U.S. EPA
Coalbed Methane
OUTREACH PROGRAM

Pre-feasibility Study on Coal Mine Methane Recovery and Utilization at Komsomolets Donbassa (KD) Mine

Located in Donetsk, Ukraine

U.S. Environmental Protection Agency
September 2013

ACKNOWLEDGEMENTS

This report was prepared by Advanced Resources International, Inc. (ARI) at the request of the United States Environmental Protection Agency's Coalbed Methane Outreach Program (CMOP). The principal authors of the report are Clark Talkington, Jason Hummel, Natalia Zolotareva and Anatoly Tuchin.

We wish to acknowledge the gracious support and guidance of Mr. Sergey Egorov, Head of the Technical Development Department, DTEK Coal Division based in Donetsk, Ukraine, and Mr. Konstantin Vyaly, General Director, Komsomolets Donbassa Mine, and his team at the Komsomolets Donbassa Mine who contributed their time and expertise. We also acknowledge the project sponsor, the Coalbed Methane Outreach Program of the US Environmental Protection Agency.

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Abbreviations & Acronyms

Ac	Acre
ARI	Advanced Resources International, Inc.
BCF	Billion Cubic Feet
BWPD	Barrels of water per day
CBM	Coalbed methane
cc	Cubic centimeter
CDM	Clean Development Mechanism
CMOP	US EPA Coalbed Methane Outreach Program
CMM	Coal Mine Methane
CH_4	Methane
CO_2	Carbon Dioxide
EB	Executive Board of the Clean Development Mechanism under the auspices of the UN Framework Convention on Climate Change
EBITDA	Earnings Before Interest, Taxes and Depreciation
ERU	Emission Reduction Units – carbon credits issued for Joint Implementation Projects by the CDM Executive Board
ft	Feet
GGV	Gob gas venthole
GMI	Global Methane Initiative
Ha	Hectare
Hg	Mercury
HV	High volatile bituminous coal
JI	Joint Implementation
KD	Komsomolets Donbassa Mine
km	Kilometer
kW	Kilowatt
kWh	Kilowatt hour
LV	Low volatile bituminous coal
m	Meters
m^3	Cubic meters
m^3/h	Cubic meters per hour
m^3/min	Cubic meters per minute
m^3/t	Cubic meters per metric tonne
MCP	Methane Control and Prediction Model from NIOSH
MMBtu	Million British Thermal Units
MMSCF	Million Standard Cubic Feet
MSCFD	Thousand Standard Cubic Feet per Day
MtCO2e	Metric tonnes of CO_2 equivalent
MW	Megawatt
NIOSH	National Institute of Occupational Safety & Health (U.S.)
OMSHR	NIOSH Office of Mine Safety and Health Research
PL	Langmuir pressure (psia);

psi	Pounds per square inch
psia	Pounds per square inch absolute
SCF	Standard Cubic Feet
Sub-bit	Sub-bituminous coal
USEPA	US Environmental Protection Program
VAM	Ventilation air methane
VL	Langmuir volume (scf/ton)

Metric/Imperial Unit Conversions

Metric	Imperial
1 hectare	2.47 acres
1 centimeter (cm)	0.4 inches
1 meter	3.281 feet
1 cubic meter (m^3)	35.3 cubic feet (ft^3)
1 metric tonne	2,205 pounds
1 kilo calorie (kcal)	3.968 Btu (British Thermal Units)
252,016 kcal	1 MMBtu (million British Thermal Units)
159 litres	1 Barrel (bbl)
1 MegaPascal (MPa)	145 psi
760 mgHg	1 atmosphere or 14.696 psi

Executive Summary

The U.S. Environmental Protection Agency's (USEPA) Coalbed Methane Outreach Program (CMOP) works with coal mines in the U.S. and internationally to encourage the economic use of coal mine methane (CMM) gas that is otherwise vented to the atmosphere. The work of CMOP and USEPA also directly supports the goals and objectives of the Global Methane Initiative (GMI), an international partnership of 41 member countries and the European Commission that focuses on cost-effective, near-term methane recovery and use as a clean energy source.

An integral element of CMOP's international outreach in support of the GMI is the development of CMM pre-feasibility studies. These studies provide the cost-effective first step to project development and implementation by identifying project opportunities through a high-level review of gas availability, end-use options and emission reduction potential.

The principal objective of this pre-feasibility study is to assess the technical and economic viability of drilling vertical pre-mine drainage wells and surface gob wells at the Komsomolets Donbassa Mine, and using this gas to produce electricity. The Komsomolets Donbassa Mine is located in eastern Ukraine outside the village of Kirovskoye, Donetsk Oblast, 52 km northwest of the city of Donetsk. The mine is a longwall mine, producing thermal coal of grade "T" and is one of the largest producers of thermal coal in Ukraine. Coal reserves are 111 million metric tonnes, but reserves will increase to 158 million tonnes after a reserve addition in 2013. Coal production is currently 4.5 million metric tonnes per year, more than double production of 2 million tonnes per year in 2000 at privatization. Plans call for production of 5.3 million tonnes by 2020; however, the mine ventilation system is operating at maximum capacity and additional methane drainage will be necessary to achieve this planned increase in coal production. The mine is owned by DTEK Holdings (Donbasskaya Toplivnaya Energeticheskaya Kompanya; www.dtek.com), a large, private, vertically integrated holding company that is the largest energy company in Ukraine. DTEK 2012 revenues totaled US$ 10.3 billion with EBITDA[1] of US$ 2.1 billion and net profit of US$ 741 million. Assets total US$ 9.6 billion[2].

Extending over an area of 63.6 km^2, 83.6 km^2 after the 2013 reserve addition, the property is located in the western section of the Chistyakovo-Snezhnoye syncline in the central part of the Donetsk Coal Basin. The Mine reserves are comprised of 9 coal seams: m_9, m_5^1, m_4^1, m_3, L_7, L_6, L_4, L_3, and $L_1^{1в}$. Currently, four coal seams are mined – L_7, L_6, L_4, L_3. The mining and geologic conditions of the KD mine operations are relatively favorable for coal production. The coal seams are relatively thin to medium

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[1] Earnings before interest, taxes and depreciation

[2] DTEK 2012 Annual Report

thickness (0.6 – 1.7 m) at depths of 7 - 1600 m. The gas content of the coal seams is between 12 and 40.5 m^3/t of dry, ash-free basis.

Coal is mined using seven longwall faces in the four seams, with the L_7 and L_4 seams having the highest reported gas contents of 37.94 m^3/t and 53.50 m^3/t, respectively.[3] Average methane releases into the mine workings total 299.84 m^3/min, with ventilation air methane (VAM) flow equaling 229.39 m^3/min and gas drainage averaging 70.45 m^3/min. The CH4 concentration in the gas drainage system averages 35-40%. The methane impacting mining operations originates principally from the coal seams rather than the adjacent strata. The rock strata adjacent to the coal seams only hold gas in fractures and other free space, and are believed to contribute only minimally to the mine's gas balance.

The objectives of this pre-feasibility study are (i) to perform an initial assessment of the technical and economic viability of pre-drainage in the study area, the new Block 5, from the two gassiest seams and the rock layers adjacent to the seams, and (ii) to compare the forecasted gas production from pre-drainage to the forecasted gas production from surface gob gas wells. In addition, the gas production profiles generated for both the pre-drainage and surface gob well development scenarios form the basis of the economic analyses for gas production and utilization. The reservoir model was constructed using ARI's proprietary reservoir simulator, COMET3®. A study area for the simulation study was designated by DTEK and encompasses an area roughly 2100 m in length by 600 m in width.

