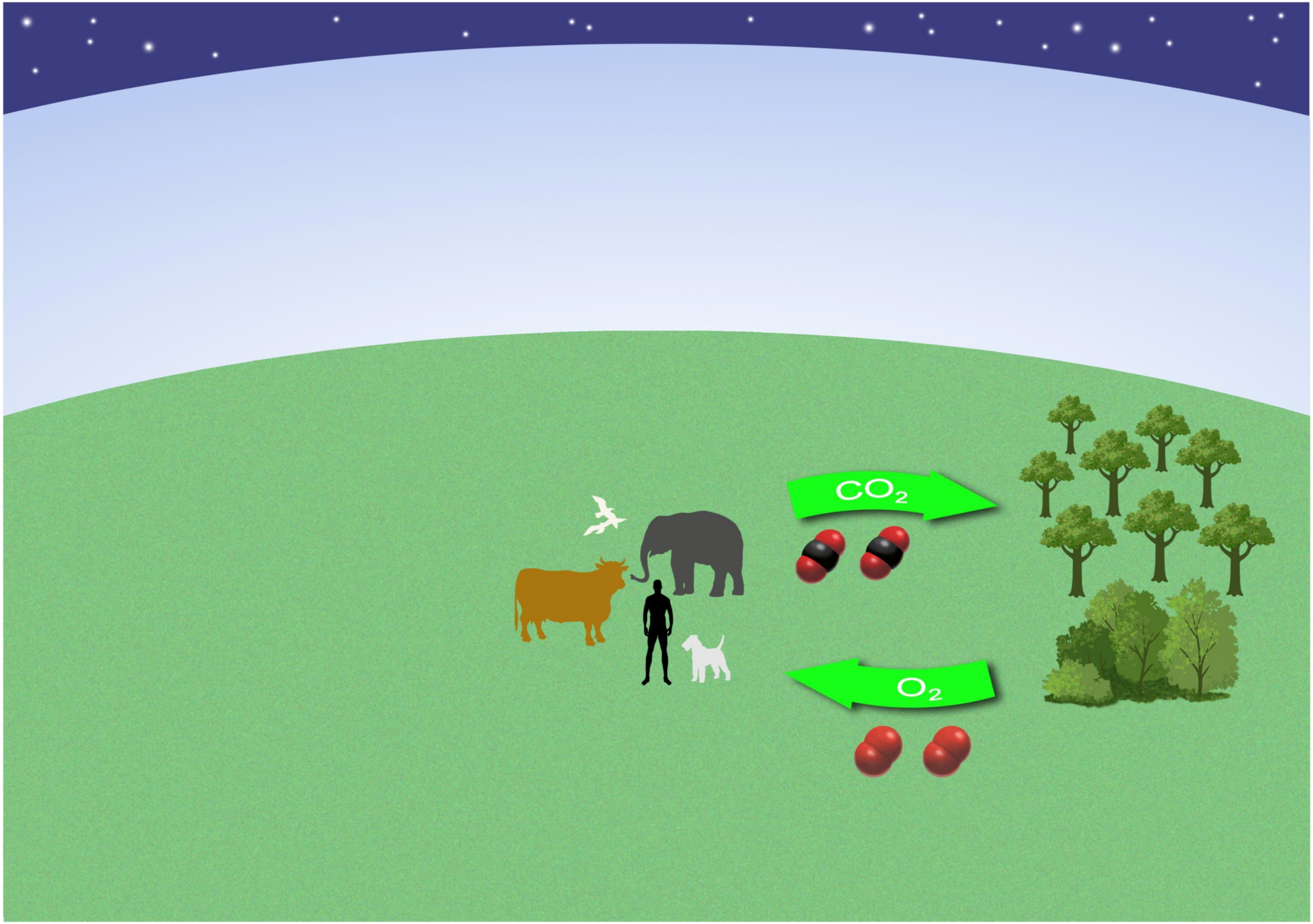
- KEY SAFETY ITEMS OF 3 EMISSION CONTROLL CASES

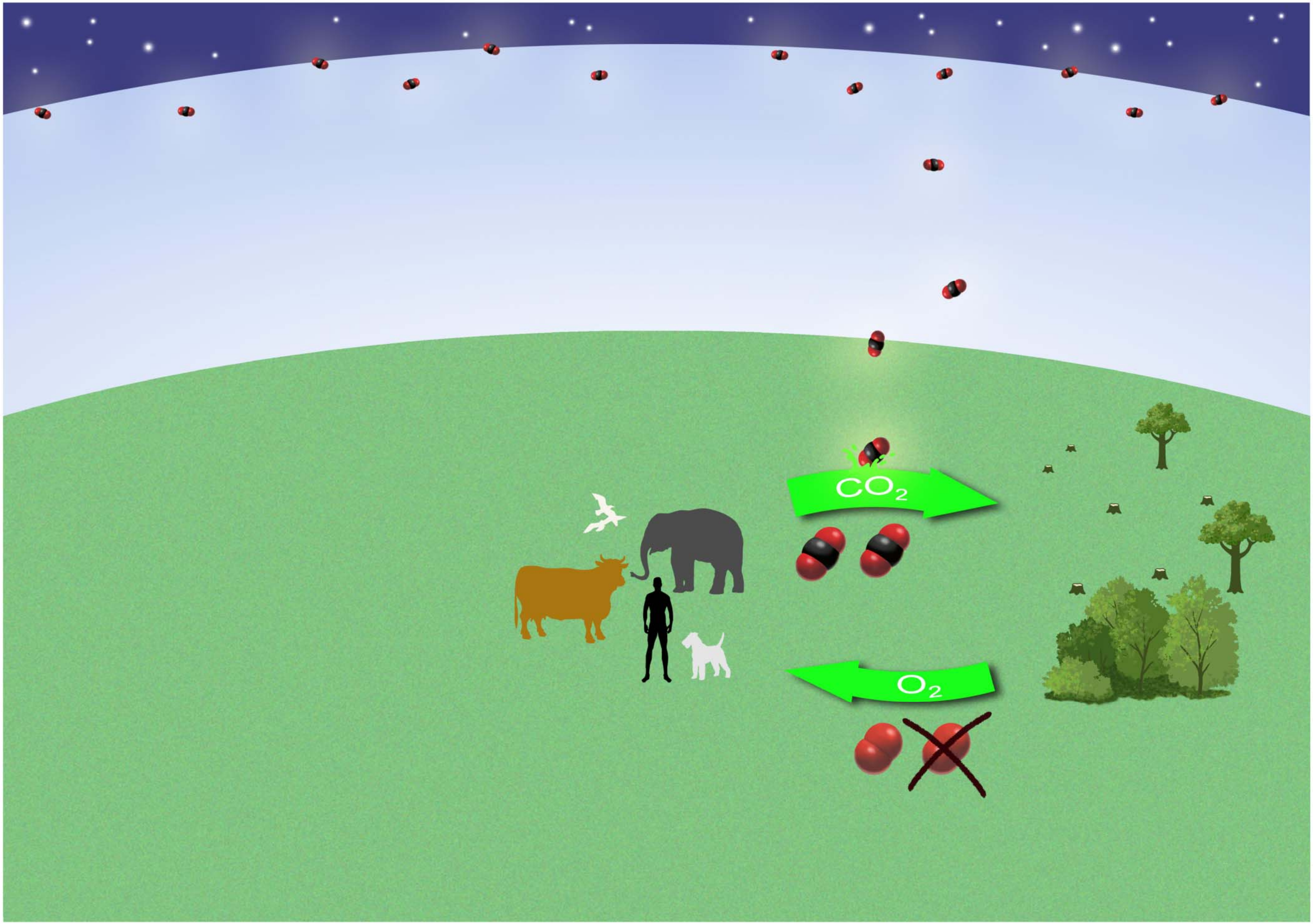
3/ VAM example of solution at **coal mine** (DaTong, China), where VAM concentration at normal operating conditions does not exceed 0.7%.

