Drilling Solutions for Methane Drainage

Workshop on Best Practices in Coal Mine Methane Capture and Utilization

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10 June 2019
Ankara, Turkey

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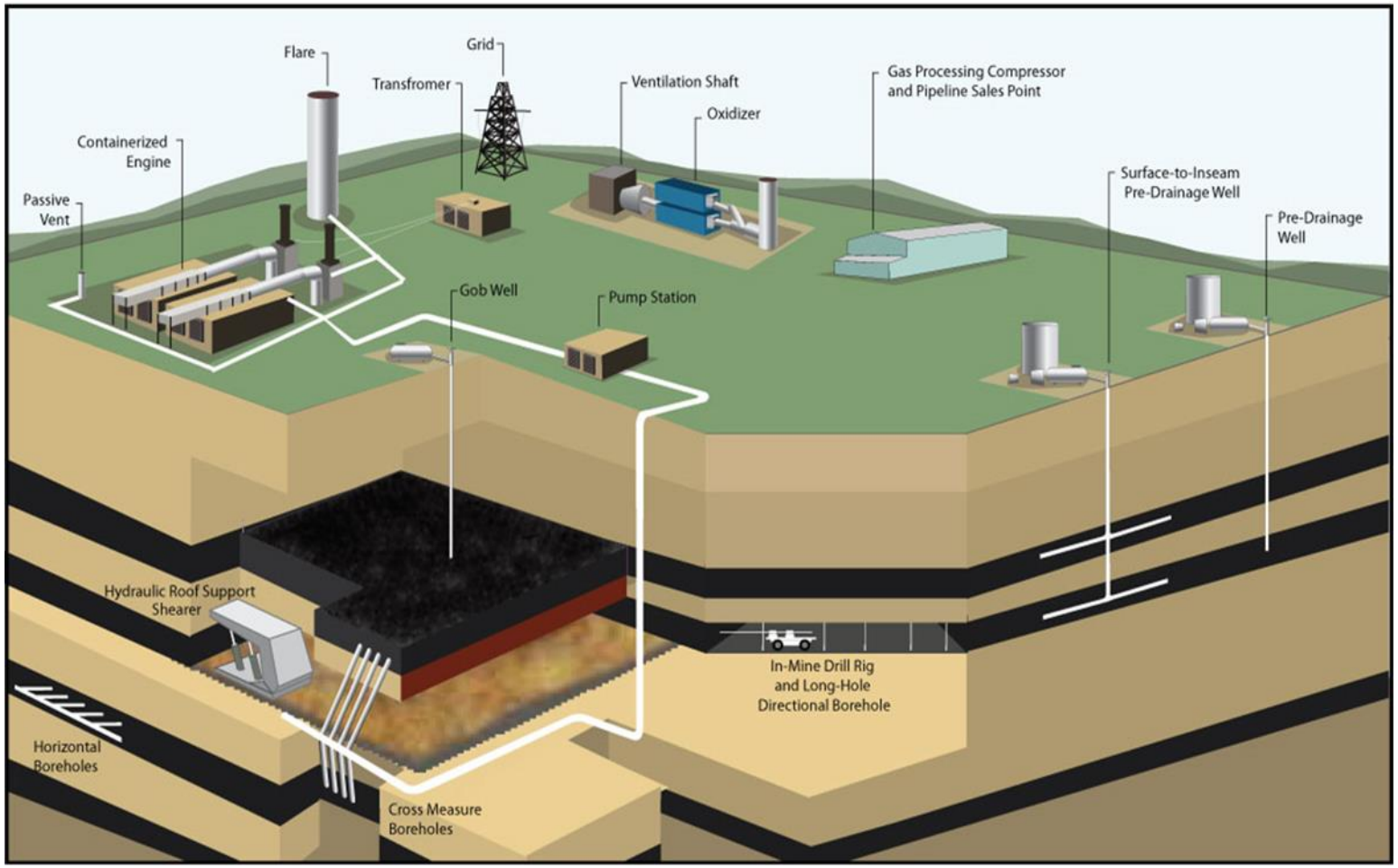
Mine gas drainage options



Source: UNECE. Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines (2016)

- Surface pre-drainage
- Surface gob (goaf) boreholes
- In-mine pre-drainage boreholes
- In-mine cross-measure boreholes
- Drainage galleries
- Case studies

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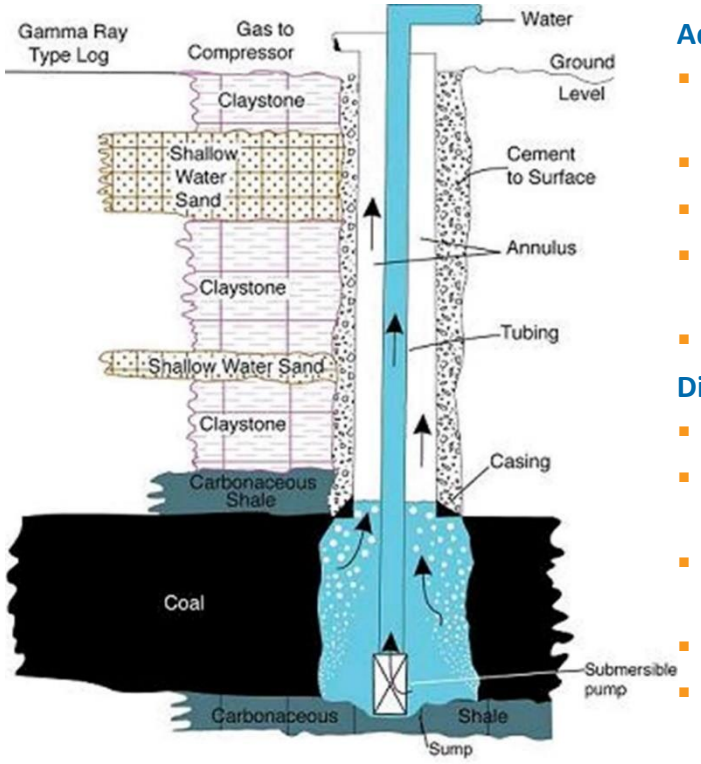
Surface pre-drainage: vertical wells