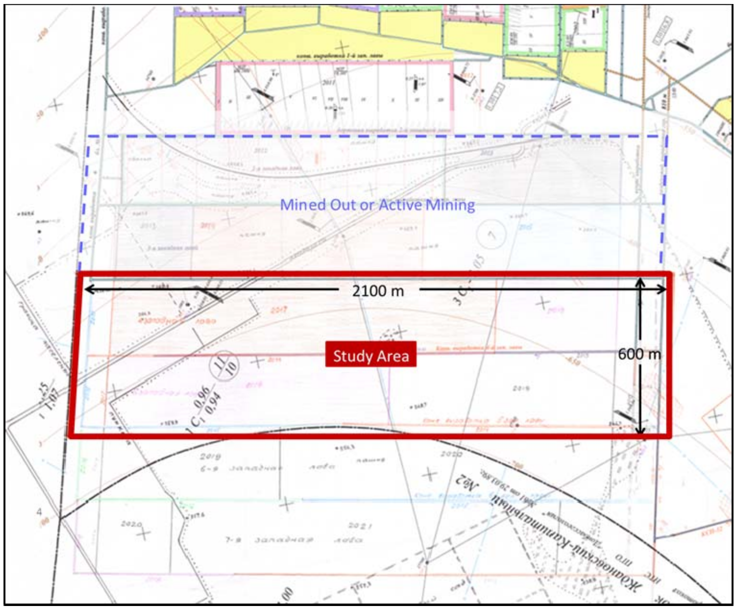

Figure E-1: Simulated Gas Production Rate for the Study Area (L_7 & L_4 Seams Combined)

The input data used to populate the reservoir model were obtained primarily from the geologic and reservoir data provided by DTEK. Any unknown reservoir parameters were obtained from analogs

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[3] Geologic data was provided by DTEK

within the Donetsk Basin, when available, and from other coal formations that are most analogous to those found in the Donetsk Region, such as primarily Permo-Carboniferous local basins in neighboring countries like Poland and the Czech Republic.

In the United States, where the natural gas industry is well developed, operators typically develop relatively tight sandstones (i.e., 1 milidarcy (mD) or less on spacing patterns of 60 acres (ac) (equal to 24 hectares (ha)) or less. Spacing on the order of 40-80 acres (16 – 32 ha) is common, with some operators going down to spacing as tight as 10 acres (4 ha). Due to the low permeability present at the study area, the decision was made to run the reservoir simulations on three spacing cases of 60 acres (24 ha), 40 acres (16 ha), and 20 acres (8 ha). Each of the models was run for a period of 10 years and the resulting gas production profiles and reduction in methane of the coal seams are highlighted in the following sections. The simulated gas production rate for the L_7 and L_4 seams combined is shown in Figure E-1, and a summary of pre-drainage simulation results for the study area is presented in Figure E-2.

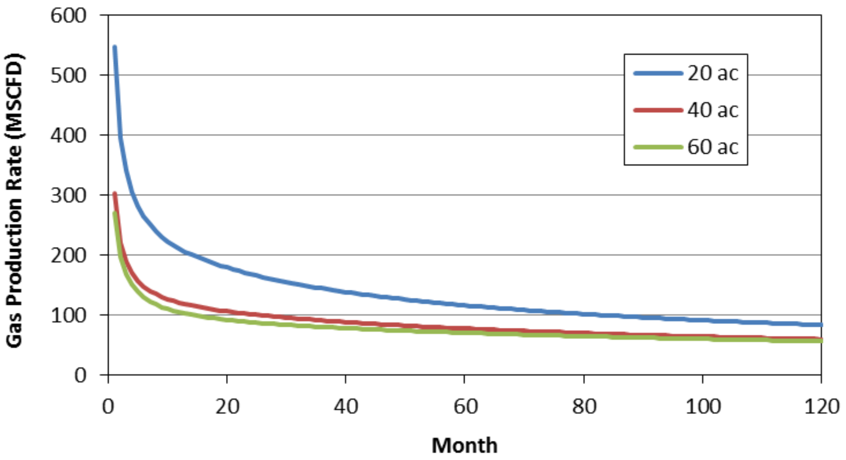


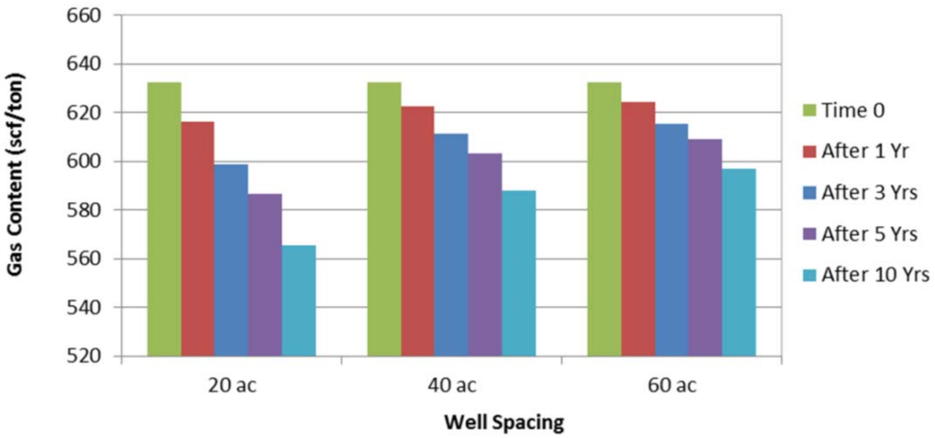
Figure E-2: Simulated Gas Production Rate for the Study Area (L_7 & L_4 Seams Combined)

Well Spacing	ac	20	20	20	40	40	40	60	60	60
Producing Seam(s)		L7	L4	L7+L4	L7	L4	L7+L4	L7	L4	L7+L4
Total Wells Drilled	wells	24	24	24	12	12	12	10	10	10
Peak Gas Rate	MSCFD	254	293	547	141	163	304	125	146	271
Cumulative Gas Production										
1 Year	MMSCF	48	59	107	27	32	60	24	29	53
3 Year	MMSCF	103	128	231	61	74	134	53	65	118
5 Year	MMSCF	129	159	324	77	94	195	67	83	172
10 Year	MMSCF	224	277	502	143	175	318	127	159	286
Methane Concentration	%	98%	98%	98%	98%	98%	98%	98%	98%	98%
CH4-In-Place	BCF	1.40	1.47	2.87	1.40	1.47	2.87	1.40	1.47	2.87
Recovery Factor (10-Yr)	%	16%	18%	17%	10%	12%	11%	9%	11%	10%

Table E-1: Summary of Pre-Drainage Simulation Results for the Study Area

As expected, the 20 acre (8 ha) spacing case produces the most gas due to the greater number of wells drilled within the study area. However, due to the low permeability of the coal seams in the study area, only 10-17% of the methane-in-place is recovered after 10 years of production.

According to mine data provided by DTEK, the L_7 and L_4 seams are the gassiest coal seams mined. DTEK currently employs gas drainage in the L_7 and L_4 seams using cross-measure boreholes drilled into the roof of the L_4 and L_7 seams. One of the benefits of pre-drainage is the reduction of methane content in the coal seams prior to mining. Figures E-3 and Figure E-4 show the simulated reduction in in-situ gas content for the L_7 and L_4 seam, respectively, within the study area.