- Double measuring of incoming methane (VAM) concentration
- Bypass when methane concentration is higher than Chinese legal level of 0.75%
- Double block-and-bleed shut of valve for incoming ventilation air when in bypass mode
- Etc

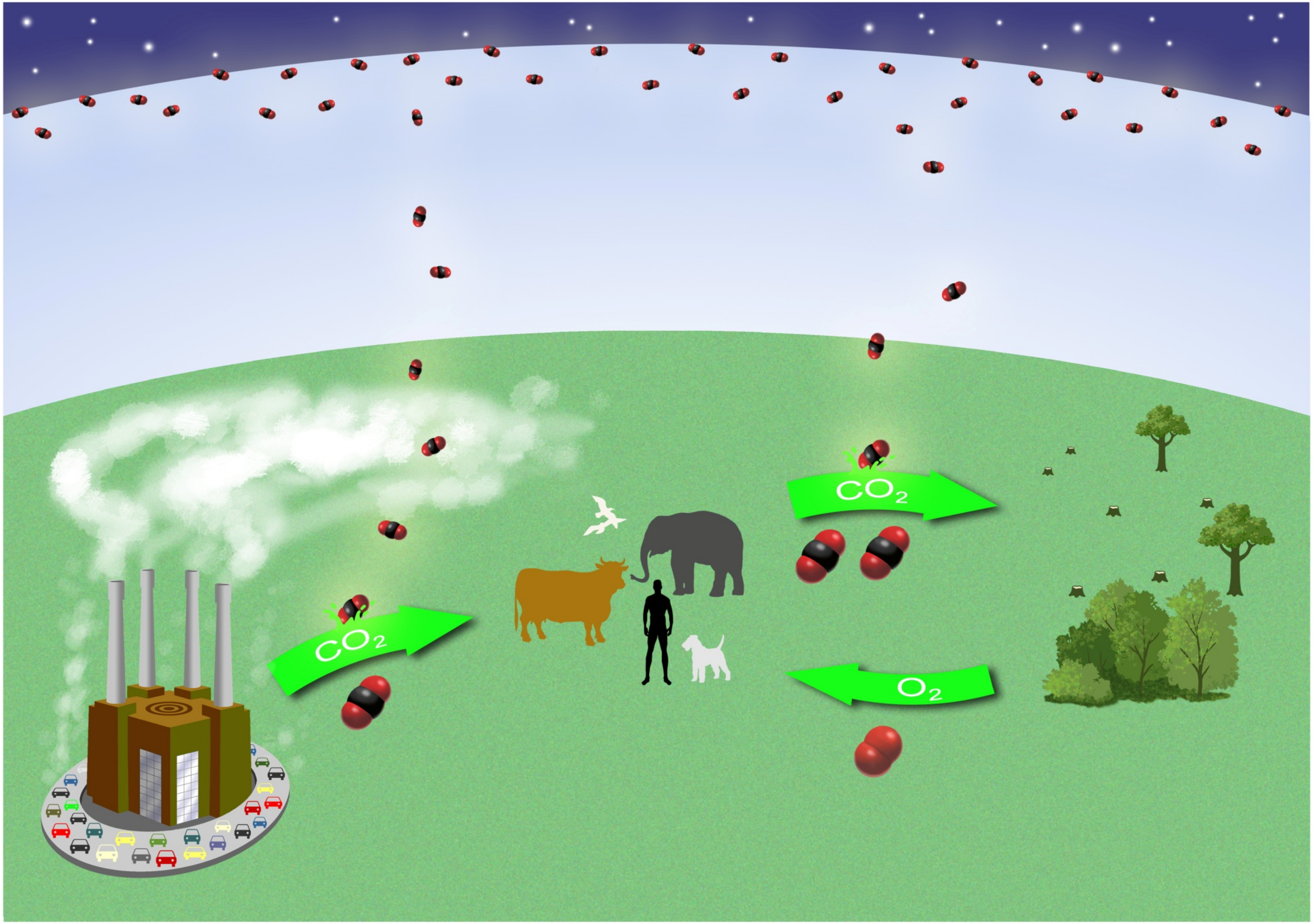


WHY ARE EMISSIONS OF VAM OF CLIMATE CHANGE INTEREST ??

