



Best Practices in CMM Project Development

Workshop on Promoting Coal Mine Methane (CMM) for Energy, Safety and the Environment: Legislation and Project Development in Kazakhstan

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Clark Talkington, Advanced Resources International, Inc.



Presentation Outline

- What is good safety practice?
- Review of methane drainage systems
- Integrating coal mine methane (CMM) capture and utilization
- CMM utilization
- Ventilation air methane (VAM) utilization
- Best practices case study
- Conclusions
- Discussion

What is Good Safety Practice?

Avoid explosive gas mixture

- Rapidly dilute explosive mixtures to safe concentrations
- Maximize methane drainage to minimize high gas concentrations in mine airways



Why employ best practice

- Mine safety
- Asset protection
- Coal Production
- Energy Recovery
- Environmental Protection

UNECE Best Practice Guidance on Effective Drainage and Use In Coal Mines

- High level principals-based guidance
- Target audience - government and corporate decision-makers
- Adopted by the UNECE in 2010
- Recommended for worldwide application by UN Economic and Social Counsel (ECOSOC) in 2011
- Supports development of safer and more effective practices
- Includes real world case studies
- Available in 7 languages including Russian
- Currently revising and 2nd edition expected to be released in 2016.
- Complements existing legal and regulatory frameworks

ЕВРОПЕЙСКАЯ ЭКОНОМИЧЕСКАЯ КОМИССИЯ

ПАРТНЕРСТВО "МЕТАН – НА РЫНКИ"

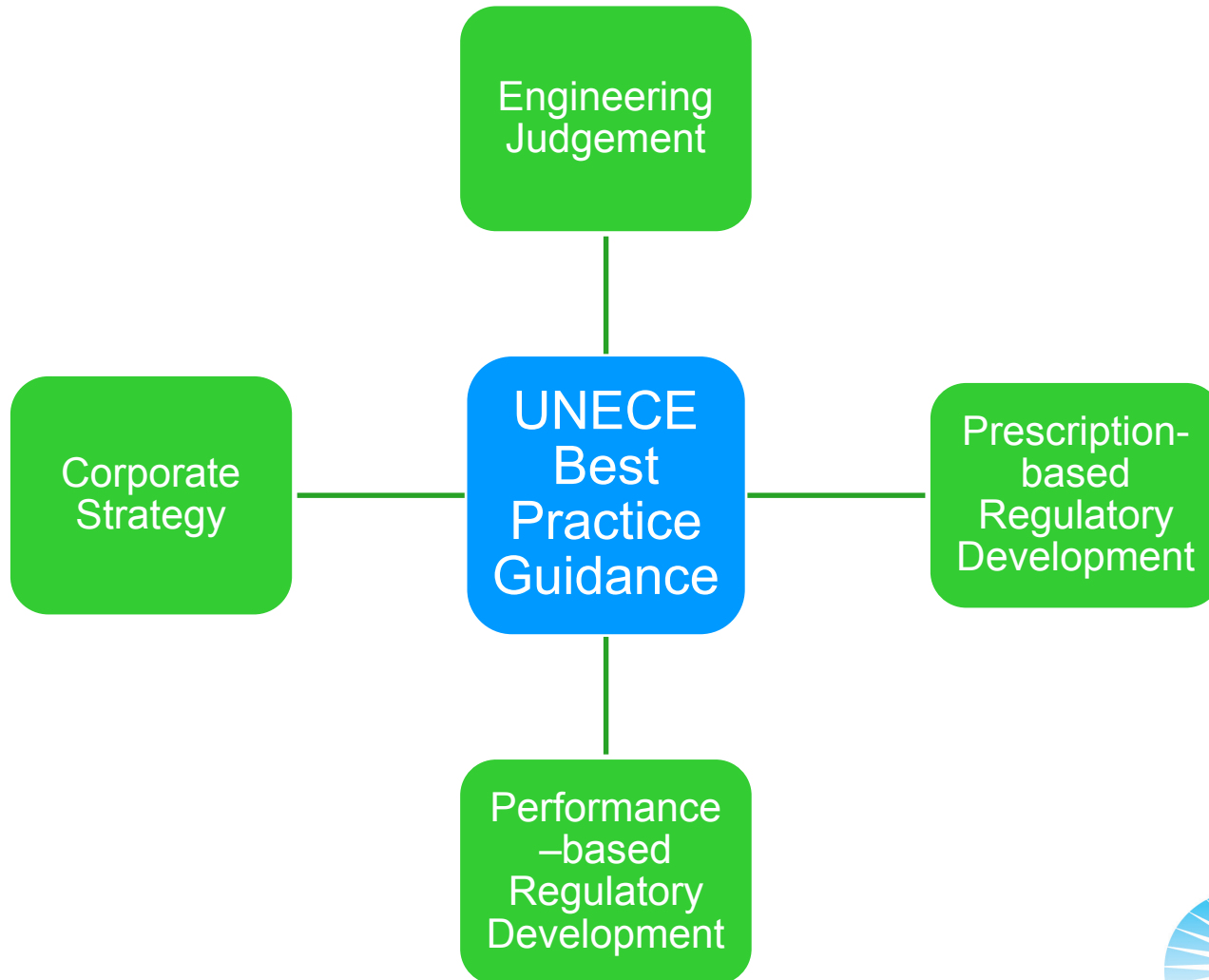
**Руководство по наилучшей практике
эффективной дегазации источников
метановыделения и утилизации метана
на угольных шахтах**