Vertical wells – unstimulated



Source: Wyoming State Engineers Office

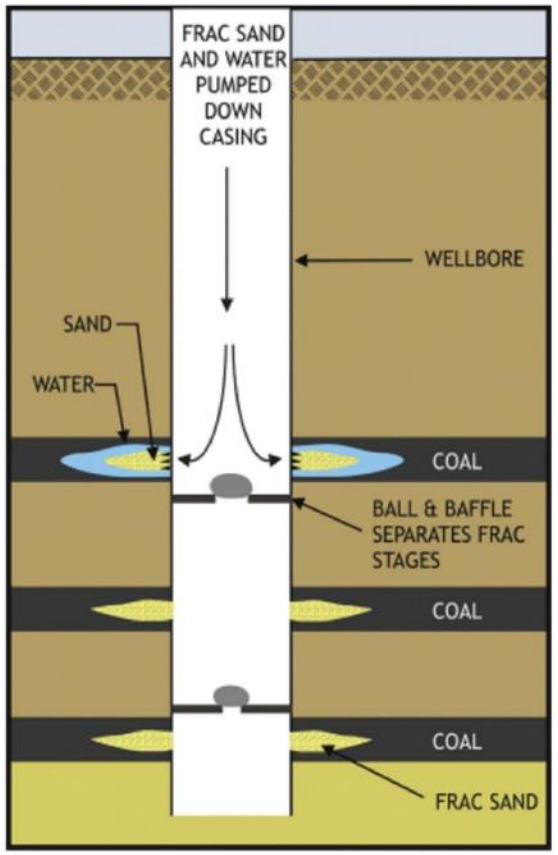
Advantages

- Eliminates need for hydraulic fracturing (operations and costs)
- No casing across the coal seam
- In use since 1970's
- Can pre-drain up to 10 years in advance of mining
- High CH4%

Disadvantages

- Not good for multiple seams
- Costs can be high in countries where not practiced
- Not cost-effective for low-permeability formations
- Requires surface access
- May require rights or license for gas resource

Vertical wells – stimulated



Advantages

- Can increase production from low permeability coal seams (up to 73%)
- Provides good wellbore control
- Ideal for multiple seams
- High CH4%

Disadvantages

- Leaves casing across the coal seam; can use fiberglass casing
- Higher cost
- Requires necessary infrastructure
- Disposal or treatment of frac fluids
- Perceived negative impact on roof stability (note – not a problem in U.S.)
- Surface access and gas rights

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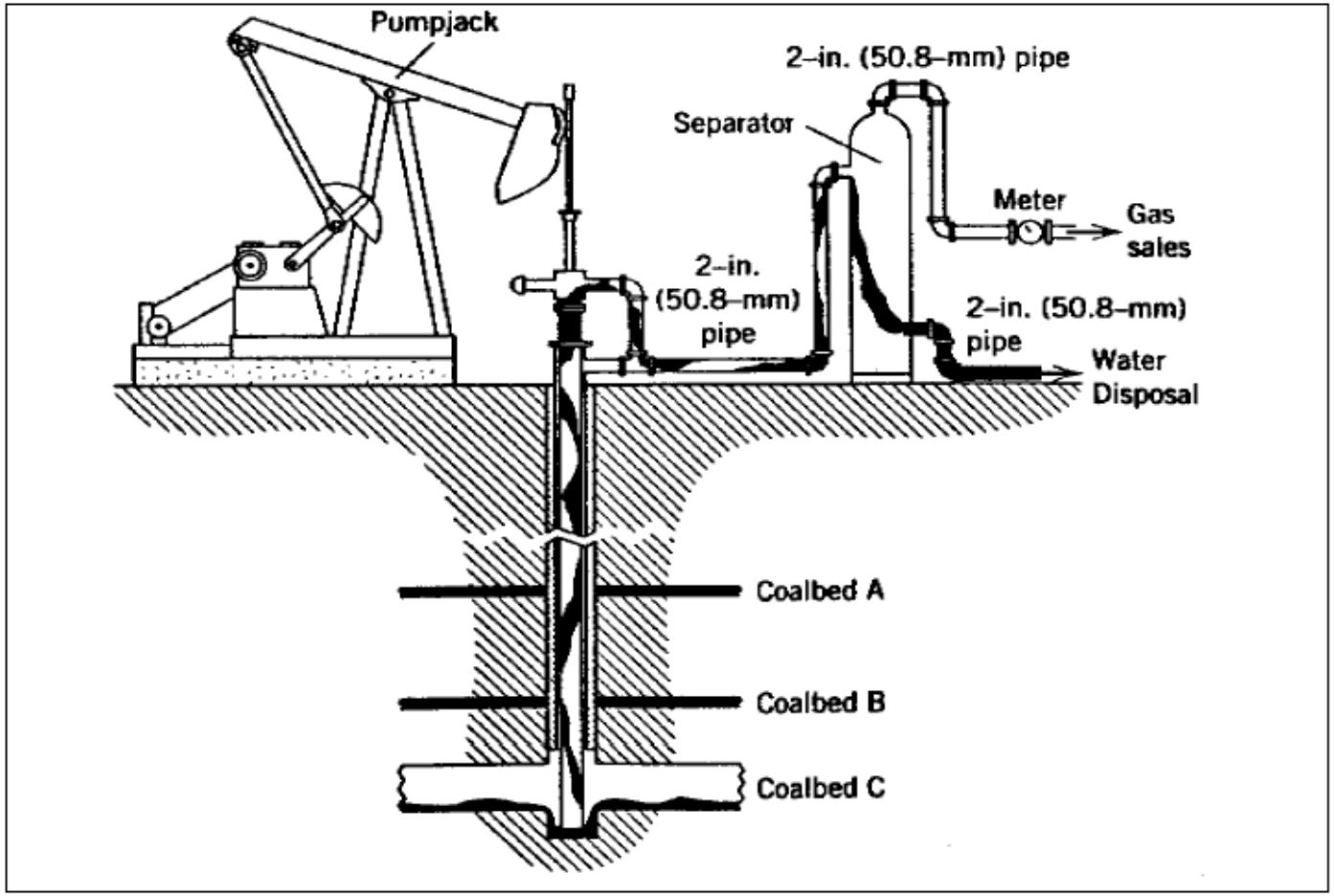
Typical vertical well setup after completion



Source: Hartman et al., 1997. Copyright 1997, John Wiley & Sons, Inc. Reprinted with permission of John Wiley & Sons, Inc.