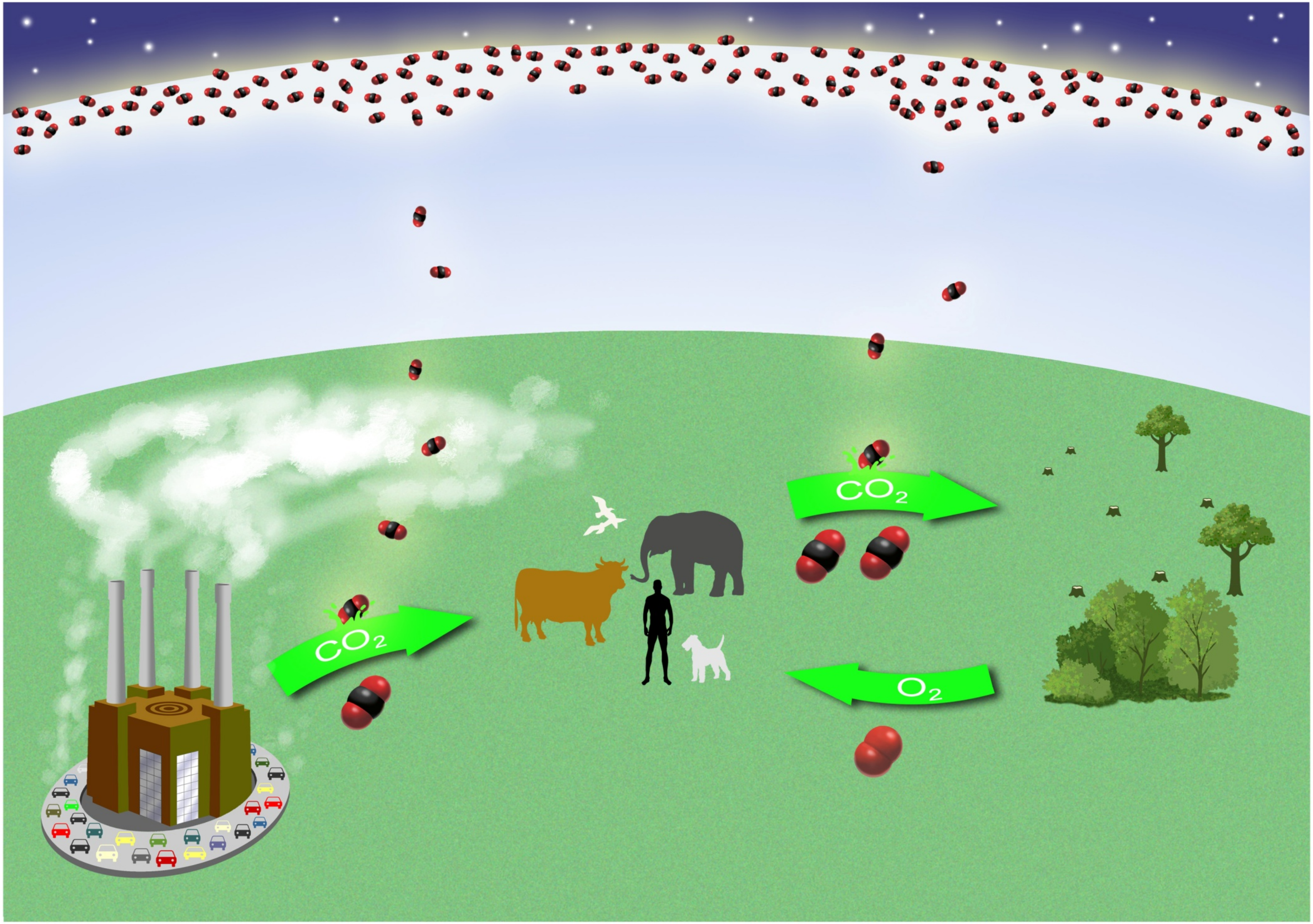

CO_2
O_2



CO_2
O_2

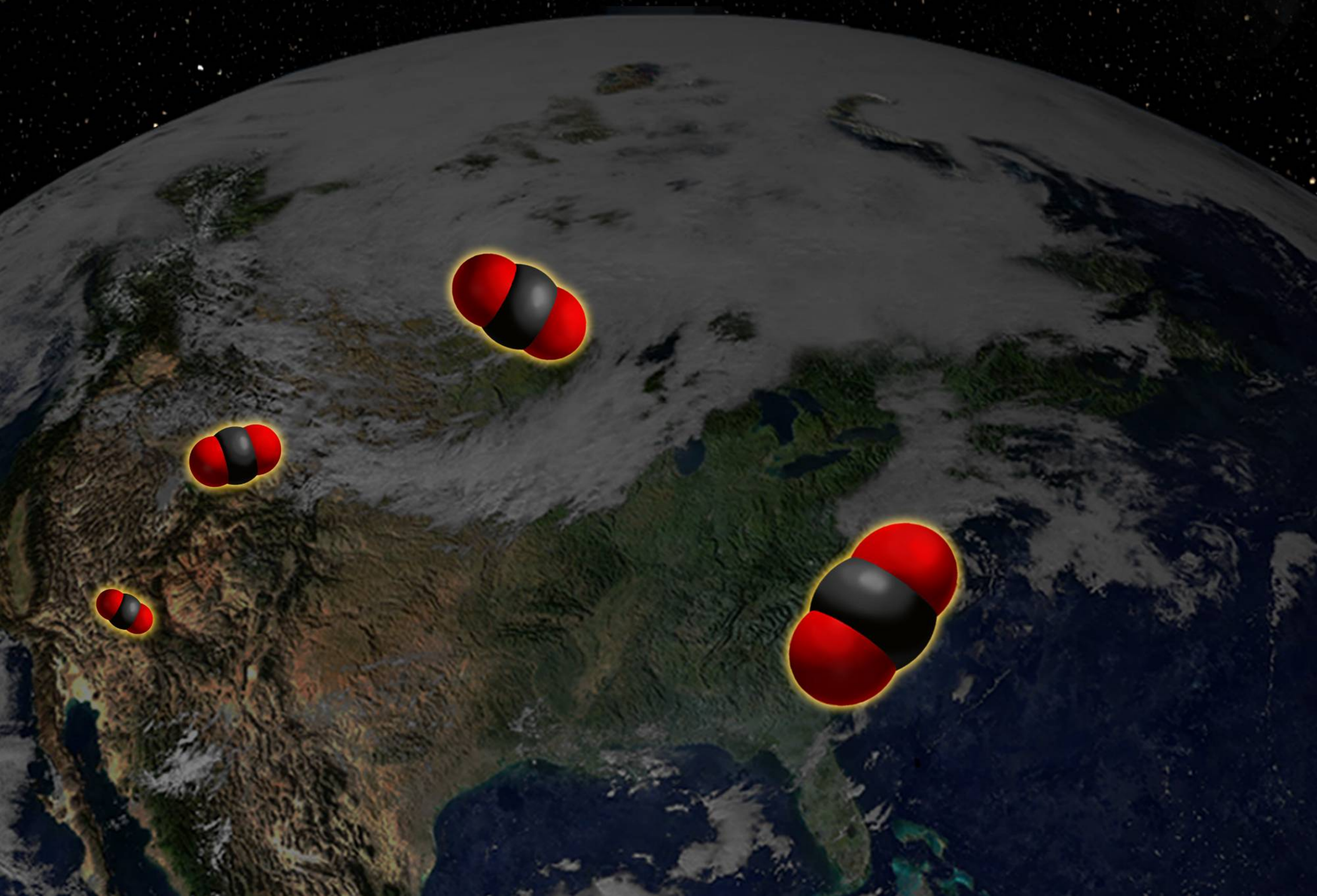


CO_2
CO_2
O_2

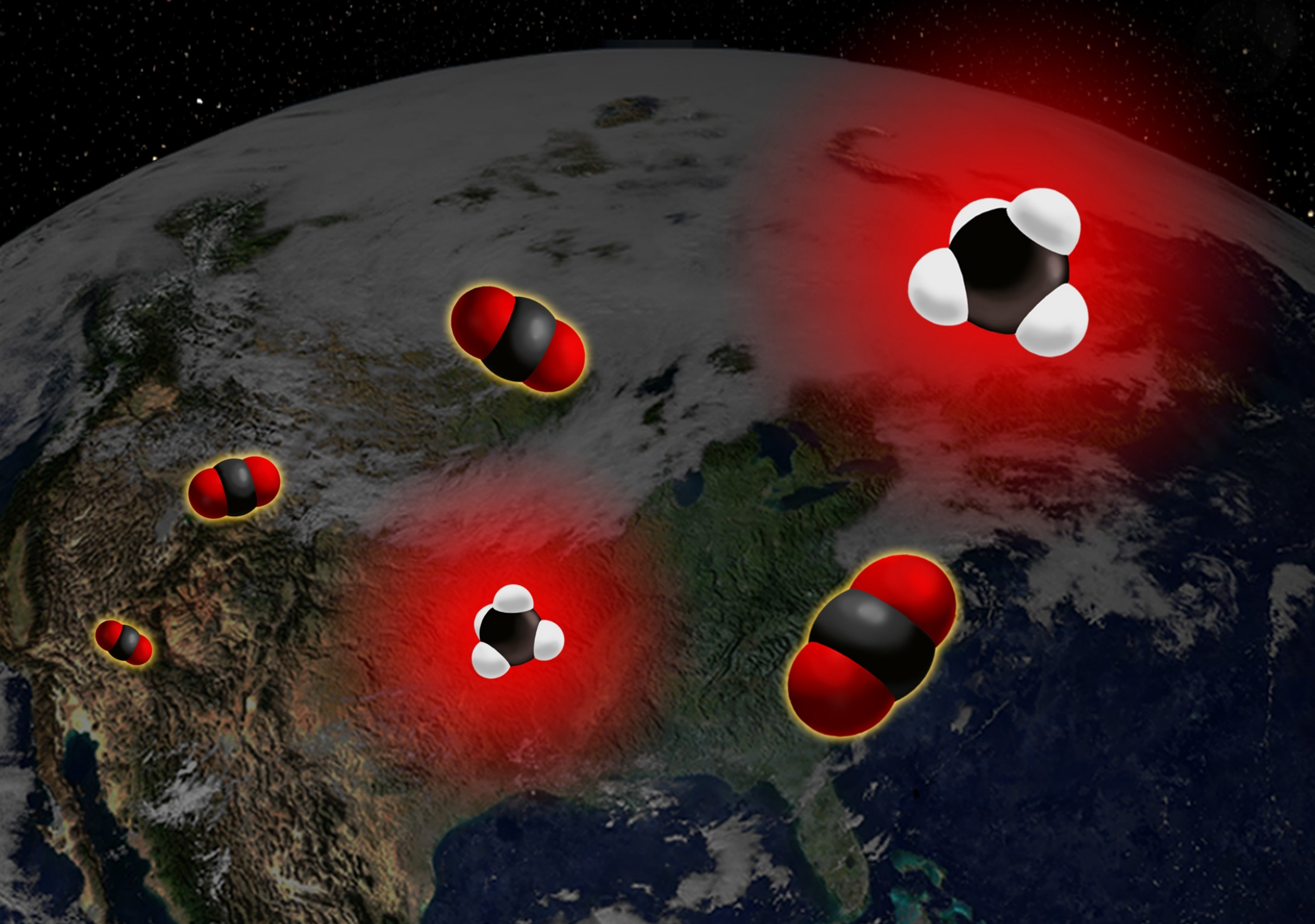


CO2
CO2
O2

The accumulated CO_2 can retain some additional heat in the atmosphere, causing Global Warming.



Methane can retain MUCH more heat!