СЕРИЯ ПУБЛИКАЦИЙ ЕЭК ПО ЭНЕРГЕТИКЕ, № 31

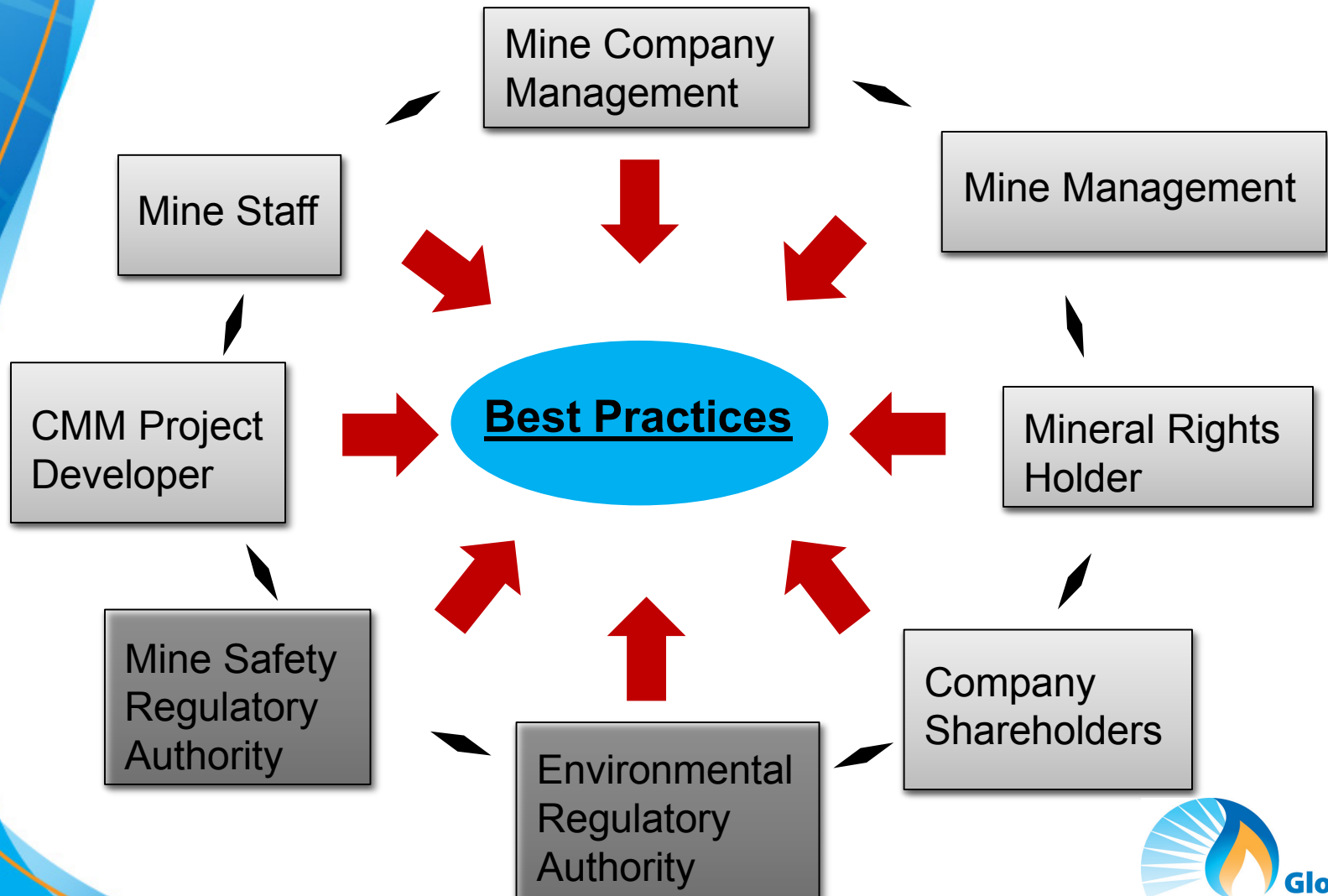


Организация Объединенных Наций
Нью-Йорк и Женева, 2010 год

Flexible Nature of Guidance



Stakeholders Critical to Achieve Best Practice



Key Tenets for Best Practices

Prediction of underground gas release

Efficient mine ventilation

Effective gas drainage

Optimal use of drained gas (CMM) and ventilation air methane (VAM) for near-zero emission coal mining