FigureE-3: Simulated Reduction in In-Situ Gas Content for the L_7 Seam within the Study Area

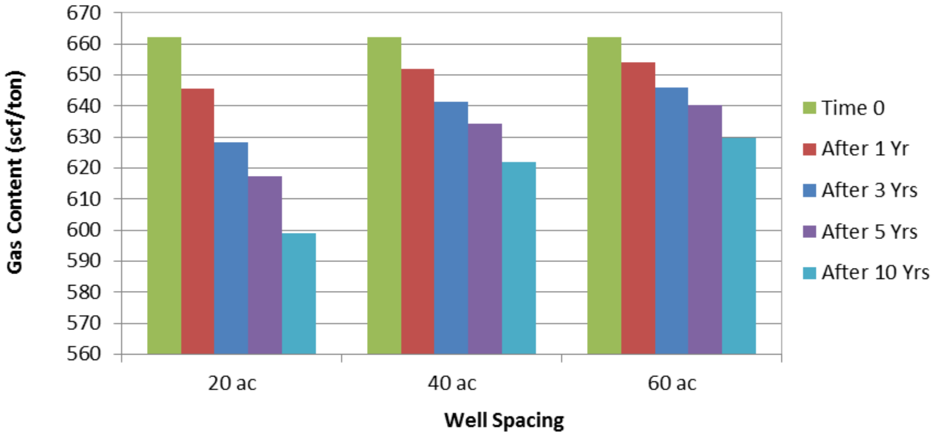


Figure E-4: Simulated Reduction in In-Situ Gas Content for the L_4 Seam within the Study Area

Again, due to the closer well spacing, the greatest reduction in gas content within the coal seams is associated with the 20 ac (8 ha) spacing case. Despite 10 years of production, the amount of gas recovered is low, mainly due to the low permeability. Down-spacing of the wells, for example 10 acre spacings, or the use of long, in-seam wells drilled from underground could potentially increase the recovery percentages. However, a vertical well program using 10 acre or even 5 acre well spacings will have limited impact due to the low permeability of the coals, and any increase in gas recovery must be weighed against the added cost for a greater number of, or more expensive, wells.

To model surface gob gas production from longwall panels at the Komsomolets Donbassa mine, the Methane Control and Prediction (MCP) model was used.[4] The MCP software suite was developed by the National Institute for Occupational Safety and Health/Office of Mine Safety and Health Research (NIOSH/OMSHR) to help address various issues related to methane control in longwall coal mines in the U.S. and other countries.

To model a longwall panel within the study area, the Gob Gas Venthole (GGV) Performance Prediction model for working depths exceeding 1,000 ft in active panels with advancing faces was used. This model is designed to predict GGV performance in order to maximize production rates, determine methane concentrations, improve mining safety, and produce pipeline-quality gas.

With a linear face advance rate of 12.5 ft/d and a longwall panel length of 5742 feet, a single panel can be mined through in 460 days, or roughly 15 months. A series of gob gas model runs were made for each of the five proposed GGV locations. For each well, total gas production rate (SCFM) and methane concentration (%CH_4) were calculated on a monthly basis according to the borehole location with respect to the position of the advancing face. Since gob wells can continue producing even after the panel over which they are located is mined through, the life of each well was assumed to be 18 months. In practice, the life of a GGV is largely determined by the gas volume and methane concentration of the produced gas. The gob gas production rates by well, as modeled for a single longwall panel, are shown in Figure E-5 while gob gas methane concentration is presented in Figure E-6.

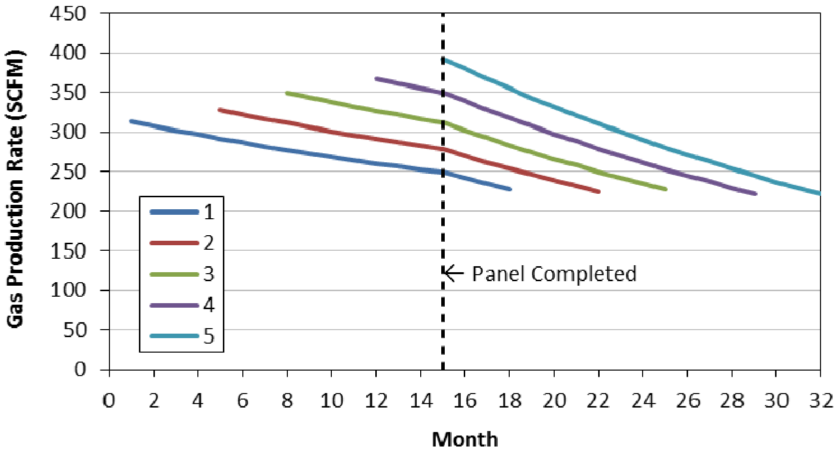


Figure E-5: Gob Gas Production Rate by Well for Single Longwall Panel

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[4] Methane Control and Prediction (MCP) Model, Version: 2.0. NIOSHTIC2 Number: 20038036. Pittsburgh, PA: U.S. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, September 2010. Available at http://www.cdc.gov/niosh/mining/works/coversheet1805.html

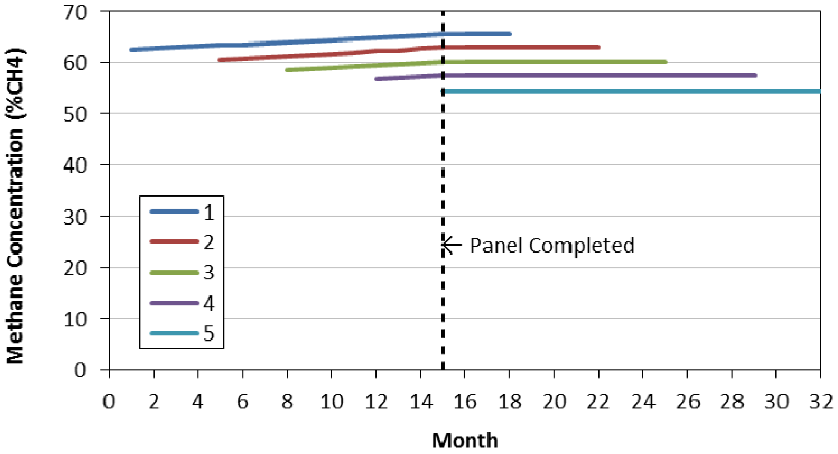


Figure E-6: Gob Gas Methane Concentration by Well for Single Longwall Panel

The results show gob gas production volumes are greater than any of the pre-drainage cases. Gob wells produce more than two times as much methane from the study area as compared to the best pre-drainage case (i.e., 20 ac spacing case) despite using less than half as many wells.

When comparing gob gas production to the results from the 60 acre pre-drainage case (10 wells each), the difference in methane production is even more pronounced with methane production from gob wells over four times that of pre-drainage wells. The recovery factor of the in-place methane resource in the study area ranges from 10% to 17% for pre-drainage, while gob gas recovery exceeds 90%. Figure E-7 and Table E-2 show the results of pre-drainage and gob venthole simulation.