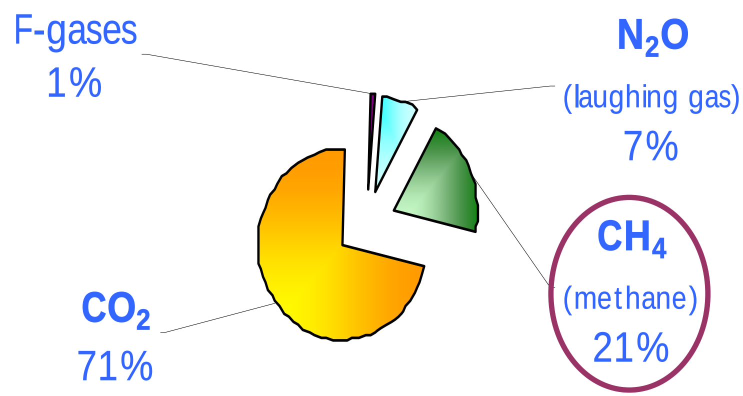


Global Methane Emissions - by source

ANTHROPOGENIC

Global GHG contributions 2004

- excluding CO_2 addition from deforestation

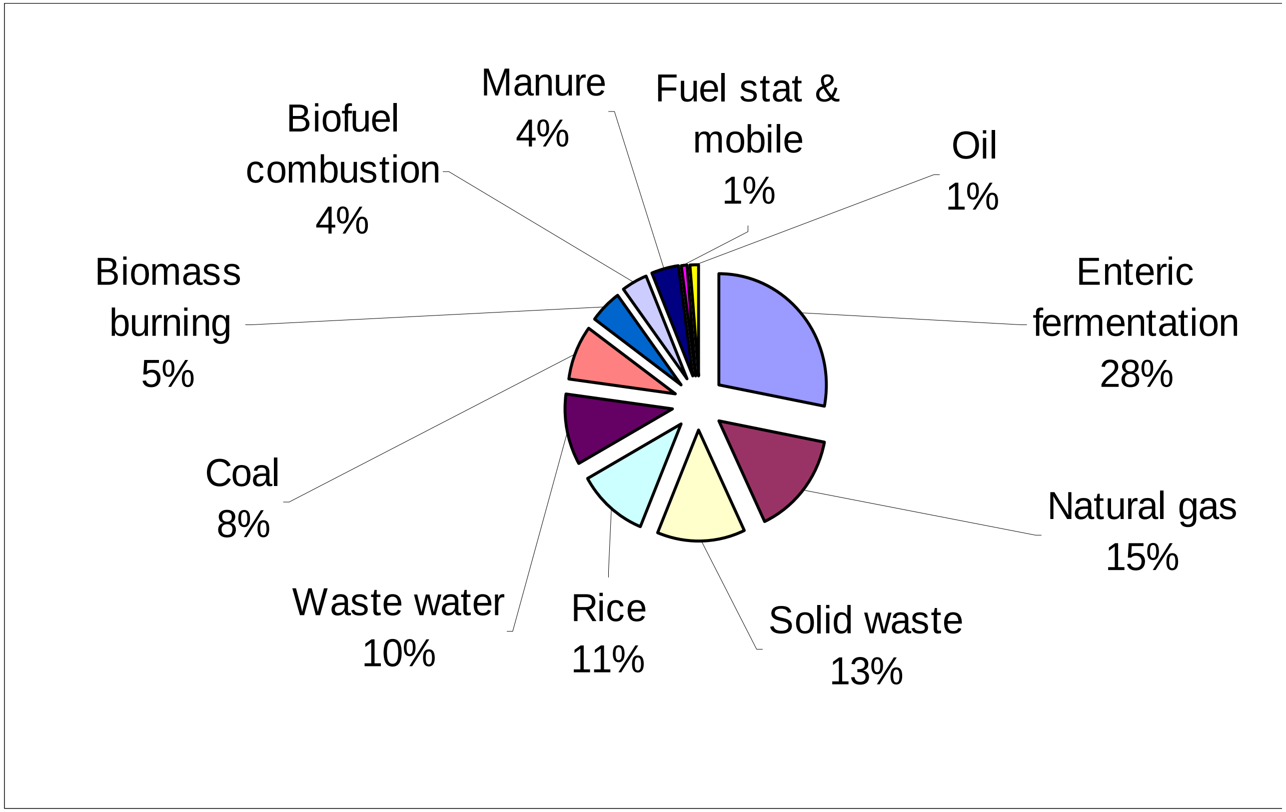


	CO_2	CH_4
Global Warming Power	1	25 (21 in the first Kyoto Period)
Life time in atmosphere (years)	20 000 – 50 000	12

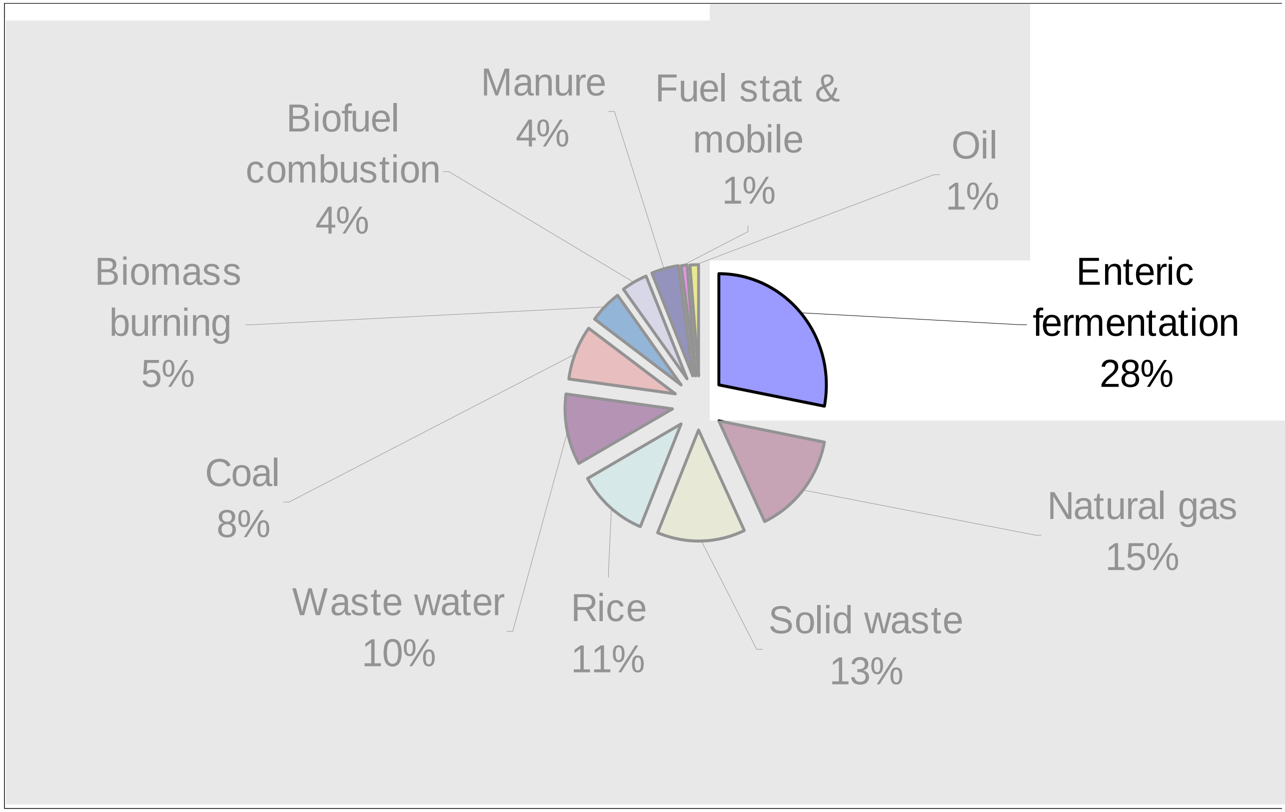
- ✓ Second most important greenhouse gas
- ✓ Much more powerful greenhouse gas than CO2
- ✓ Short life time in atmosphere, so emission reductions will have a quick, positive impact
- ✓ **Generates energy when abated (oxidized)**

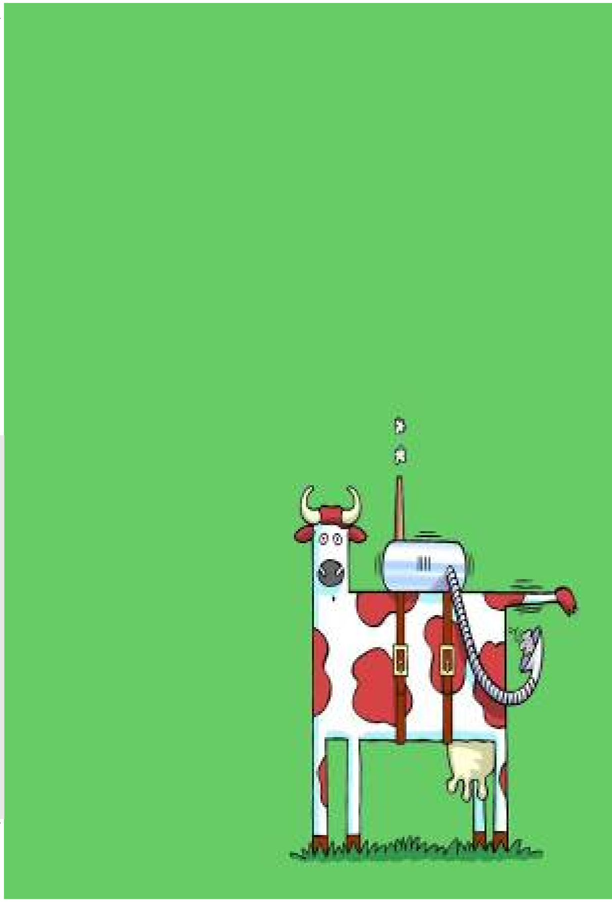
Global Methane Emissions - by source

(ANTHROPOGENIC)