Management and staff education and training

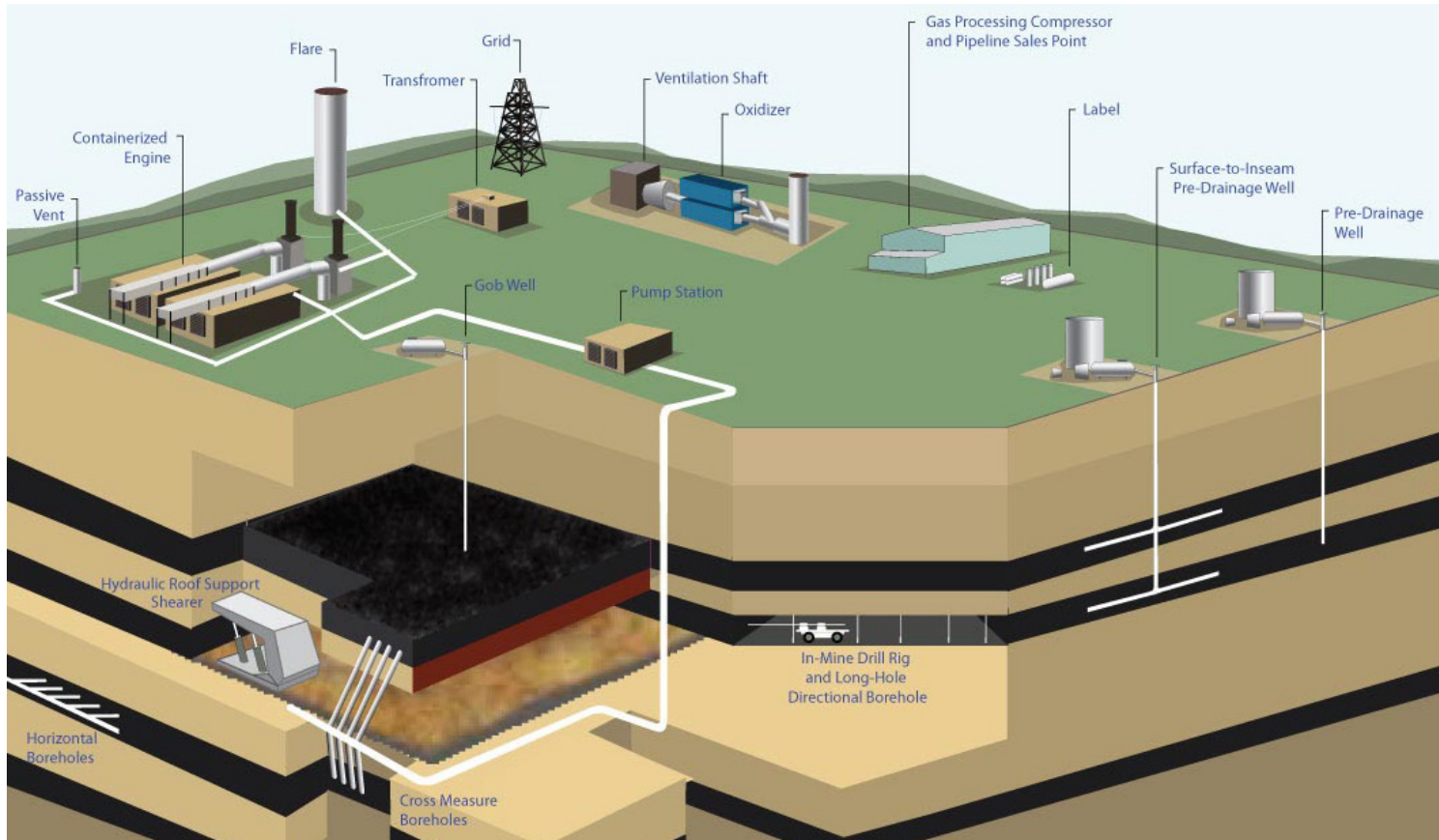
Reinvestment in mine and gas operations



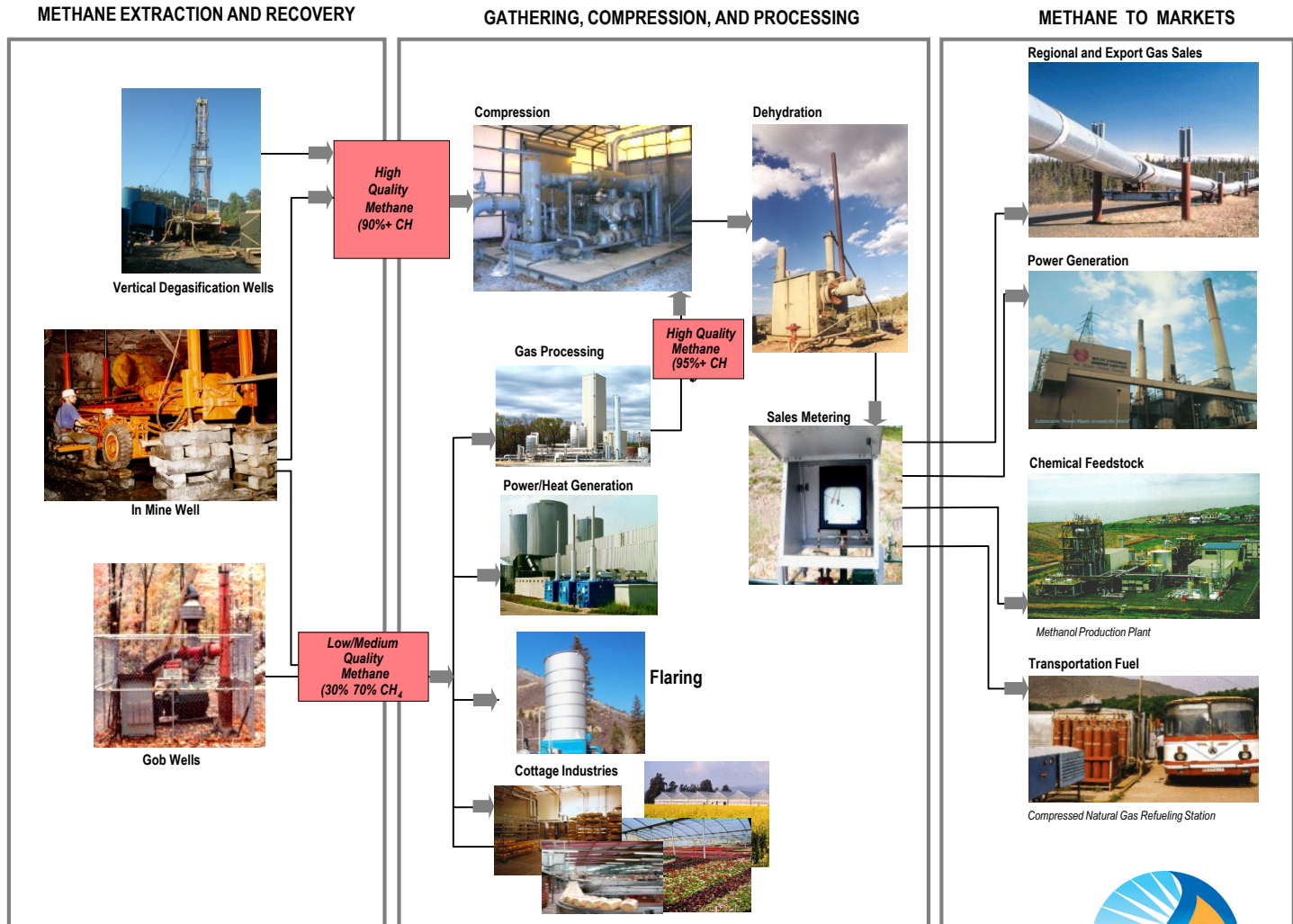
Methane Drainage Techniques

Technique	Advantages	Disadvantages
Conventional Vertical Unstimulated Pre-Drainage	<ul style="list-style-type: none"> • Simple • Does not interfere with mining operation 	<ul style="list-style-type: none"> • Perform poorly in low permeability
Surface Vertical Hydraulic Fracture Pre-Drainage	<ul style="list-style-type: none"> • Multi-seam completions • High recovery efficiency of 40-70% 	<ul style="list-style-type: none"> • Limited effectiveness in complex geology • Large footprint
Surface Directionally Drilled Pre-Drainage	<ul style="list-style-type: none"> • High recovery efficiency, up to 90% • Smaller footprint than vertical wells • No hydraulic fracturing 	<ul style="list-style-type: none"> • Expensive • Can be difficult to steer in complex geology
In-Mine Short Hole	<ul style="list-style-type: none"> • Simple – use non-steerable rotary drills • Relatively inexpensive 	<ul style="list-style-type: none"> • Requires access to galleries • Drainage efficiency is limited by very short drainage period
In-Mine Long-Hole Directionally Drilled Borehole	<ul style="list-style-type: none"> • Up to 1 year in advance of mining • Up to 50% recovery efficiencies 	<ul style="list-style-type: none"> • Requires access to galleries • Lower drainage efficiency than surface pre-drainage