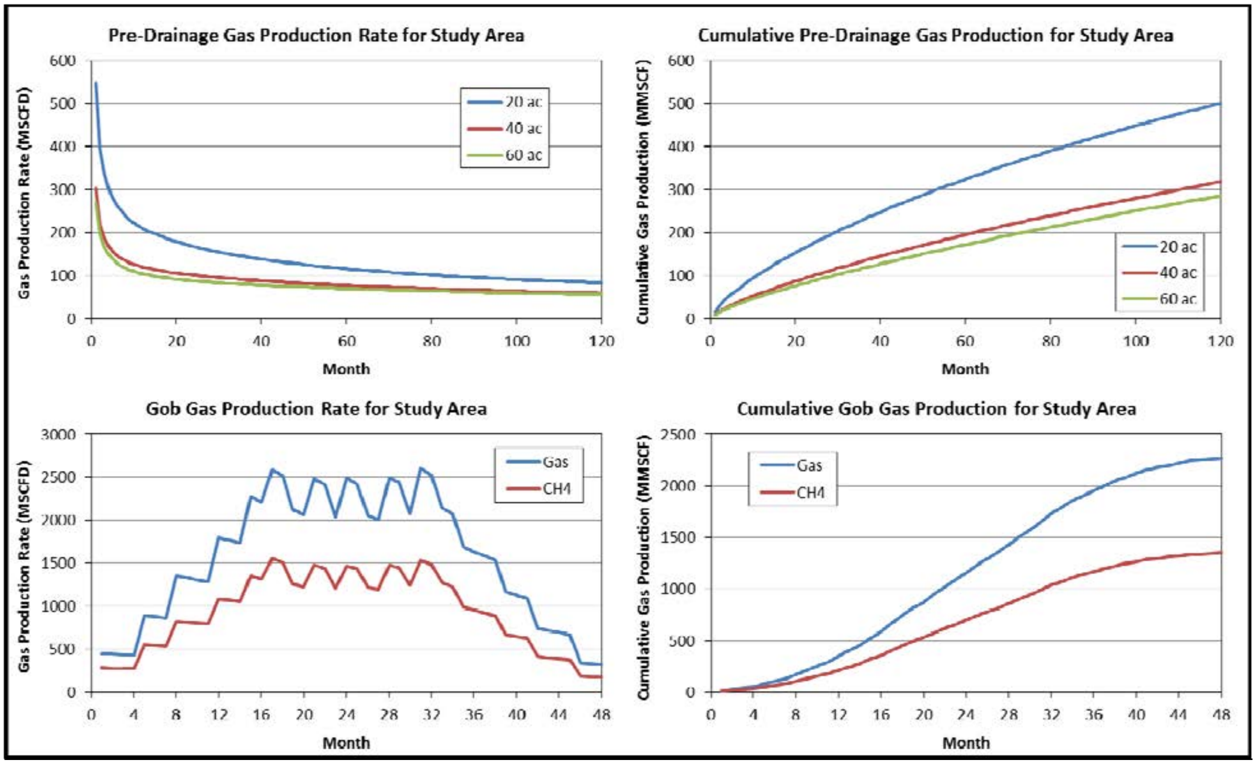


Figure E-7: Comparison of Pre-Drainage and Gob Gas Modeling Results for the Study Area

Production Case		PD-20ac	PD-40ac	PD-60ac	Gob
Producing Seam(s)		L7+L4	L7+L4	L7+L4	L7
Total Wells Drilled	wells	24	12	10	10
Peak Gas Rate	MSCFD	547	304	271	2607
Cumulative Gas Production	MMSCF	502	318	286	2270
CH4 Concentration	%	98%	98%	98%	59%
Cumulative CH4 Production	MMSCF	491	311	280	1349
CH4-In-Place	BCF	2.87	2.87	2.87	1.40
Recovery Factor	%	17%	11%	10%	96%

Table E-2: Summary of Pre-Drainage and Gob Gas Modelling Results for the Study Area

The primary markets available for a CMM utilization project at the Komsomolets Donbassa mine are power generation using internal combustion engines, flaring and boilers. DTEK is specifically targeting power generation for this project. From a technical standpoint, vehicle fuel in the form of liquefied natural gas (LNG) or compressed natural gas (CNG) would be possible with a successful pre-drainage program. At this time, sales to natural gas pipelines are neither technically nor economically viable.

In order to assess the economic viability of the two degasification options presented throughout this report, it is necessary to define the project scope and schedule. Based on the mine maps provided by DTEK, a total of four longwall panels (two included in the original study area) are scheduled to be mined over a five-year period beginning in 2017. These are the only longwall panels identified on the mine maps provided, and it is assumed the project area will be limited to these four panels only. Figure E-8 is a map showing the proposed project area and the mine progression by year (panels are named A through D). With four panels mined over five years, it is assumed that each panel takes 1.25 years (15 months) to mine. Delineation work for the L_7 seam is currently being conducted and is expected to be completed by the end of 2015. Coal production is scheduled to begin in 2017 and continue through the end of 2021. Table E-3 presents the results of the simulation for pre-mine drainage of the L_4 and L_7 seams and gob gas drainage for the L_7 seam for the entire production area.

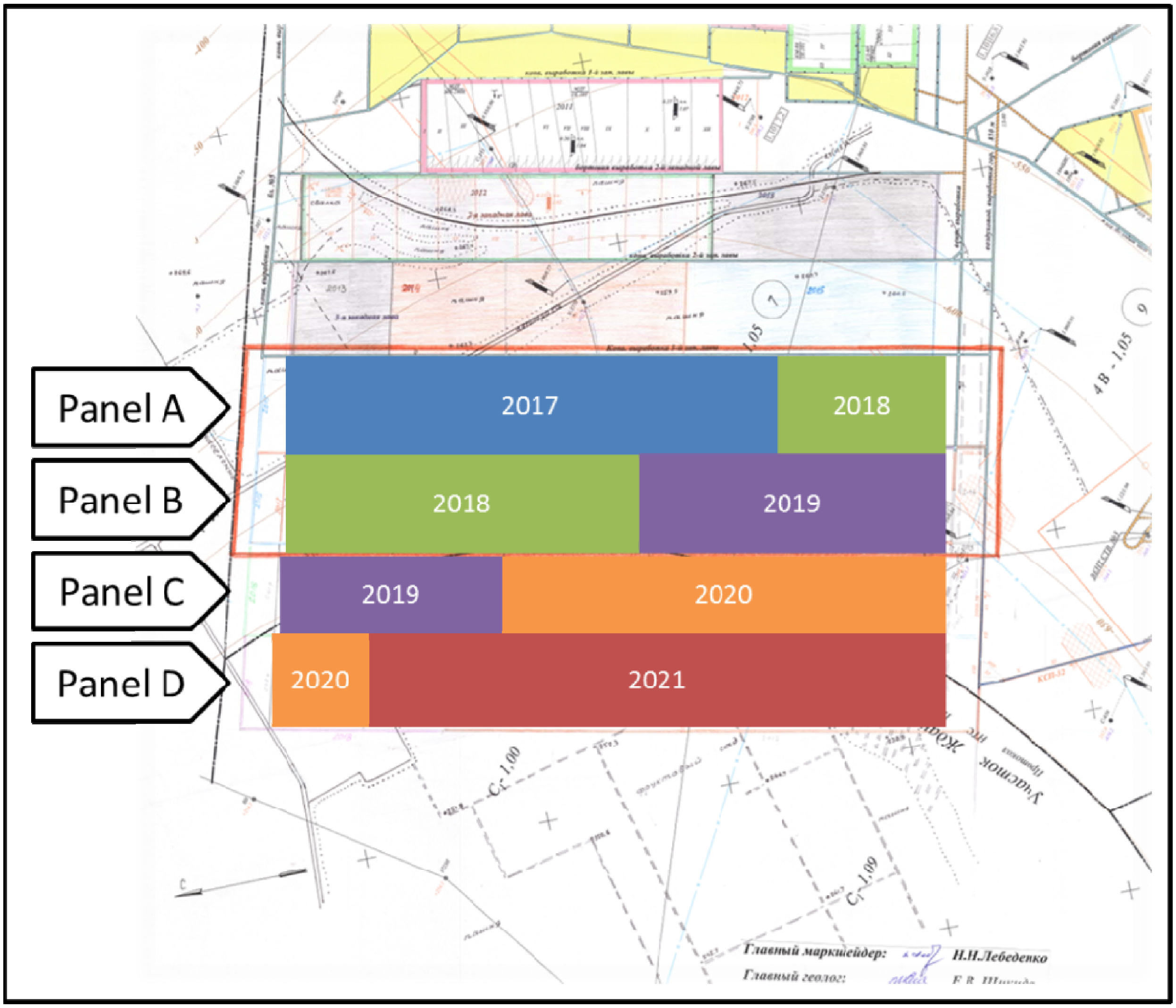


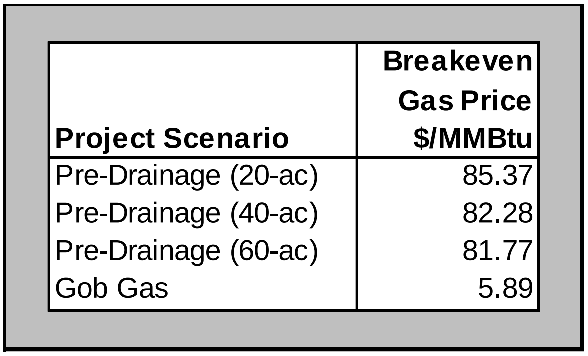
Figure E-8: Mine Map Showing Project Area and Mine Progression by Year