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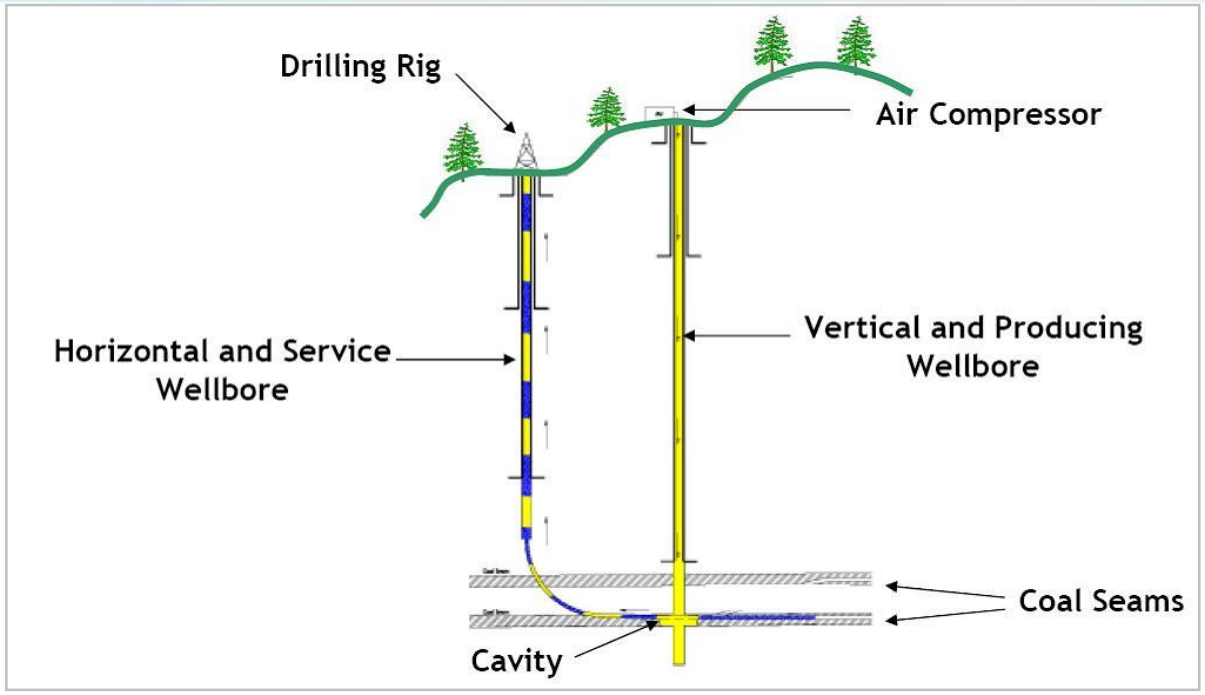
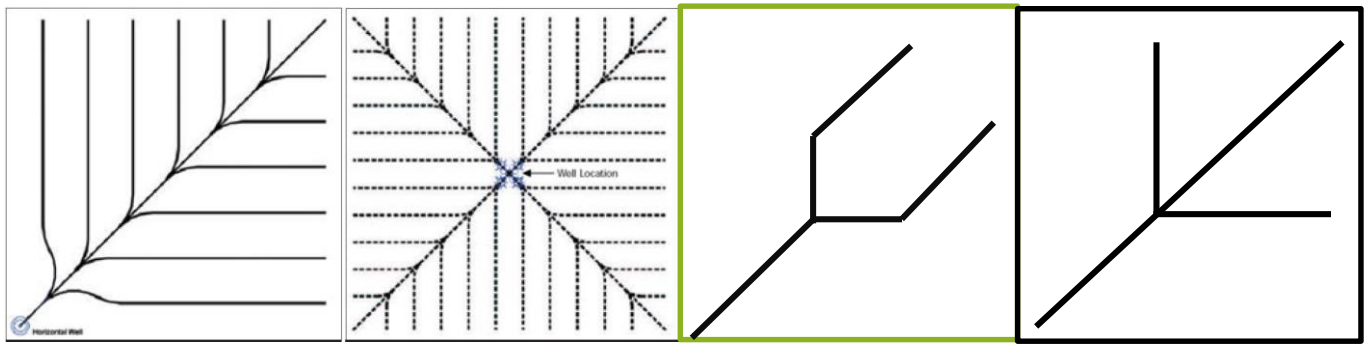
Surface pre-drainage: surface to in-seam drilling





Source: CDX Gas, 2005 and Ruiz, Kelafant, Talkington, 2012

Advantages

- Multiple laterals off single pad
- Different drilling patterns
- In right conditions, very high reduction in gas content
- Continuing technology advancement
- High CH4%

Disadvantages

- Higher cost
- Limited infrastructure or services in many countries
- Skill and experience required to steer boreholes
- Not as effective in very low permeability seams
- Requires surface access
- May require gas rights

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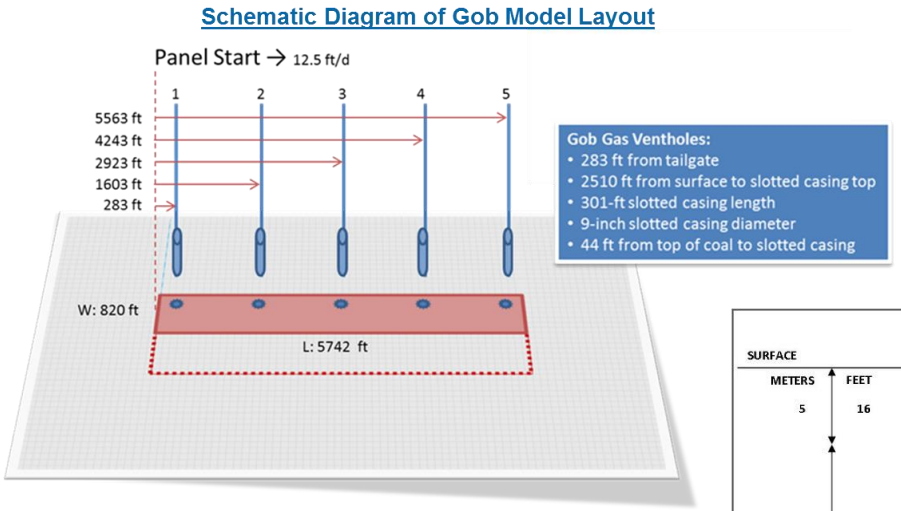
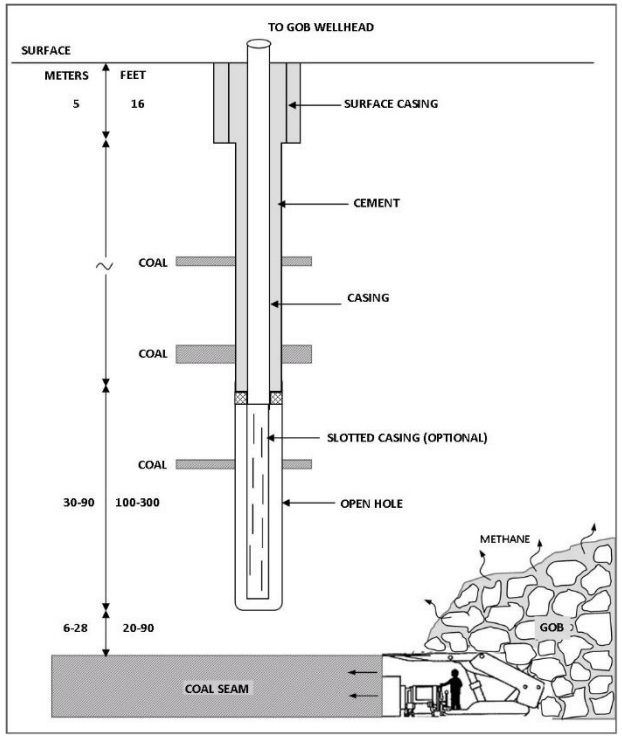
Surface post-drainage: vertical gob (goaf) vent boreholes