Drainage Galleries	<ul style="list-style-type: none"> • Lower cost and widely used • Does not require boreholes 	<ul style="list-style-type: none"> • Inflexible to change during mining • Can be inefficient
Cross Measure Boreholes	<ul style="list-style-type: none"> • Practicable for deep coal seams • Effective in low permeability 	<ul style="list-style-type: none"> • High capture efficiencies difficult to sustain
Surface Gob Vent Boreholes	<ul style="list-style-type: none"> • Very effective for shallower coal seams • Lower drilling cost than pre-drainage 	<ul style="list-style-type: none"> • CH₄ concentration declines rapidly • Challenging in mountainous terrain

Integrated CMM Capture and Utilization at an Operating Mine



Coal Mine Methane (CMM) Value Chain



Methane Drainage Use and Destruction Technology Options

Technology	Comments
Natural Gas Pipeline Sales	<ul style="list-style-type: none">• Requires consistently high gas quality to meet pipeline specifications.
Power Generation	<ul style="list-style-type: none">• Small IC engines (500kW-3 MW) are most common because they can handle lower CH₄ concentrations down to 25% CH₄• Containerized modular construction allows for cost effective operation. Most popular use outside the US.
Vehicle Fuel – CNG/LNG	<ul style="list-style-type: none">• LNG/CNG can be used for mine vehicles or external markets• Requires very pure CH₄ stream - expensive options
Boiler Fuel	<ul style="list-style-type: none">• Not technologically complex and can use mine gas with 30% CH₄ concentration.• Very common use – usually involves conversion of a coal-fired boiler