Production Case		PD-20ac	PD-40ac	PD-60ac	Gob
Producing Seam(s)		L7+L4	L7+L4	L7+L4	L7
Total Wells Drilled	wells	48	24	20	20
Peak Gas Rate	MSCFD	585	356	312	2988
Cumulative Gas Production	MMSCF	640	328	275	4540
CH4 Concentration	%	98%	98%	98%	59%
Cumulative CH4 Production	MMSCF	626	321	269	2699
CH4-In-Place	BCF	5.74	5.74	5.74	2.80
Recovery Factor	%	11%	6%	5%	96%

Table E-3: Summary of Gas Production Forecast Results for Project Area

ARI modeled project economics on both the upstream (i.e., gas production) costs for vertical pre-drainage wells and gob gas boreholes, and on the downstream utilization of the gas for power production at the mine (Table E-4). The objective is to determine the cost of gas production as a cost of gas for CMM utilization.

The cost of vertical pre-drainage is prohibitively expensive. Based on the gas production achieved, the cost is estimated to be between US$ 81.77 and US$85.37 per MMBtu (Million British Thermal Units), roughly equivalent to $2,887 - $3,014 per thousand cubic meters. In contrast, the breakeven cost of producing gob gas through surface boreholes is $5.89/MMBtu ($210 per thousand m^3).

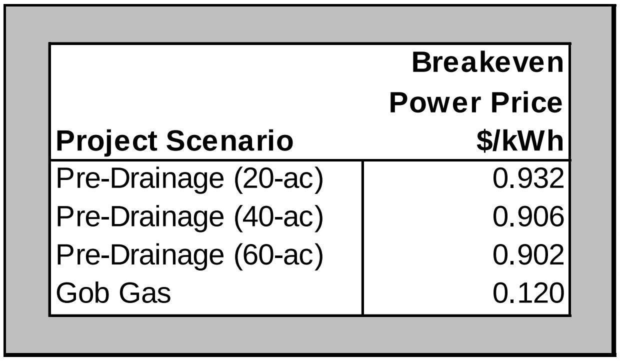


Project Scenario	Breakeven Gas Price $/MMBtu
Pre-Drainage (20-ac)	85.37
Pre-Drainage (40-ac)	82.28
Pre-Drainage (60-ac)	81.77
Gob Gas	5.89

Table E-4: Breakeven Gas Price as Calculated in Upstream Evaluation

In addition, gas production from pre-drainage wells is so low that it can only sustain a very small power project. Even using 20 acre (8 ha) spacing, there is only enough gas to support 1.3 MW of power production. Gob well production will support 4.6 MW of electricity generation. Table E-5 presents the breakeven costs for power generation incorporating the costs of gas production into the overall cost of gas capture and utilization.

The cost of power production using gob vent boreholes is $0.12/kWh inclusive of the cost of methane drainage. At this price, a power project could be potentially economic, especially considering the additional benefits of methane degasification in terms mine safety and increasing the advance rate for the longwall. Some project developers and mine operators do differentiating the costs of degasification and methane utilization, and removing the cost of mine degasification from the economic analysis because it is a sunk cost would significantly reduce the breakeven costs for power production.



Project Scenario	Breakeven Power Price $/kWh
Pre-Drainage (20-ac)	0.932
Pre-Drainage (40-ac)	0.906
Pre-Drainage (60-ac)	0.902
Gob Gas	0.120

Table E-5: Breakeven Power Sales Price as Determined in Downstream Evaluation

In summary, the analysis performed by ARI reveals that surface gob gas ventholes are likely to be the most effective method for degasification of the coal seams at the Komsomolets Donbassa mine. The recovery efficiency is significantly higher for the gob wells in comparison to the low recovery efficiencies and the high remaining gas in place that ARI reservoir simulation showed for pre-mine drainage. However, the most effective gas drainage program for the Komsomolets Donbassa Mine is likely to be a combination of gob gas ventholes drilled form the surface combined with in-mine cross measure boreholes, for which the Komsomolets Donbassa Mine has significant experience implementing and operating. Another alternative is to employ long-hole in-mine directional drilled wells.

Should DTEK and the Komsomolets Donbassa Mine wish to continue with gob well or pre-mine drainage, ARI recommends that DTEK prepare a more thorough and detailed analysis, produce detailed engineering and design documents, and conduct a pilot well test program, followed by a full field feasibility study.

1.0 Introduction

The U.S. Environmental Protection Agency's (USEPA) Coalbed Methane Outreach Program (CMOP) works with coal mines in the U.S. and internationally to encourage the economic use of coal mine methane (CMM) gas that is otherwise vented to the atmosphere. Methane is both the primary constituent of natural gas and a potent greenhouse gas when released to the atmosphere. Reducing emissions can yield substantial economic and environmental benefits, and the implementation of available, cost-effective methane emission reduction opportunities in the coal industry can lead to improved mine safety, greater mine productivity, and increased revenues. The work of CMOP and USEPA also directly supports the goals and objectives of the Global Methane Initiative (GMI), an international partnership of 41 member countries and the European Union that focuses on cost-effective, near-term methane recovery and use as a clean energy source.

An integral element of CMOP's international outreach in support of the GMI is the development of CMM pre-feasibility studies. These studies provide the cost-effective first step to project development and implementation by identifying project opportunities through a high-level review of gas availability, end-use options and emission reduction potential. In recent years, CMOP has sponsored feasibility and pre-feasibility work in China, India, Kazakhstan, Mongolia, Poland, Russia Turkey, and Ukraine. This is the second pre-feasibility study for a Ukraine coal mine supported by CMOP. As a major coal mining country and one with significant challenges related to methane emissions into mine workings, success in delivering CMM projects in Ukraine will contribute greatly to reducing regional and global methane emissions.

The principal objective of this pre-feasibility study is to assess the technical and economic viability of drilling pre-drainage wells and surface gob wells at the Komsomolets Donbassa Mine. The Komsomolets Donbassa (KD) Mine is an excellent candidate for increased methane use and abatement, and was chosen for this pre-feasibility study for the following reasons:

- The mine is one of the largest and most productive in Ukraine, but an increase over current production is constrained by high methane releases into the workings.
- Although the KD mine employs methane drainage using cross-measure boreholes, mine management is interested in pre-drainage and/or surface gob wells to improve gas drainage efficiency.
- Anticipating an increase in gas availability (i.e., gas quality and quantity), KD Mine management is also interested in exploring the technical and economic viability of on-site power generation to supplement already installed gas boilers and flares.
- In meetings with USEPA, DTEK and KD Mine management have expressed support to develop their CMM resources to improve environmental performance and contribute to local economic development in addition to mine safety and increased coal production.
- The mine is privately owned by DTEK Holdings and is well-capitalized to make the investments to increase gas capture and utilization.

This pre-feasibility study is intended to provide **an initial assessment** of project viability. A final Investment Decision (FID) should only be made after completion of a full feasibility study based on more refined data and detailed cost estimates, completion of a detailed site investigation, implementation of well tests, and possibly completion of a Front End Engineering & Design (FEED) study.