Global Methane Emissions - by source
(ANTHROPOGENIC)



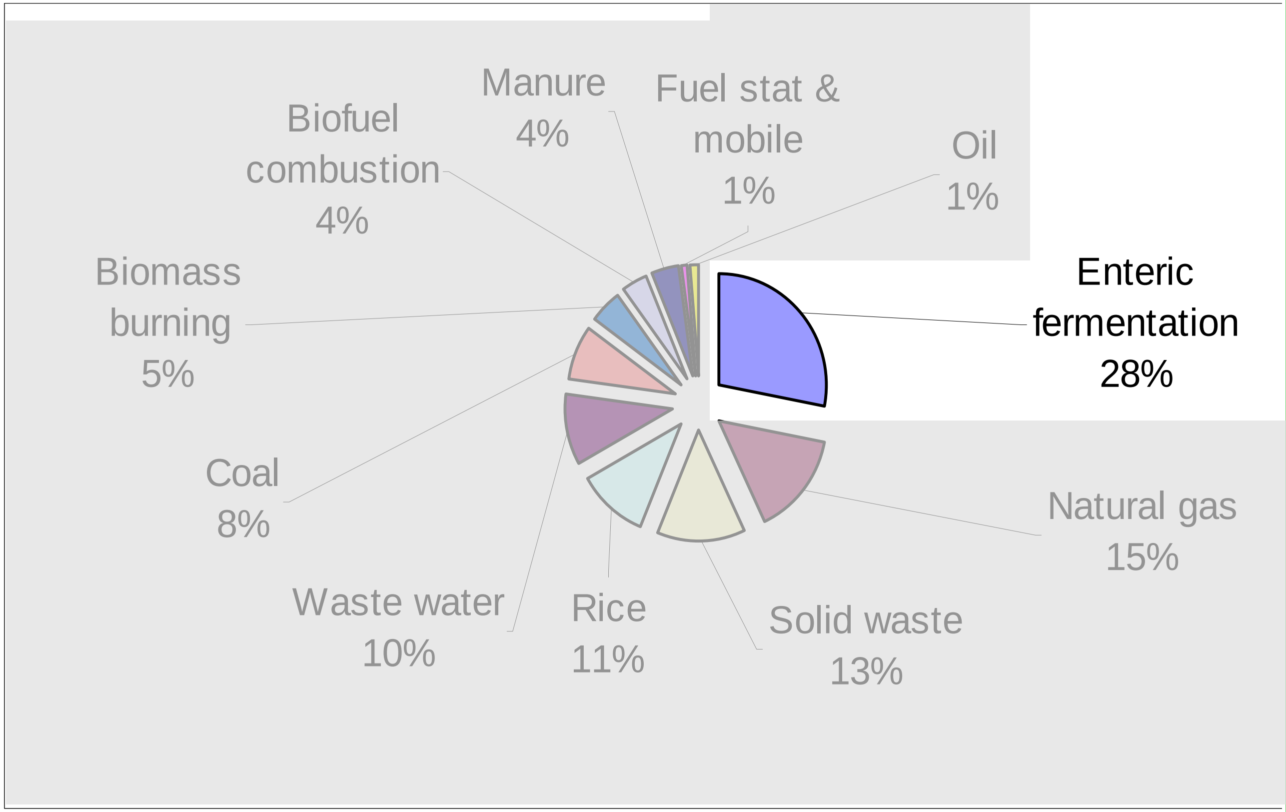


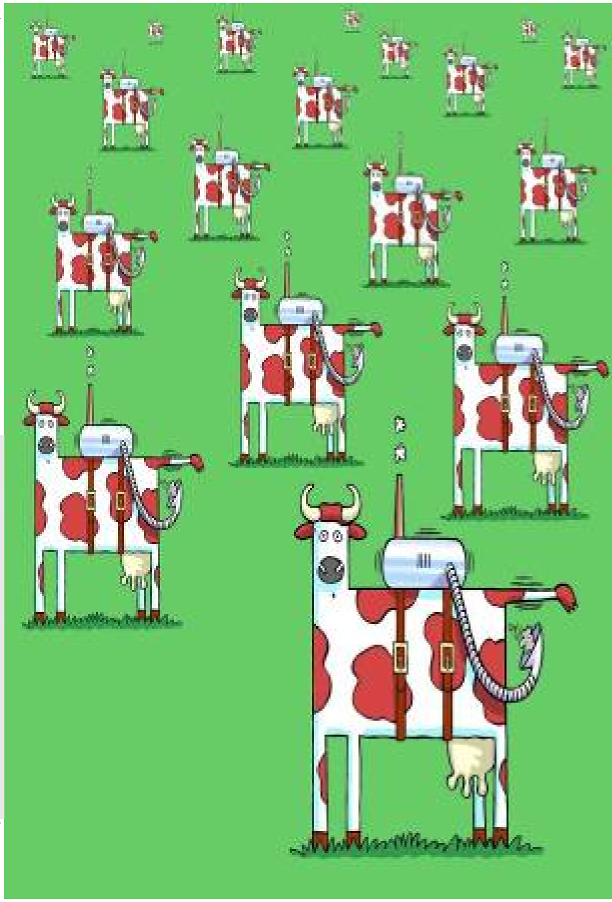
BIGGEST TOTAL SOURCE: Cows, sheep etc

PROBLEM: Each source is very small

50-100 kg CH_4 per cow and year = 1-2 t CO_2e

Global Methane Emissions - by source
(ANTHROPOGENIC)