Direct Heating	<ul style="list-style-type: none">• Use in industrial burners or industrial flares• Primary use is mine shaft heating in winter or in manufacturing
Flaring	<ul style="list-style-type: none">• Used for stranded gas with no market, as an interim GHG destruction option, or to destroy excess GHGs in an integrated CMM project.
Other uses	<ul style="list-style-type: none">• CMM has been used in methanol production, glass making, steel manufacturing, desalination plants, green houses, and coal drying.

Methane Drainage Key Points

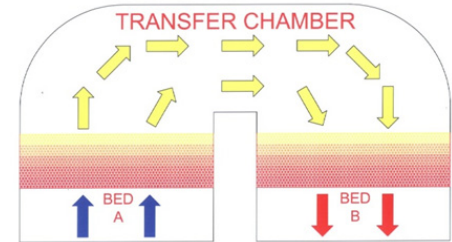
- Technologies to use or destroy CMM are the same as those that use natural gas.
- End use is determined by many factors:
 - Gas quality (CH_4 %)
 - Gas quantity ($4.2 \text{ m}^3/\text{min CH}_4 = 1 \text{ MW}$)
 - Access to markets
 - Infrastructure
 - Financial position
 - Staff capacity
 - Mining company priorities
 - Government policy priorities

Methane Drainage Key Points

- Projects often include a portfolio of technologies to maximize gas use.
- When deciding what technology to use:
 - Power, flaring, boilers, and vacuum pumps require minimal gas treatment
 - LNG, CNG, and pipeline sales require expensive gas treatment
- In order to implement a successful methane drainage project:
 - Improve gas availability (gas quantity and quality) and maintain CH₄ concentrations above the explosive range
 - Size plant properly- 80% of average gas flow
 - Flare gas when not used rather than venting
 - Regular maintenance and overhaul are required to keep the plant operating