Advantages

- Lower cost than pre-drainage boreholes
- Effective at capturing gas in overlying strata
- Drilled and completed above mined seam – no interference with longwall production
- Medium gas quality – can be used in gas engines, flares, boilers or upgraded to pipeline quality

Disadvantages

- May not be cost effective for very deep mines compared to in-mine drainage
- Wells have short life with rapid reduction in gas quality
- Requires surface access
- Limited effectiveness when mining multiple seams

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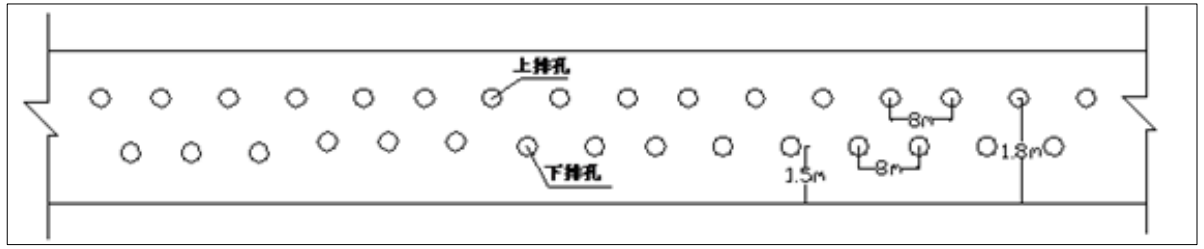
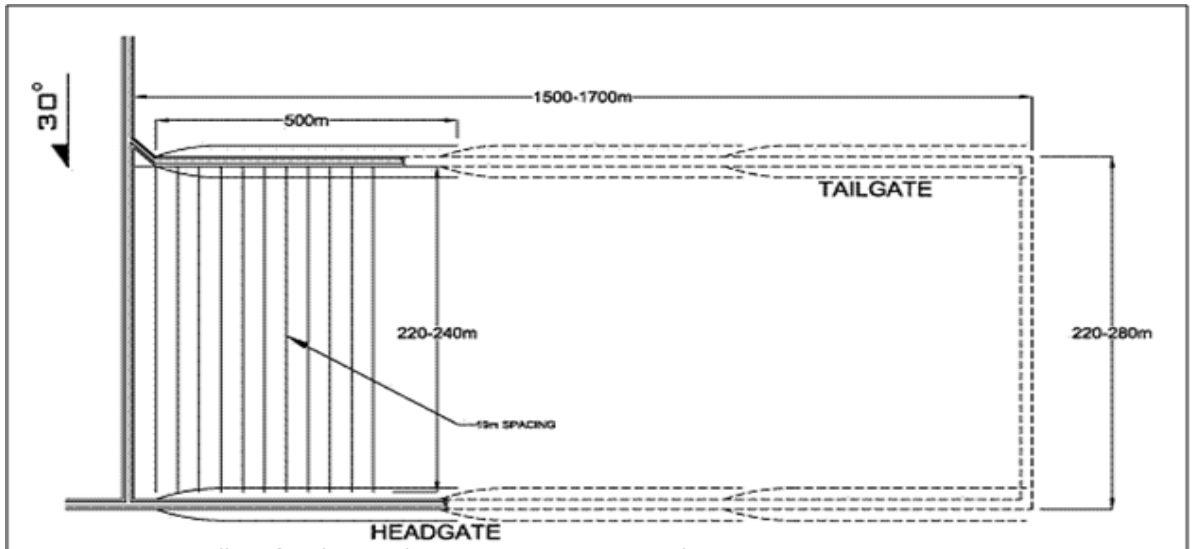
In-mine pre-drainage: cross-panel boreholes

Profile view of cross-panel drilling



Plan view of cross-panel drilling



Courtesy: REI Drilling & Advanced Resources International, Inc.

Advantages

- Low cost
- Widely practiced in many countries
- Can produce high quality gas

Disadvantages

- Limited by gate road development
- Poor borehole stability in soft coals
- Low permeability seams require many boreholes
- Easy to reduce gas quality with too much vacuum
- Often necessary to use with post-drainage technique

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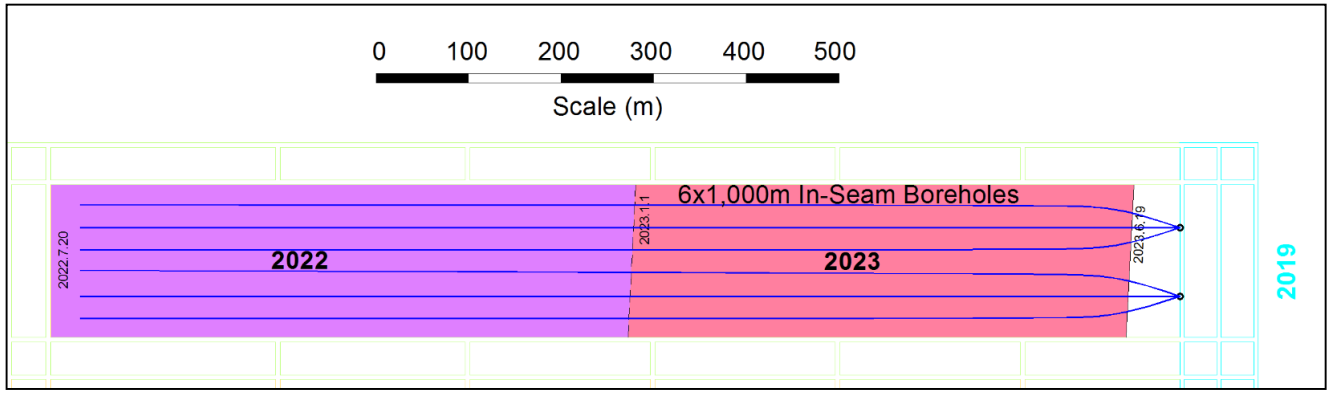
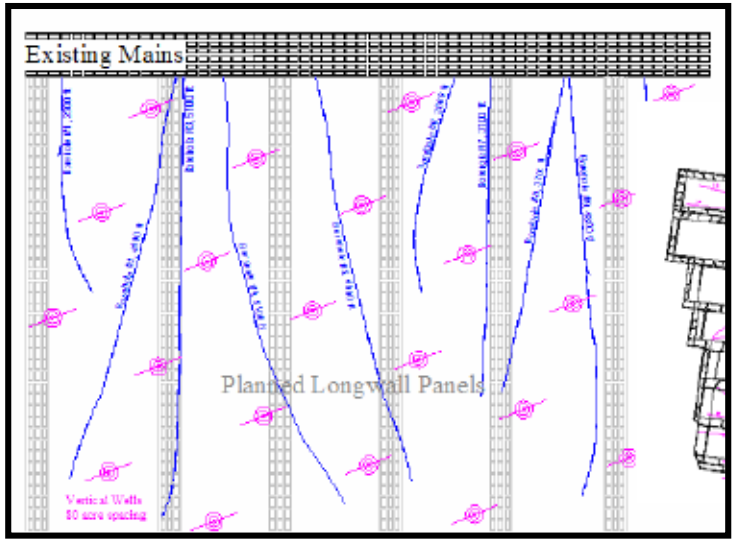
In-mine pre-drainage: directionally drilled boreholes

Birdseye view of proposed directional drilling



Source: EPA, TengHui Mine Pre-feasibility Study (2019)



Source: REI Drilling, Inc.