50-100 kg CH4 per cow and year = 1-2 t CO2e

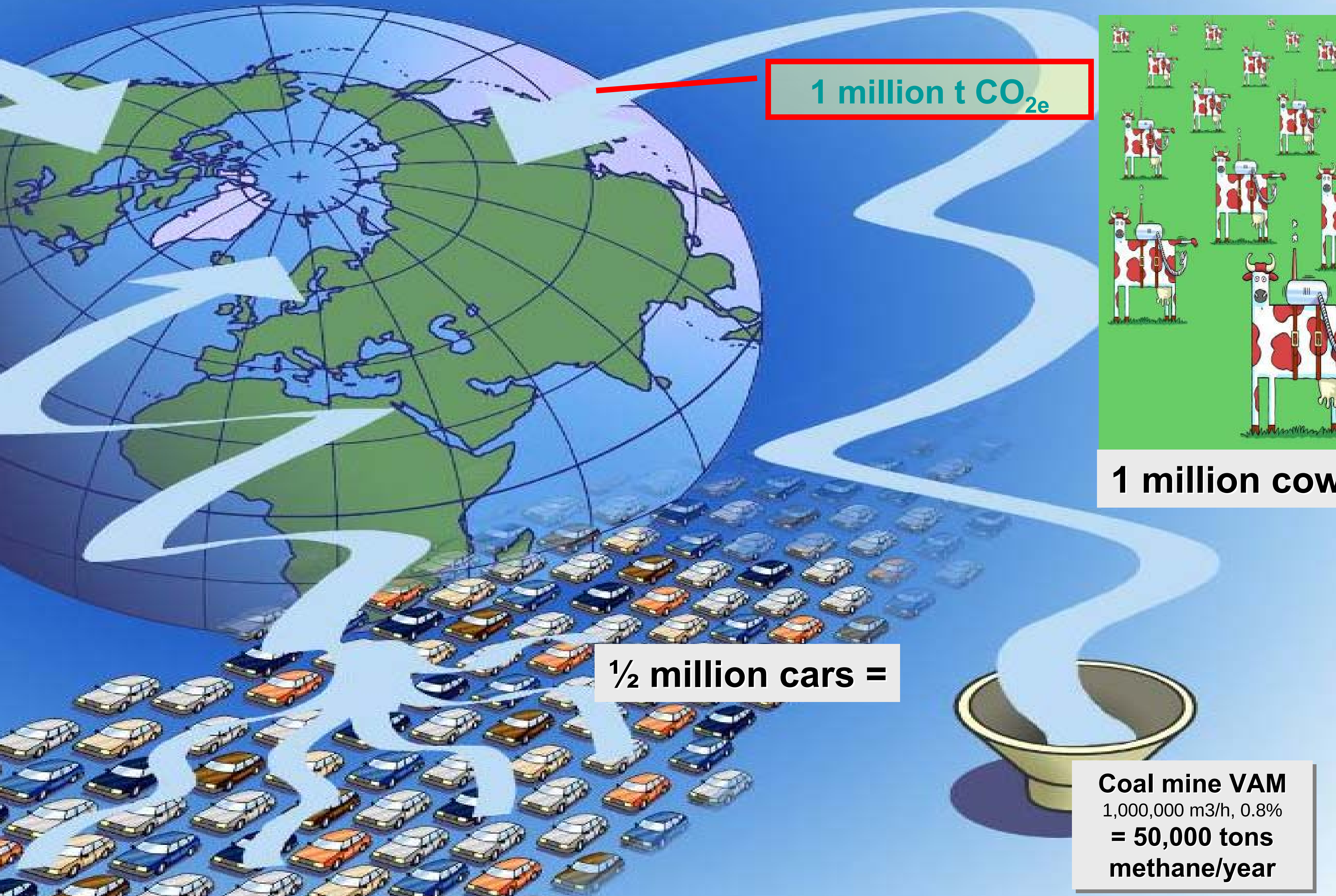
BIGGEST TOTAL SOURCE: Cows, sheep etc

PROBLEM: Each source is very small

Coal Mine VAM = singular large source of methane emission

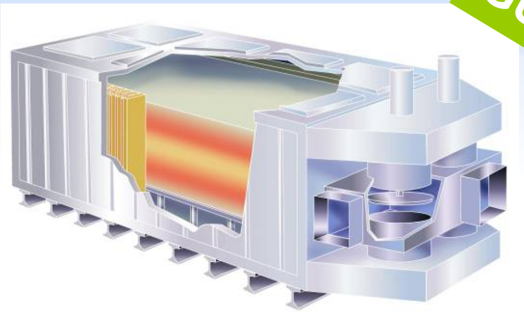
Coal Mine VAM = singular large source of methane emission

Coal Mine VAM = singular large source of methane emission



Calculations of CERs from VAM processing

GUIDE LINES



<u>Examples</u>:
250 000 Nm3/h @ 0.9 % VAM comes to 240 000 tonnes of CO_2e
125 000 Nm3/h @ 0,9 % VAM comes to 120 000 t CO_2e
125 000 Nm3/h @ 0,3 % VAM comes to 40 000 t CO_2e

VAM conc'n / Nm3/h vent air	0.3 %	0.6 %	0.9 %
125 000	***40***	***80***	***120***
250 000	***80***	***160***	***240***
500 000	***160***	***320***	***480***
1 000 000	***320***	***640***	***960***

Annual emission reductions in thousand tons of CO_2e

Indications of VAM project economics

GUIDE LINES

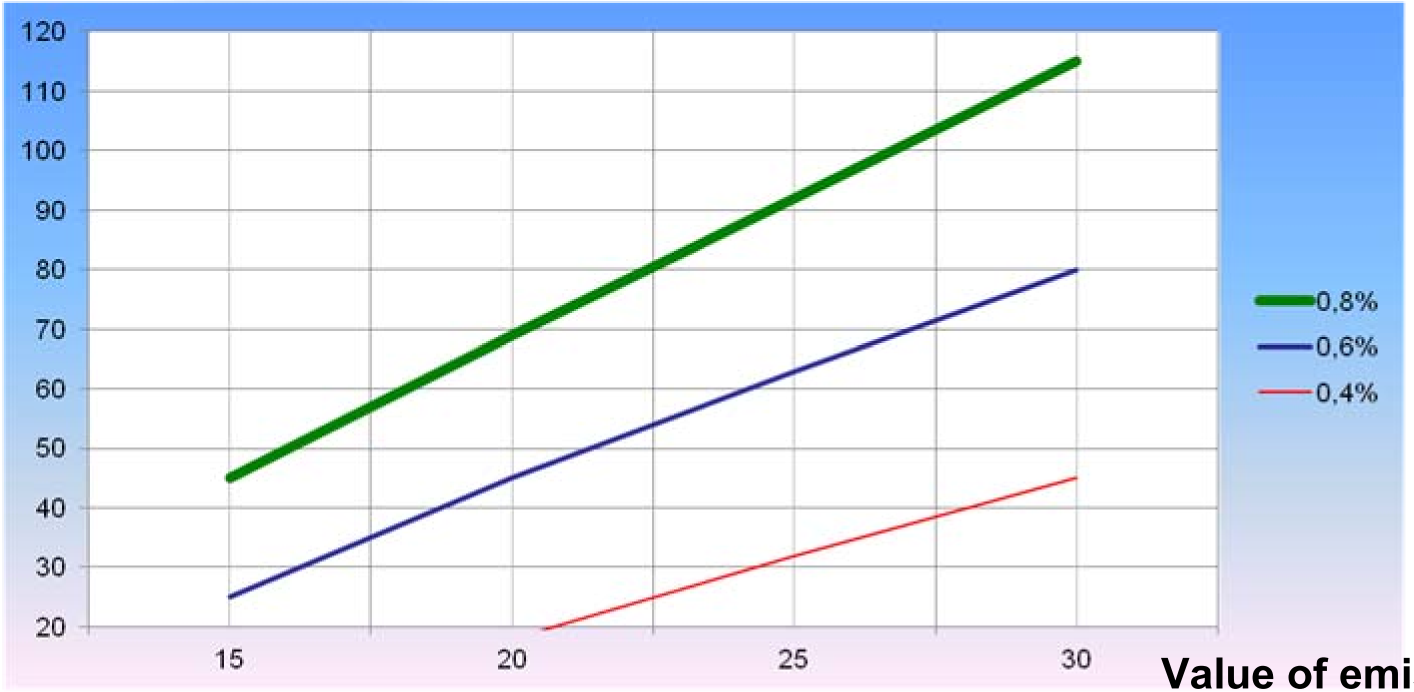
- ✓ The project economics of a VAM processing installation will largely depend on;
  - ❖ Total costs for investment, operation and maintenance.
  - ❖ Average VAM concentration of the ventilation air being processed.
  - ❖ The value of reducing the emissions.