Ventilation Air Methane (VAM) Abatement Technology

- Regenerative Thermal Oxidizer (RTO) technology has become standard through successful demonstration in Australia, China, and U.S.
- Currently 2 VAM projects operating in U.S., 1 in Australia, with 1 in under development in China



- **Other technologies are in development and close to commercialization**
 - Regenerative Catalytic Oxidation
 - Lean-burn turbines
 - Monolithic reactors
 - Rotary kilns

Commercial VAM Projects

Marshall County Mine, West Virginia, USA

- Mine formerly owned by CONSOL and project began under CONSOL
- Mine purchased by Murray Energy in December 2013
- VAM project financed and developed by Sindicatum Sustainable Resources
- 3 2-can RTOs from Durr
- Capacity = 160,000 cfm
- Emission reductions = 197,411 tCO₂e



Gaohe Mine, Shanxi Province, China

- Owned by Shanxi LuAn Group
- In development
- 12 RTOs + steam turbine
- Will rely solely on power sales revenue
- Full capacity will be 700,000 cfm and utilize RTOs
- Using drained gas to enrich VAM to 1% CH₄



VAM RTO Manufacturers

- MEGTEC
- Biothermica
- Durr
- HEL-East Ltd
- Gulf Coast Environmental
- Shendong (China)

VAM Best Practices

- VAM projects are a significant investment – requires careful planning before development and considerable oversight after operations begin.
- Understand the methane resource, mine plan, and mine ventilation plan including gas drainage.
- Design should be based on air flow and CH₄% data obtained from regular sampling and analysis or preferably continuous emissions monitoring systems.
- Most projects will be destruction-only. Success is almost entirely dependent on carbon markets
- Some potential for power generation with consistent flow and high VAM concentration (0.90% CH₄ or greater).

VAM abatement is essential for near-zero emissions coal mining!

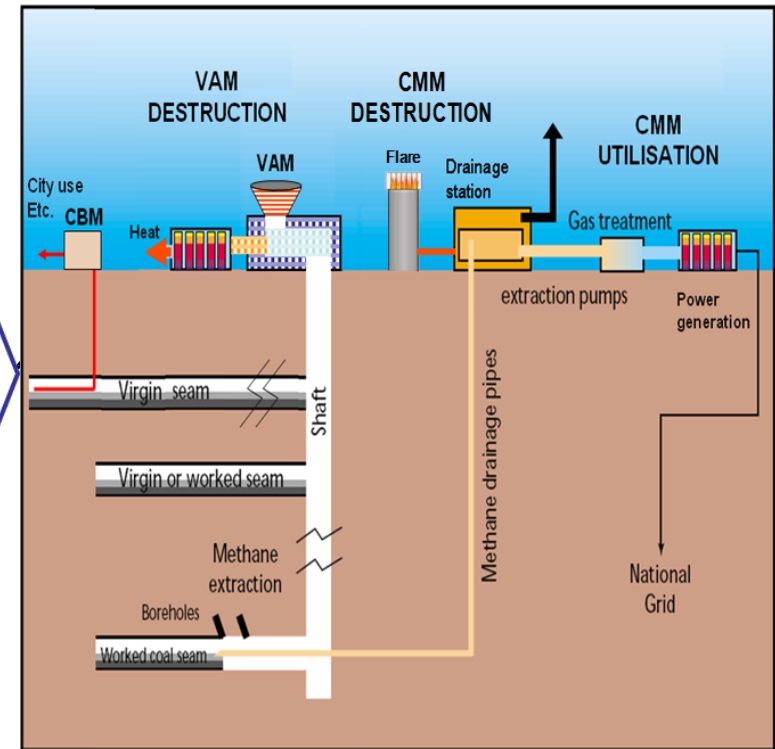
Case Study: Duerping Coal Mine, China

- Owned by Xishan Coal & Electricity Co Ltd, a subsidiary of Shanxi Coking Coal Ltd (Jiaomei Group)
- Xishan Coal Field near Taiyuan City
- 1,600m above sea level
- Metallurgical coal mine
- Production capacity = 5 Mtpa
- 700 Mt reserves
- 50 year life
- Relative emissions = 17.7 m³/t (567 ft³/st)
- CH₄ emissions increasing as mine goes deeper and production increases
- Drainage system before project
 - in place prior to project development
 - Prior CH₄ concentrations: 25-30%
 - Drainage efficiency = 15%
- No CMM utilization prior to the CMM utilization project



Near Zero Emission Mining for the Duerping Mine CMM Project:

- Maximise gas drainage capture
- Optimise utilisation of the drained coal mine methane (CMM)
- Thermal destruction of surplus CMM
- Destruction of the methane in the ventilation air (VAM)
- Exploit waste heat