Longhole drilling from within a mine entry

Source: EPA, CMM Primer (2018)

Advantages

- May be more cost-effective than surface pre-drainage
- Higher marginal costs than cross-panel boreholes, but may lower total costs
- Entire length of borehole is pressure sink
- Produces high quality gas
- May not be affected by gate road development – can be drilled from main entry
- Can drill to other seams to drain gas far in advance of mining

Disadvantages

- Poor borehole stability in soft coals
- Limitations in difficult geology – faulting, folding, thin seams, igneous intrusions
- Requires skilled and experience drilling crew

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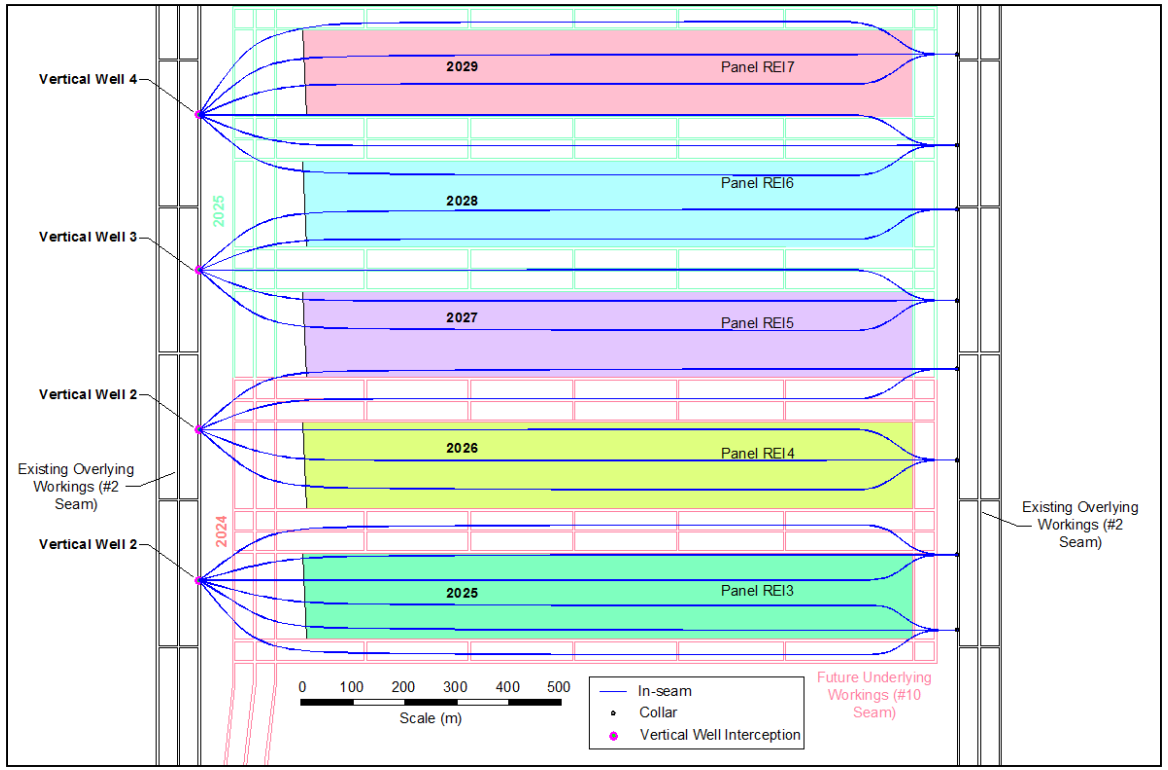
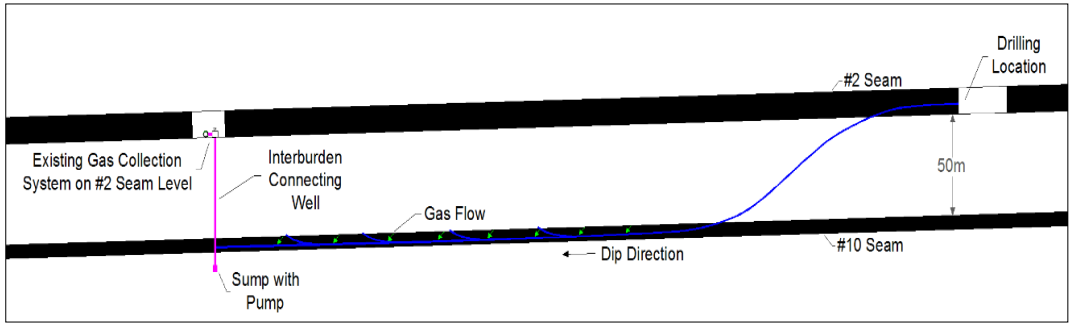
Application of directionally drilled borehole to future seam





Source: EPA, TengHui Mine Pre-feasibility Study (2019)