MEGTEC

Indications of VAM project economics

GUIDE LINES

IRR
Internal Rent of Return (%)



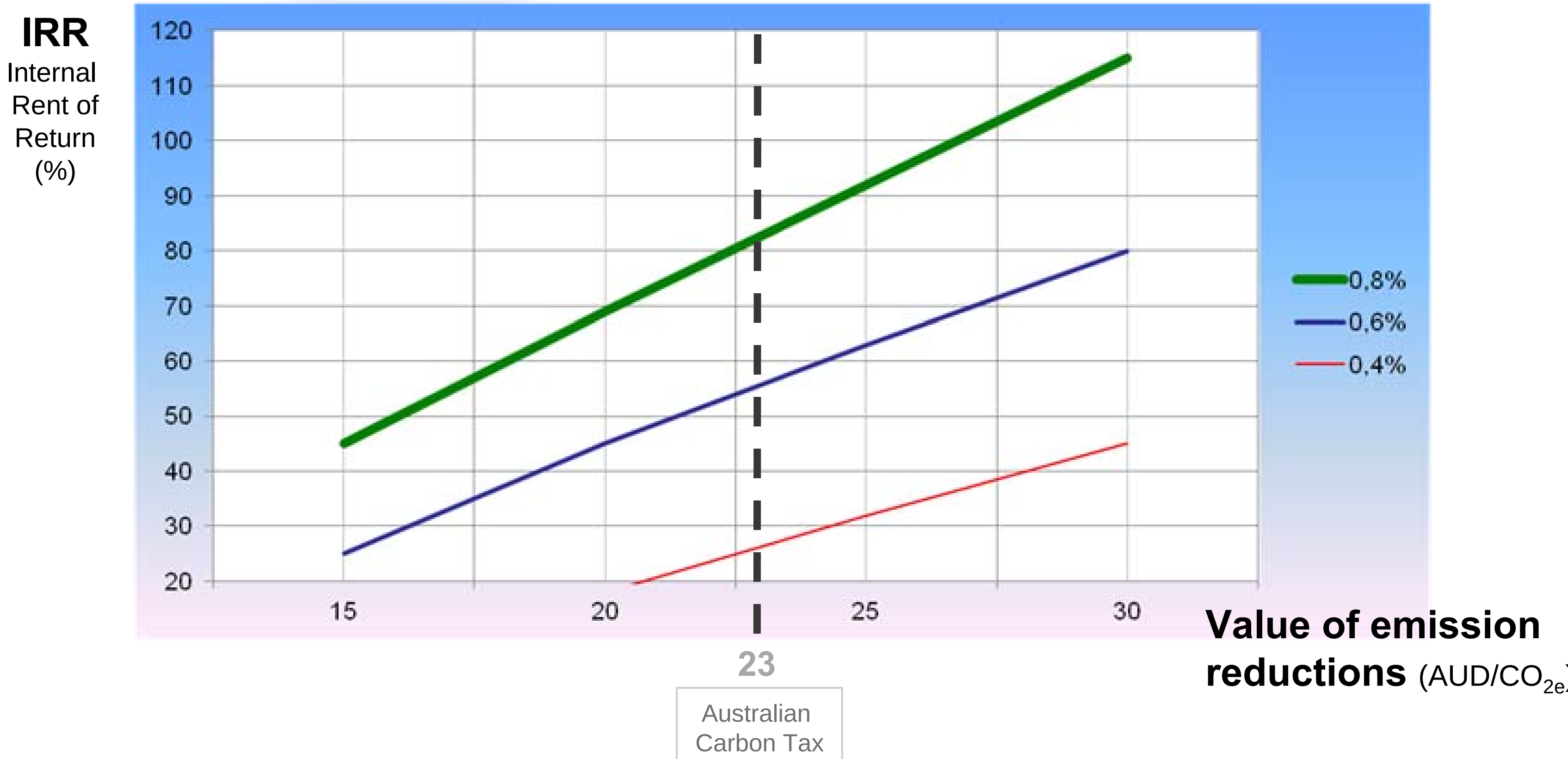
Value of emission reductions (AUD/CO_{2e})

<u>CONCLUSIONS for reasonable/good pay back:</u>

- VAM concentrations should be over ½ percent
- Carbon Credits should be worth min AUD ~20/t CO_{2e}

Indications of VAM project economics

GUIDE LINES



<u>CONCLUSIONS for reasonable/good pay back:</u>

- VAM concentrations should be over ½ percent
- Carbon Credits should be worth min AUD ~20/t CO_{2e}

MEGTEC

MEGTEC VAM Power Plant technology

WestVAMP at BHP Billiton in Australia

Field trip on Thursday will visit the VAM fuelled power plant of BHP Billiton;

WestVAMP

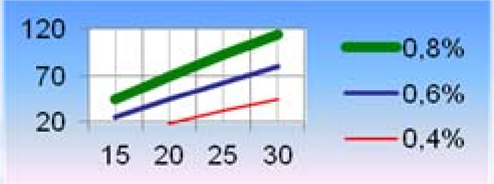
MEGTEC

Environmental Responsibility

MEGTEC was awarded the prestigious US EPA Climate Protection Award for 2008

- for finding a technical solution to the VAM emission problem and for bringing it to the global market.

VAM CONCLUSIONS



1. Most methane from coal mines is emitted as VAM.
2. MEGTEC has extensive experience of VAM Processing, in total over 30 years of VAM RTO unit operations.
3. VAM Processing can have a major positive impact on Global Warming and Climate Change.
4. With methane concentrations of at least half a %, Australian VAM projects can be financially attractive.

MEGTEC

Pilot VAM VOCSIDIZER
- available in Australia for VAM processing demonstration

Thank you!

RMATTUS@MEGTEC.SE