A holistic approach to mine safety, energy production & environmental protection

Approach for the Duerping Mine CMM Project*: Steps 1 and 2

Step 1: Determine Gas Availability

- Confirmed gas content data, structure of the coal matrix and permeability of the coals
- Modeled CH₄ liberation rates

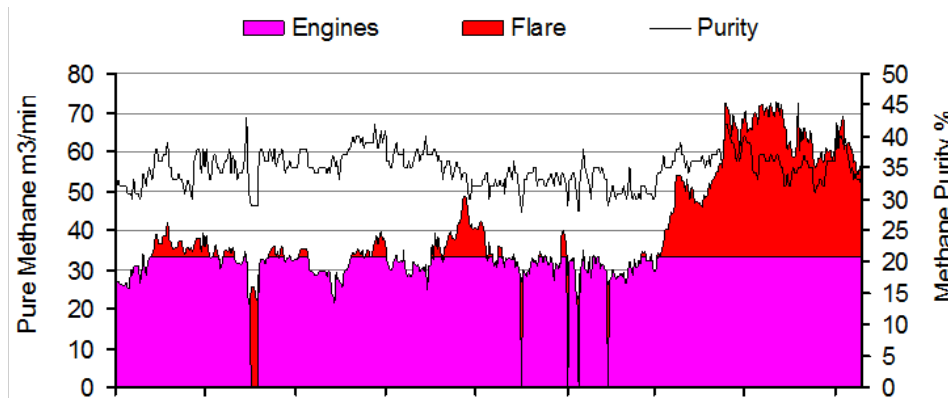
Step 2: Improve Gas Quality & Quantity

- Enhanced methane purity
 - Improved borehole sealing (2-stage)
 - Regulated Suction
- Raised gas capture
 - Increase orifice - plate size in the choke
 - Improved borehole design and pattern
 - Controlled extraction from sealed areas

*Acknowledgment to Sindicatum Sustainable Resources and Xishan Coal & Electricity Co.

Step 3: CMM Utilization System Design

- CMM power plant includes:
 - Power generation - 12 MW
 - 5000 m³ per hour enclosed flare
 - Closed loop oil-based heat recovery system
 - Passive vent
 - Minimal gas processing: dewater with knock-out pot and chiller and use 2-stage dust control
- Employed a conservative approach for power plant design
 - Sized project at 80% of the average CH₄ flow
 - Assume 80-85% availability for gas engines
- Focus first on utilization of gas drainage
- VAM destruction was secondary objective