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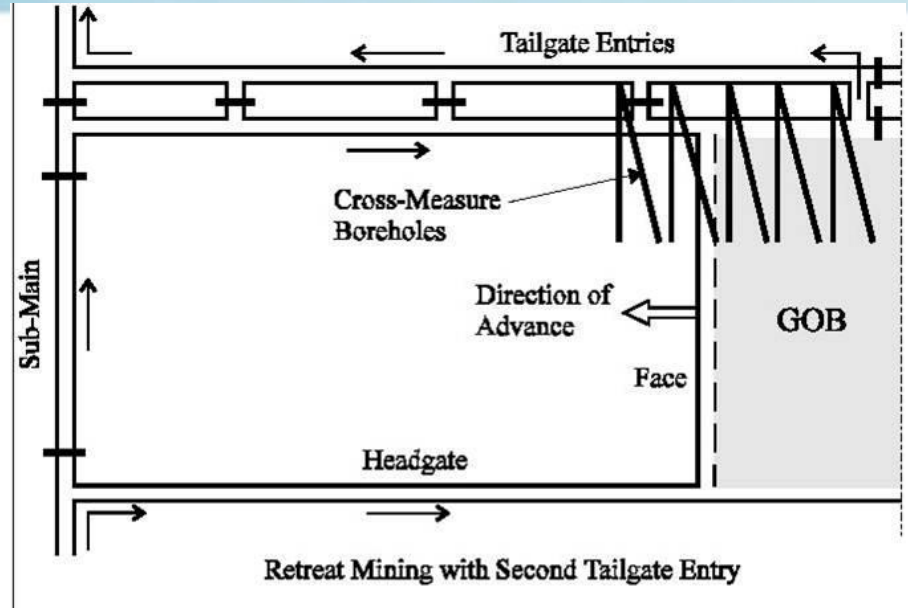
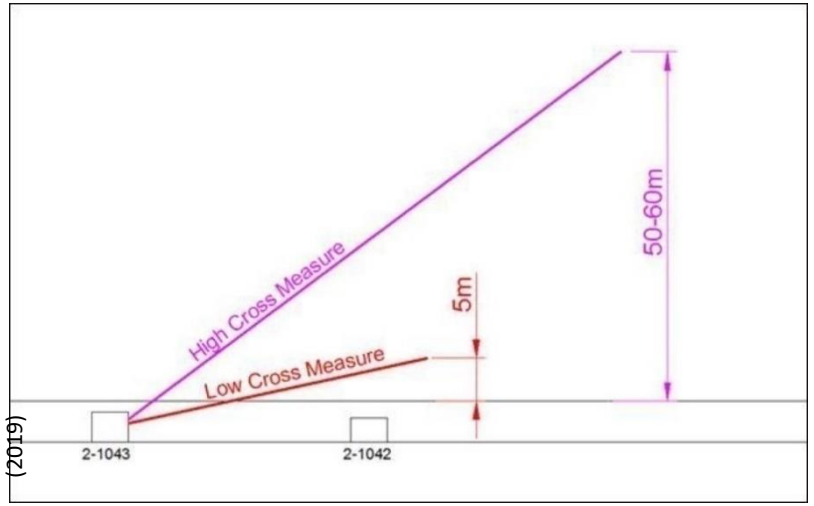
In-mine post-drainage: cross-measure boreholes



Source: EPA, CMM Primer (2018)



Source: EPA, TengHui Mine Pre-feasibility Study (2019)

Source: EPA, CMM Primer (2018)

Advantages

- Lower cost than pre-drainage boreholes
- Widely practiced
- Can be drilled above or below mined seam
- Medium quality gas

Disadvantages

- Limited by gate road development
- Poor borehole sealing at many mines
- Over-pressurized vacuum often results in poor gas quality

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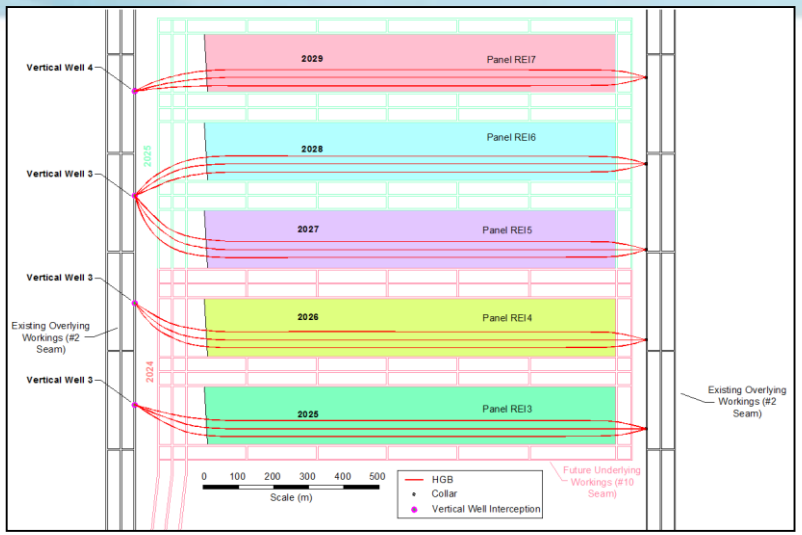
In-mine post-drainage: directionally drill gob boreholes



Plan view

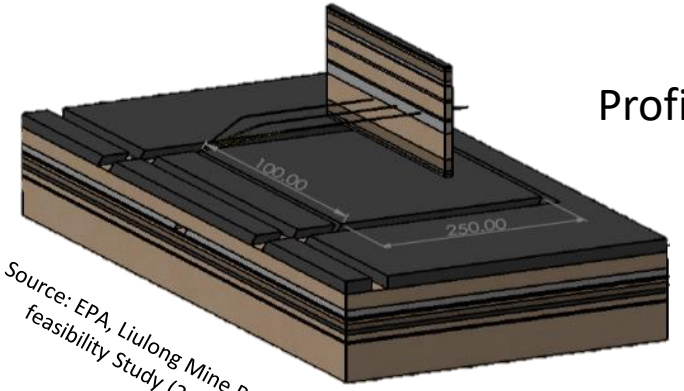
Source: EPA, TengHui Mine Pre-feasibility Study (2019)

Advantages

- Can be lower total cost where cross-measure or cross-panel boreholes are drilled at high frequency
- Can be drilled above or below mined seam
- Entire borehole is a pressure sink
- Not limited by gate road development
- Medium quality gas

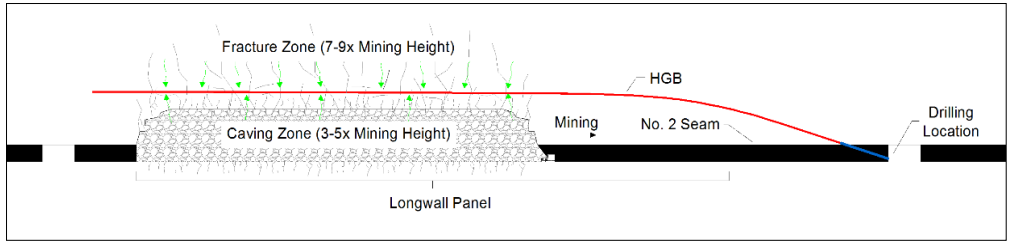
Disadvantages

- Higher marginal cost than other in-mine gob gas drilling techniques
- Requires skilled and experienced drilling crew



Source: EPA, Liulong Mine Pre-feasibility Study (2016)

Profile views



Source: EPA, TengHui Mine Pre-feasibility Study (2019)