2.0 Background

2.1 The Ukrainian Coal Industry

The Donetsk Coal Basin (Donbass) in eastern Ukraine was one of the leading coal producing basins of the Soviet Union, and today it holds 4% of the world's coal reserves and almost 5% of hard coal reserves. In 2011, Ukraine ranked 14th in global coal production with 68 million short tons of production, mostly hard coal. Following the collapse of the Soviet Union, coal production in Ukraine declined steadily but the trend was reversed in 2011 and coal production increased to 71 million short tons in 2012[5]. The decline was largely due to the closure of unprofitable state-owned mines. The resurgence is the result of privatization and investment in the remaining mines.

Total coal resources are estimated to be 54 billion metric tonnes with economically mineable coal reserves at 34 billion tonnes, of which 6.1 billion tonnes are located in active mines. The Donetsk Basin holds 45.6% of the reserves. Shallower reserves have been largely mined out, and Ukrainian mines must produce coal from deeper and more geologically complex seams. The average depth of Ukrainian mines is about 700 meters, and the deepest mine is 1,332 meters. There is reportedly some preparatory work being undertaken at a depth of 1,386 meters.[6]

Currently, there are 149 mines operating in Ukraine - 120 state-owned mines and 29 private mines – employing 271,000 staff. The "Energy Strategy of Ukraine" is guiding the long-term development of the coal industry including a major restructuring of the industry that will ultimately see the privatization and modernization of the industry leading to stable growth. As a result of the restructuring of the mining sector, 101 mines are already slated for closure.[7]

2.2 Coal Mine Methane in Ukraine

Ukraine is one of the world's leading emitters of CMM releasing 30 million metric tonnes of CO2 equivalent (MtCO2e) per year. Although it ranks 14th in coal production, the gassiness of Ukraine's mines rank it fourth worldwide in CMM emissions after China, the U.S., and Russia. Methane gas has long been a problem in Ukrainian mines due to several factors. The depth of mining is extreme compared to most countries. The gas contents of the coal are very high and are often under great pressure. Permeability is exceptionally low, porosity is low, and the geology is very complex with extensive faulting and folding.

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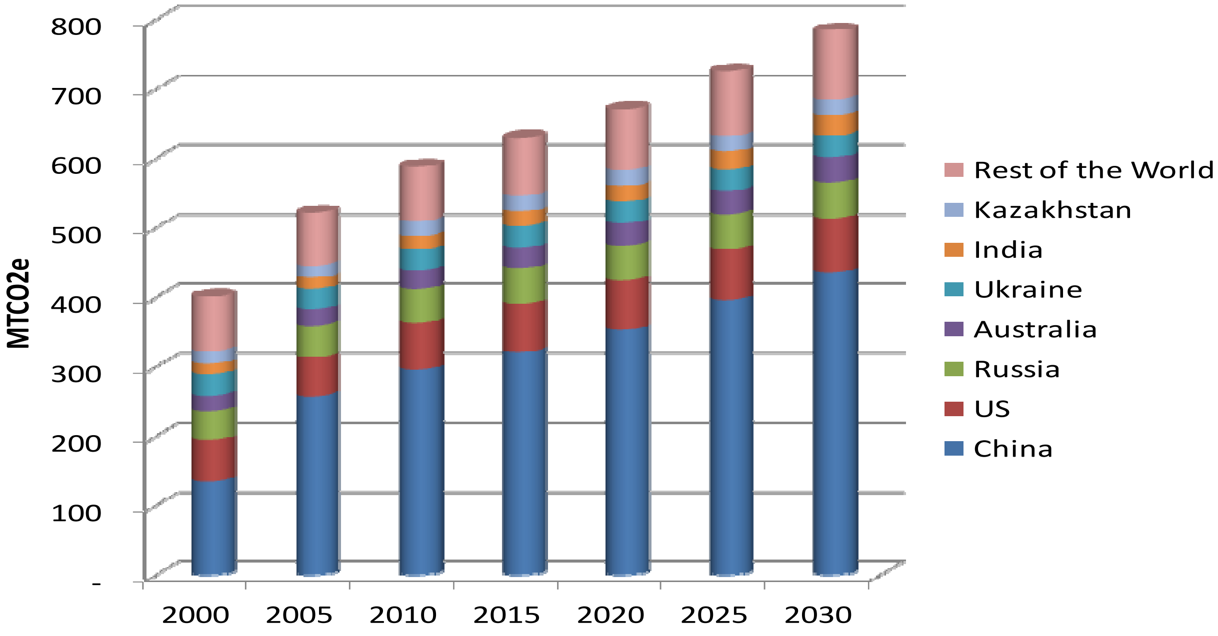
[5] U.S. Energy Information Administration.

[6] EURACOAL

[7] EURACOAL



Source: USEPA, 2012[8]

Figure 2-1: Global Coal Mine Methane Emissions

Although the geologic and mining conditions present significant hurdles, they are not insurmountable. A U.S. Department of Labor project demonstrated the effectiveness of long-hole in-mine directional drilling.[9] But these practices have not been implemented on any scale underscoring that one of the biggest problems in Ukraine has been underinvestment in mining operations and the absence of best practices for methane drainage and use in coal mines.

2.3 The Komsomolets Donbassa Mine

The Komsomolets Donbassa (KD) Mine is located in eastern Ukraine outside the village of Kirovskoye, Donetsk Oblast, 52 kilometers (km) northwest of the city of Donetsk. Driving time to the mine is about one hour from central Donetsk. The mine became operational December 19, 1980, as an "independent" mine which meant that it was not part of any mine group or association. In 2000, it became the first state-owned mine to be privatized. The mine covers an aerial extent of 63.6 km^2 under the existing mining plan, but this will increase to 83.6 km^2 with a reserve addition in 2013. As of January 2013, the

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[8] USEPA. *Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990 – 2030*. December 2012) http://www.epa.gov/climatechange/Downloads/EPAactivities/EPA_Global_NonCO2_Projections_Dec2012.pdf

[9] Schwoebel & Triplett. *Directional Drilling for Gob Gas Drainage at the Belozerskaya Mine*. (September 2011) https://www.globalmethane.org/documents/events_coal_20110921_schwoebel.pdf

total length of the active mine workings is 184.3 km. Production will begin in the reserve addition in 2015 or 2016.

Figure 2-2: Map Location of the Komsomolets Donbassa Mine

The Komsomolets Donbassa Mine is a longwall mine, producing thermal coal of grade "T" and is one of the largest producers of thermal coal in Ukraine. Coal reserves are 111 million metric tonnes, but reserves will increase to 158 million tonnes after the reserve addition in 2013. Coal production is currently 4.5 million metric tonnes per year, more than double production of 2 million tonnes per year in 2000 at privatization. DTEK's plans call for production of 5.3 million tonnes by 2020; however, the mine ventilation system is operating at maximum capacity and additional methane drainage will be necessary to achieve this planned increase in coal production.

The KD Mine complex includes its own coal-preparation complex, as well as a drainage pump station that houses boilers capable of burning CMM, two flares and a passive vent. The flares and boilers have operated as a Joint Implementation project under the Kyoto Protocol. The project was registered by the

CDM Executive Board in August 2008 and crediting started on August 9, 2008. Total Emission Reduction Units (ERUs) issued by the CDM Executive Board are 461,891 through June 30, 2012.[10] The flares are currently not operating due to very low ERU prices in the emissions markets.

2.4 DTEK Holdings – Parent Company

The KD Mine is owned by DTEK Holdings (Donbasskaya Toplivnaya Energeticheskaya Kompanya; www.dtek.com), a large, privately owned and vertically integrated holding company that is the largest energy company in Ukraine. DTEK 2012 revenues totaled US$ 10.3 billion with EBITDA of US$ 2.1 billion and net profit of US$ 741 million. Assets total US$ 9.6 billion.[11] .