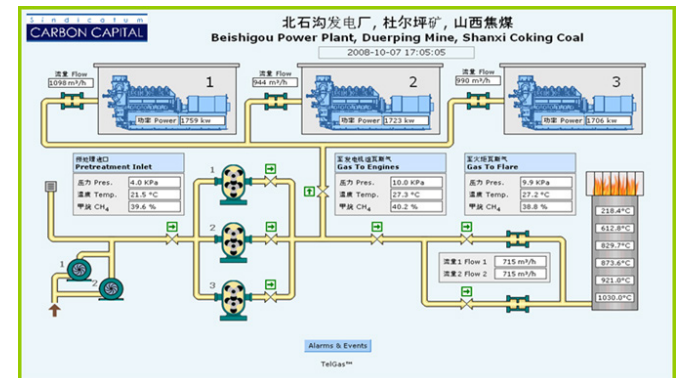


Step 4: CMM Plant Operation

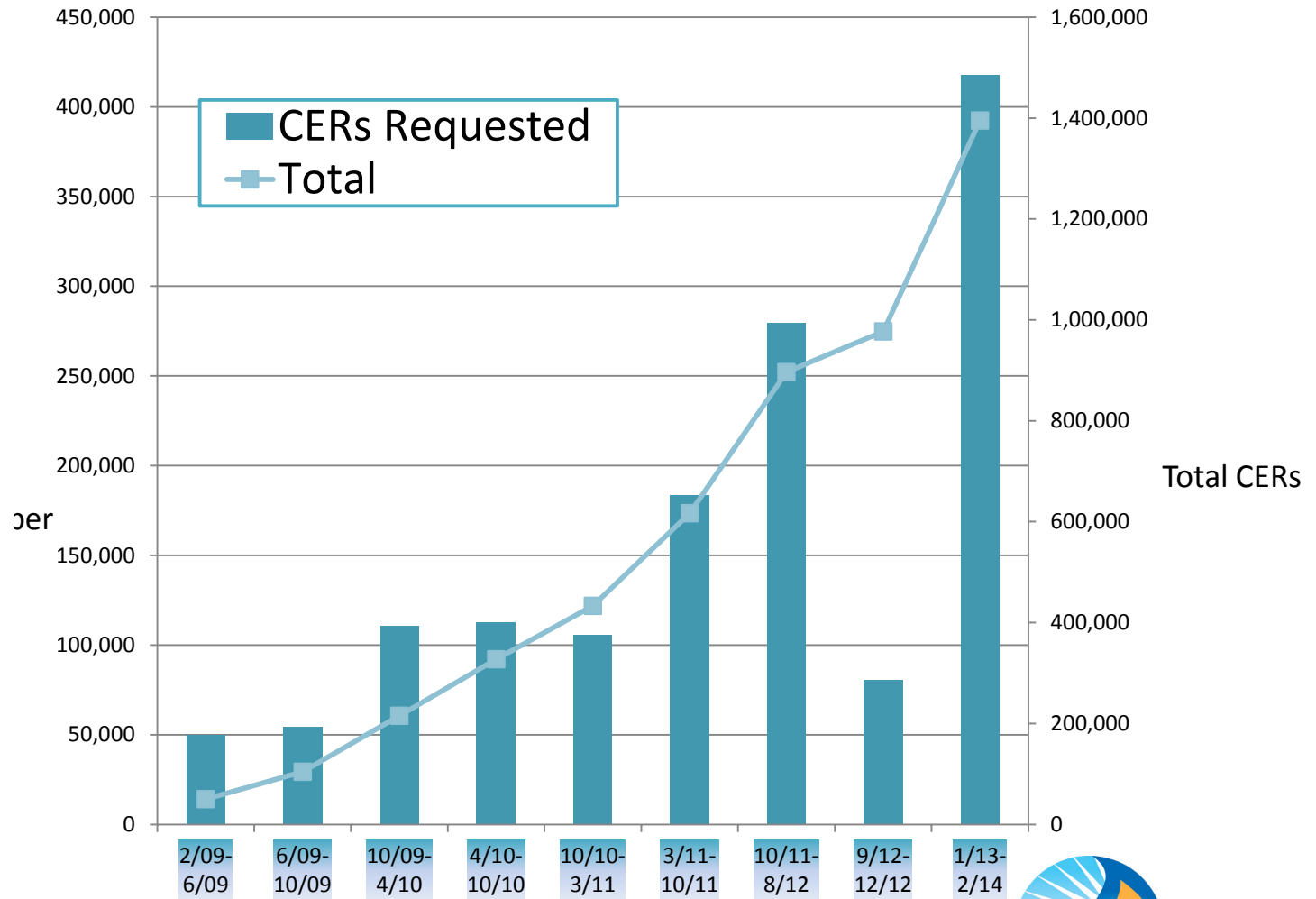
- After start-up, implemented best practices to maintain plant operations
 - Training for mine and SSR staff
 - Team to worked with the mine staff to maintain gas availability.
 - Telemetry to monitor operations remotely.
 - Regular walk-throughs and scheduled maintenance including
- Operational monitoring
 - Constant observation to ensure project is operating as planned
 - Alarms and notice system alert staff to problems



Duerping Phases 1&2



Power Plant & Flare Performance



Step 5: VAM Plant

- Preparation
 - Installed continuous emissions monitoring system for 3 years recording CH₄% data every 15 minutes
 - Regular air flow data at the fan provided by mine staff
- Contracted with manufacturer in 2011
 - One 35 m³/sec RTO
 - One 20 m³/sec RCO
 - Plant is destruction only
- Project registered as CDM project in November 2011
- Construction in 2012/2013
- Plant is currently idled due to low CDM prices

Conclusions

- Every project is unique – tailor each project to the operations, mine gas characteristics, regulatory framework, and market conditions
- Be open to employing a portfolio of methane capture and use technologies to achieve near-zero emissions mining
- Project success will be enhanced by
 - Excellent communication among stakeholders
 - Thorough preparation and planning
 - Conservative approach – it is easier and more cost-effective to scale up than scale down.
- But be prepared to still face range of issues throughout project development, construction and operation
 - Gas quality and quantity
 - Mechanical issues
 - Changes in mine operations
 - Changes in market conditions

Contact Information

Clark Talkington

Vice President

Advanced Resources International, Inc.

4501 Fairfax Dr, Suite 910

+1 (703) 528-8420

ctalkington@adv-res.com

www.adv-res.com