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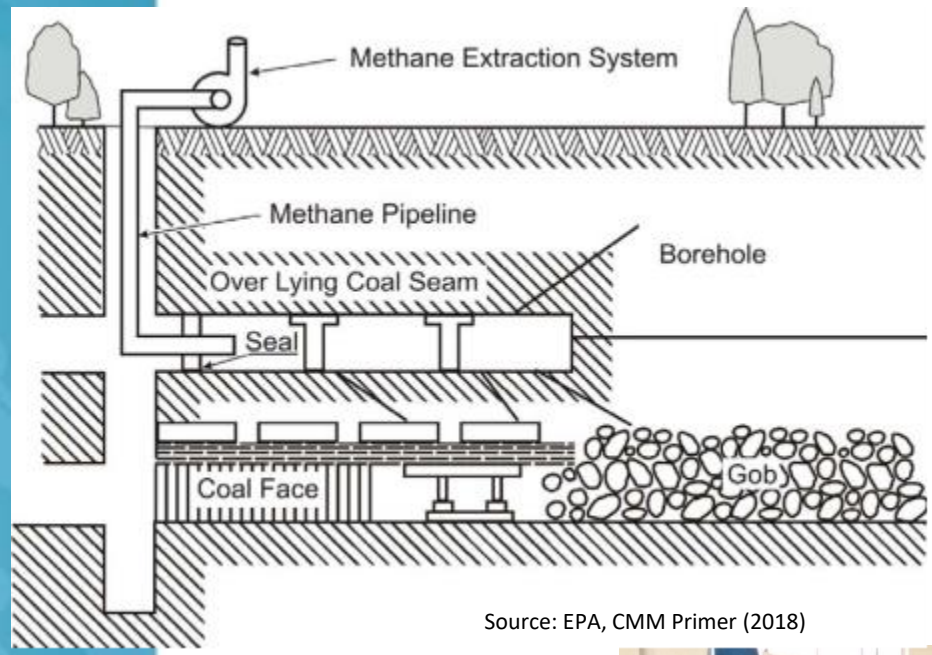
In-mine post-drainage: drainage galleries



Profile view

Source: EPA, CMM Primer (2018)

Vacuum pump for drainage gallery at Chinese mine

Advantages

- Uses pre-existing roadway or new gallery with vacuum above mined seam to capture gas
- Does not interfere with current mining operations
- Developed in 1940's, in use for many years in several major countries of Europe and Asia
- Can be lower cost than cross-measure boreholes

Disadvantages

- Can result in very diluted CH4 stream with too much vacuum
- May not be cost-effective if gallery does not already exist

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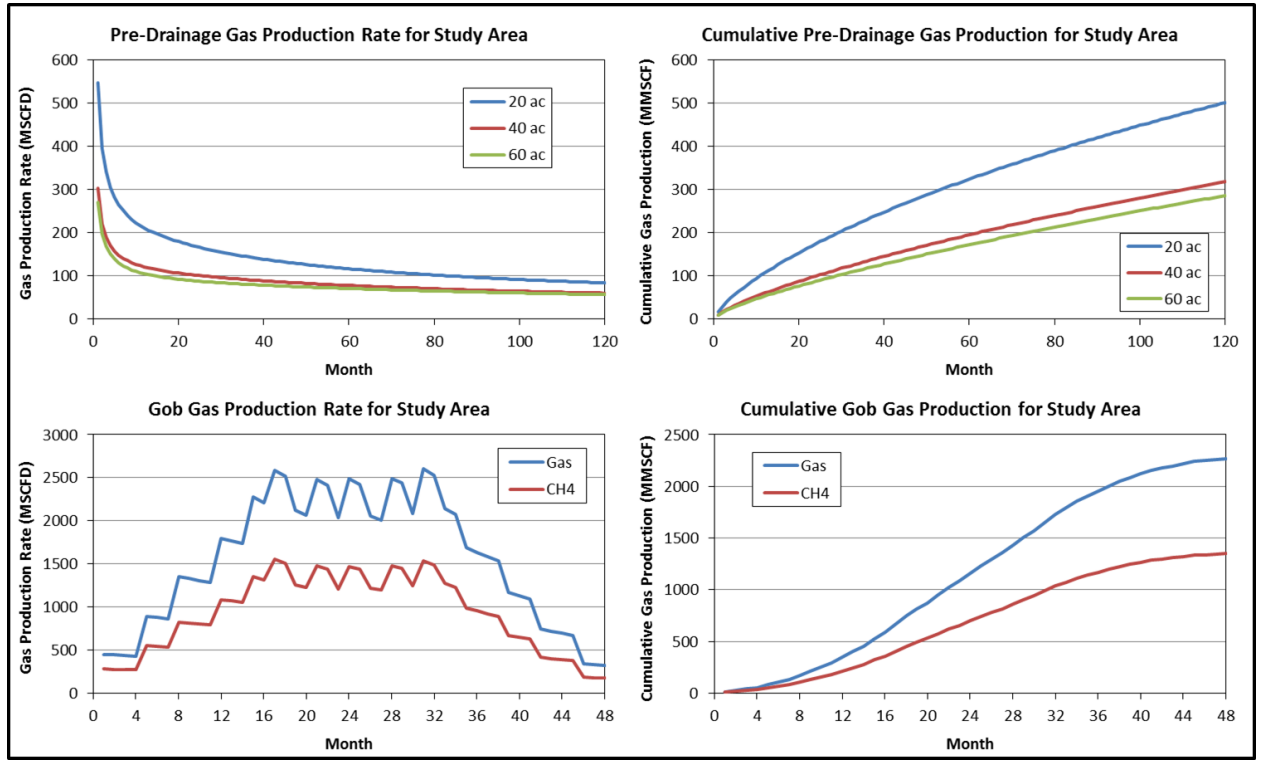
Case study (Ukraine): surface vertical pre-drainage vs surface gob wells

EPA-sponsored pre-feasibility study of the Komsomolets Donbassa mine, Ukraine
https://www.epa.gov/cmop/coal-mine-methane-ukraine



- Vertical surface pre-drainage wells vs. surface gob vent boreholes
- Modeled gas production
  - Pre-drainage borehole – reservoir simulation software, COMET®
  - Gob vent borehole – U.S. NIOSH *Gob Gas Venthole (GGV) Performance Prediction* model
- Gob vent boreholes were better option
- Unstimulated vertical pre-drainage wells were not economic
  - Low permeability required tight spacing driving up costs
  - Even most optimistic scenario showed that pre-drainage wells would produce 1/3 of CH4 production from surface gob wells