DTEK controls 38 coal mines, 36 of which are in the Donbass region in Ukraine. The other two mines are in Russia. Eighteen of DTEK's mines are considered very gassy and 8 of those are extremely gassy mines. In addition, DTEK controls 12 coal preparation plants. The company produces both thermal and coking coal for its own enterprises including power generation, steel making, district heating and household use. In 2012, DTEK produced 39.7 million metric tonnes of coal and 51.4 billion kWh of electricity.[12]

3.0 Summary of mine characteristics

Extending over an area of 63.6 km^2, 83.6 km^2 after the 2013 reserve addition, the property is located in the western section of the Chistyakovo-Snezhnoye syncline in the central part of the Donetsk Coal Basin. The surface above the mine is an undulating plain that is crisscrossed by several major ravines with either continuous or seasonal streams. The elevation ranges from 269.7 to 152.5 meters above sea level.[13] Most of the surface is farmed, although parts of the mine operations are located under the village of Kirovskoye.

The Donetsk region experiences a continental climate with warm to hot summers and cold winters. The average temperatures are −5 °C (23 °F) in January and 18 °C (64 °F) in June.

3.1 Coal Production

The Komsomolets Donbassa mine has seen steady growth in coal production since privatization in 2000. In 2011, the KD Mine produced 4.3 million tonnes of coal increasing to 4.5 million tonnes in 2012. Target production is 5 million tonnes per year, but production is gas constrained.

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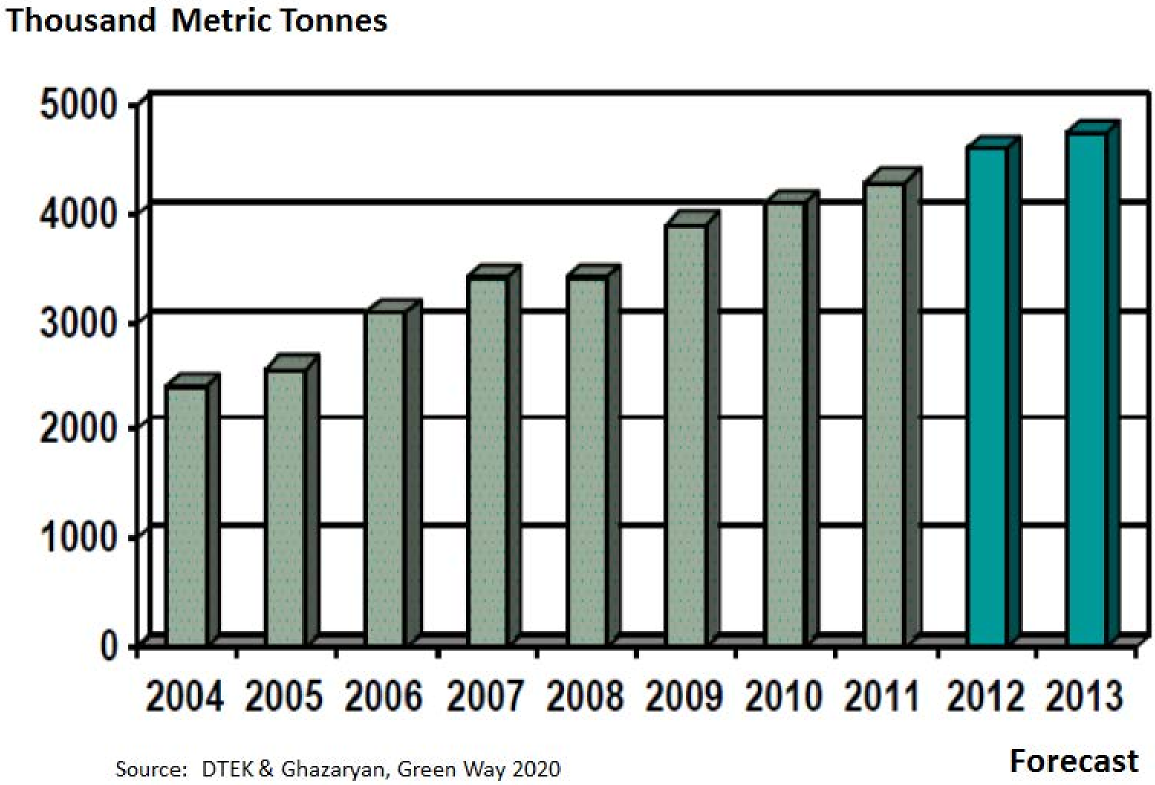
[10] UNEP Risoe Center – JI Pipeline (September 2013)

[11] DTEK 2012 Annual Report

[12] DTEK 2012 Annual Report

[13] PEER Komsomolets Donbassa Mine Investment Plan



Source: DTEK & Ghazaryan, Green Way 2020

Figure 3-1: Komsomolets Donbass Mine Coal Production

3.2 Geological characteristics

Sections 3.2 through 3.5 summarize the site geology of the Komsomolets Donbassa mine. Additional detail is contained in Appendix A.

The methane impacting mining operations originates principally from the coal seams rather than the adjacent strata. According to DTEK and KD Mine geologists and engineers, studies of the porosity and permeability of the rock (sandstone, limestone, sandy shale) show that the rock is very dense (2.5-2.87 g/cm^3), has low porosity (total – up to 3.8%, open – 1.5-1.9%) and low gas permeability (0.00-0.02 mD) limiting the volume of gas in the pore space. However, numerous local methane accumulations are located in zones of fracturing caused by tectonic faults, flexure bends, or mining activities, but there are no detailed studies with significant additional details on the fractured zones.

The geology of the area has been explored extensively for a variety of purposes by many organizations. The first geological studies within the area were performed from 1900-1916, followed by additional geological exploration in subsequent years. The last geological exploration was performed between 1985-1992 by the Zapadnoantratsitovskaya Exploration Company. The re-estimation of coal reserves within the Komsomolets Donbassa mine field was developed based on this work.[14]

3.3 Geological structure (stratigraphy, lithology, tectonics)

Within the mine area, Upper and Middle Carboniferous sediments are represented by suites C_3^1, C_2^7 and C_2^6, and are covered by Quaternary deposits, except for minor areas of drainage and hill slopes, where the coal deposits crop out.

Carboniferous deposits contain the typical terrigenous sediments with alternating layers of sand, shale, clay shale, multi-sized sandstones, thin limestones, coal seams and carboniferous shales. Bedding Plane contacts within the mine area vary both in the mine field plane and cross section: there is a smooth transition between the shale layers with various grain size over an area of interlaid thin laminae at the border of lithotype transition. The boundaries between shale and massive sandstones are clearer. Within the thick (m = 11.0-18.0 m) clay shale there are smooth surfaces at 0.8-1.2 m height from the coal seam with no contact in some areas.

In terms of geological structure the area is associated with the western and central parts of the Chistyakovo-Snezhnoye syncline represented by a symmetrical fold with an abrupt northern slope and shallow southern slope. Its axis gradually deepens in the north-west direction at an angle of 5-6^0. The rock dips vary from 5-17 degrees in the south to 15-25 degrees in the north. Westward, the dip angles grow to 47 degrees, while in the axial part the angles are 2-8 degrees. The relatively smooth bedding of carboniferous rocks is disrupted by minor amplitude (0.05-3.0 m) folds and bedding structures.