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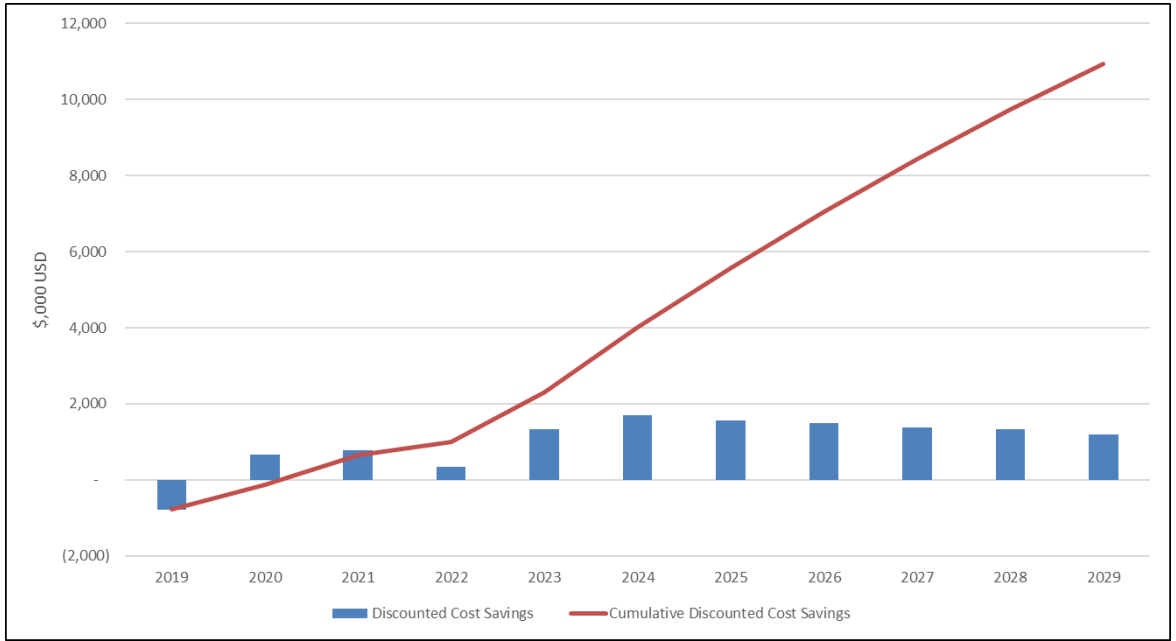
Case study (China): cross-measure + cross-panel boreholes vs directionally drilled in-seam and gob boreholes

EPA-sponsored pre-feasibility study of the TengHui mine, China
https://www.globalmethane.org/tools-resources/resource_details.aspx?r=4778

Case	Max Power Plant Capacity	NPV ($,000s)	IRR	Payback (Years)	Net CO_2e Reductions (t CO_2e)
High	**5.23 MW**	**$9,491**	**22.06%**	**4.9**	**1,481,616**
Base	**3.71 MW**	**$1,684**	**12.23%**	**6.45**	**1,139,704**
Low	**3.47 MW**	**$(943)**	**8.72%**	**7.24**	**797,793**



- Existing degas system:
  - 2 cross-measure boreholes and 1 cross panel borehole at 4m intervals (300m borehole every 4m)
  - Low marginal cost ($30-$40/m) but high total cost
  - Low gas concentrations: 2-8%
  - No CMM utilization
- GMI recommended alternative
  - Replace cross-measures and cross-panel boreholes with directionally drilled in-seam and gob boreholes
  - Gas prediction modeling: reservoir simulation for in-seam boreholes and engineering equation for gob gas
- Results
  - Total CMM production remains same
  - Significant improvement to gas quality allowing utilization
  - Potential for 5 MW of power generation
  - Higher marginal costs ($100-$130/m) for drilling but significant reduction in total meters drilled reducing total drilling costs

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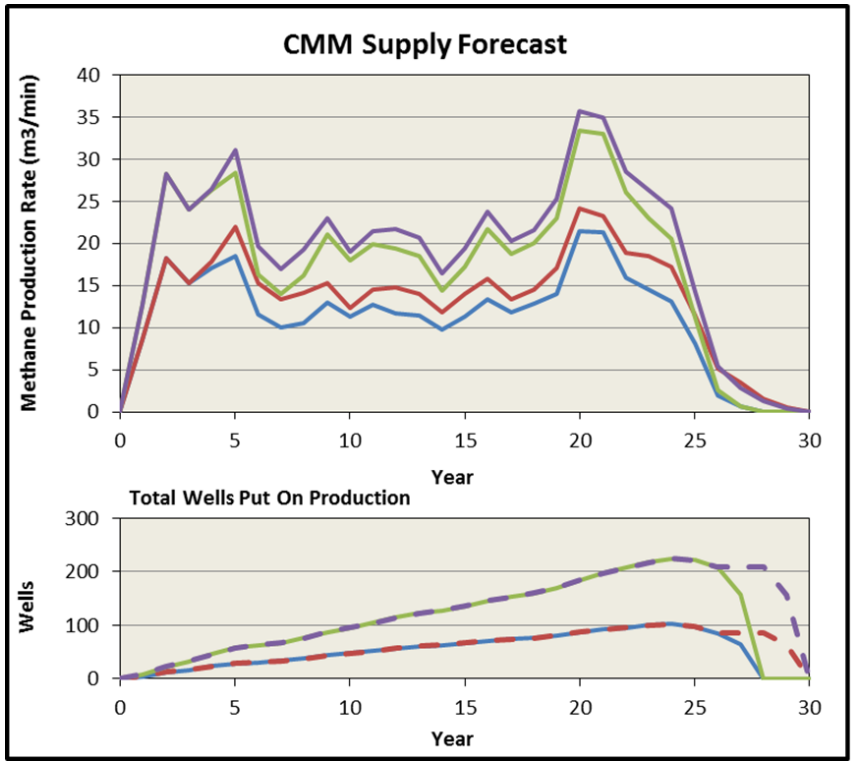
Case study (Turkey): directionally drilled in-seam and gob boreholes at

EPA-sponsored pre-feasibility study of the Amasra mine, Turkey
https://www.epa.gov/cmop/cmop-international-partners-turkey



Case	Wells per Panel	Years of Pre-Drainage	Breakeven Gas Price $/1000m3
1	2	3	71.93
2	2	5	63.57
3	4	3	90.85
4	4	5	84.00

Case	Description
1	2 wells per panel; 3 years pre-drainage
2	2 wells per panel; 5 years pre-drainage
3	4 wells per panel; 3 years pre-drainage
4	4 wells per panel; 5 years pre-drainage

- Study conducted during mine planning
- Gas Content: 6-13 m3/ton/Permeability: ~1 MD
- Evaluated different options for in-mine directionally drilled boreholes
  - Pre-drainage: Drilled length of the 300x1000m panel
  - compared 2 vs 4 boreholes per panel
  - Post-drainage: 1 gob well per panel
  - Gas prediction modeling: reservoir simulation for in-seam and engineering equation for gob gas
- Total CMM production remains same
  - Best case: 2 pre-drainage wells + 1 gob well draining for 5 years

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Acknowledgements

- Volha Roshchanka, Valerie Askinazi and Monica Shimamura, U.S. Environmental Protection Agency
- Global Methane Initiative
- UN Economic Commission for Europe
- Jon Kelafant and Kyle Turpin, Advanced Resources International, Inc.
- Dan Brunner and Alex Schumacher, REI Drilling, Inc.

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Thank You!

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