Table 3-1 provides a summary of the thickness and composition of the principal coal layers:

Suite	Thickness, (m)	Number of coal seams	Number of commercial seams	Lithological composition of reservoir, %				
				Sandstones	Sand shales	Clay shales	Limestones	Coal
C_3^1	570	10	1	57.9	8.2	31.6	1.4	0.9
C_2^7	709	23	7	25.0	55.9	14.4	3.5	1.2
C_2^6	365	17	6	43.0	45.2	7.2	2.2	2.4
Total				42.0	36.2	18.0	2.3	1.5

Source: Supplied by DTEK

Table 3-1: Coalbearing Strata of the Komsomolets Donbassa Mine

3.4 Mining and geologic conditions of operations

Mine reserves are comprised of 9 coal seams: m_9, m_5^1, m_4^1, m_3, L_7, L_6, L_4, L_3, and $L_1^{1\text{в}}$. Currently 4 coal seams are mined – L_7, L_6, L_4, L_3.

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[14] approved by the minutes No. 1534 TES of Ukruglegeologia dated 10.12.1992

The mining and geologic conditions of the KD mine's operations are relatively favorable for coal production. The coal seams are relatively thin to medium thickness (0.6 – 1.7 m) at depths of 7 - 1600 m depth. The dip of the seams is low, with a seam inclination angle of 0 – 35 degrees.

The gas content of the coal seams is between 12 and 40.5 m^3/t of dry, ash-free basis. The rock strata adjacent to the coal seams only hold gas in fractures and other free space, and are believed to contribute only minimally to the mine's gas balance.

The host rocks feature medium cavability and unstable roof when mining coal with powered longwalls. Roof control involves full caving. The subsidence of limestone and sandstone is abrupt and is a reservoir for methane accumulation. The extent of caving is 16-18 meters high for the primary roof subsidence increasing to 30-50 m for the primary main roof subsidence. At full longwall production, the area of disturbed rocks increases to 180-200 m above the seam.

One of the main features of Chistyakovo-Snezhnoye industrial region of Donetsk basin is the abrupt change in the reservoir characteristics after disturbance with mining operations. T grade coal and its host rocks are quite dense and have low permeability for gas and water. At the same time the coal and rock formations are very fragile and insensitive to plastic deformations. The impact on the strata after unloading is that they form a large number of open fractures and significantly change the reservoir characteristics. But, there have been no systematic studies or measurements; therefore, representative figures are not available.

The aquifers that impact water influx into the mine workings are associated with carboniferous sandstone and limestones. The Komsomolets Donbassa Mine is located in the axial portion of Chistyakovo-Snezhnoye syncline and is in hydraulic communication with the adjacent mines that developed coal seams of the Diamond suite. The average water influx into the mine workings of the mine is 650 - 1250 m^3/h.

The coal seams are not prone to rock bursts, nor are they prone to self-ignition.

3.5 Characteristics of the mined coal seams

3.5.1 Seam L_3

Coal seam L_3 is dangerous in terms of coal and gas outbursts and in terms of arching, but not dangerous in terms of rock bursts and coal dust is not explosive. The seam produces coal of grade "T".

Coal seam L_3 has a complex structure, often splitting into four multiple seams. The thickness of interbeds comprised mainly of clay shale varies from 0.05 to 0.35 m. Useful seam thickness is up to 1.80 m, with a total thickness of 2.00 m. From the central to the southern area there is a reduction in seam thickness to 0.7 – 1.55 m.

Within the entire mine field the dip of the coal seam varies from 1 - 28 degrees. The gas content of the seam is 30 - 35 m^3/t on dry, ash-free basis. (A max gas content of 40.5 m^3/t on dry, ash free basis is observed near the north-east field border at 499 m of depth).

3.5.2 Seam L_4

Coal seam L_4 is dangerous in terms of sudden gas and coal outburst below the absolute elevation of 389 m, and dangerous in terms of sudden gas and coal outburst and arching below an elevation of 645 m. It is not dangerous in terms of rock bursts, and the coal dust is not explosive. The coal seam mainly has a simple structure, with a typical thickness of 0.95–1.10 m. To the west and south-west the seam thins to 0.7– 0.78 m. Within some areas with the seam splits into two benches with a total thickness of 0.78 – 1.15 m

Within the mine area the dip of the coal seam varies from 2 – 30 degrees. The gas content of the seam is 25 - 35 m^3/t on dry, ash free basis. (A max gas content of 36.4 m^3/t on dry, ash free basis is observed near the eastern field border at 331.9 m of depth).

3.5.3 Seam L_6

Coal seam L_6 can experience sudden gas and coal outbursts below the elevation of 550 m. It is not dangerous in terms of rock bursts and the coal dust is not explosive.

Coal seam L_6 has a relatively continuous structure and covers most of the mine area. The exclusion is in the extreme south-east part of the field and a narrow band along the southern field boundary, where the seam is parted by an over 0.40 m interbed. Within the area of uniform seam coverage, the complex seam structure prevails with thin interlayers (0.05 – 0.10 m). The typical useful thickness is 1.20–1.50 m, while the total thickness is 1.5 – 1.8 m.

3.5.4 Seam L_7

Coal seam L_7 is dangerous in terms of sudden gas and coal outburst below an absolute elevation of 389 m and dangerous in terms of sudden gas and coal outburst below an elevation of 700 m. It is not dangerous in terms of rock bursts and coal dust is not explosive.

The coal seam has a simple structure (except for a small area in the north-west parts of the field, where the structure is complex). The typical thickness of seam L_7 is 1.0 – 1.10 m with a minimum thickness ranging from 0.8 – 0.68 m.

Within the mine area the dip of the coal seam varies from 2 - 24 degrees. The gas content of the seam is 30 - 35 m^3/t on dry, ash free basis. According to DTEK, the maximum gas content of 39.1 m^3/t of dry, ash free mass is observed at 434 m depth.

4.0 Gas Resources

4.1 Overview of Gas Resources

There are nine seams classified as reserves by the company, four of which are being developed: the L_7, L_6, L_4 and L_3 seams; the L_7 is closest to surface. Coal is mined using seven longwall faces in the four seams, with the L_7 and L_4 seams having the highest gas contents with reported contents of 37.94 m$^{3/}$t and 53.50 m^3/t, respectively.[15]

Average methane releases into the mine workings total 299.84 m^3/min, with ventilation air methane (VAM) flow equaling 229.39 m^3/min and gas drainage averaging 70.45 m^3/min. The methane concentration in the gas drainage system averages 35-40%.

Table 4-1 below shows the regulatory requirements for methane concentrations in Ukrainian mine workings.

Air flow, pipeline	Unacceptable methane concentration, % by volume
Return air from a blind working, chamber, maintained working	Over 1
Return air from a production face, extraction section with no gas meters available	Over 1
Return air from a production face, extraction section with gas meters available	Over 1.3
Return air from a mine-take wing	Over 0.75
Fresh air to an extraction section, production faces, blind workings and chambers	Over 0.5
Local methane accumulation at blind, extraction and other workings	2 and more
Return air from a mixing chamber	2 and more
Pipelines for the isolated methane drainage with the help of fans (venturi jets)	Over 3.5
Gas drainage pipelines	From 3.5 to 25

Table 4-1: Regulatory (legal) requirements to methane content in the return air, in the gas pipelines

The mine maintains three main ventilation units located in the main shaft and ventilation shafts 1 and 3 and employs an exhausting ventilation system. The longwalls employ a Y-type ventilation system to manage the higher methane output at the longwall face. These systems are often employed where the available airflow is insufficient to dilute the gas emitted from the workings.[16] In addition to mine

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[15] Geologic data was provided by DTEK

[16] UNECE *Best Practice Guidance* - note: Y-type ventilation systems require higher investment such as driving of an additional roadway, roadside dam (pack wall), and strong support of the roadways remaining open behind the longwall in the goaf.

ventilation, DTEK employs gas drainage in the L_7 and L_4 seams to degas the mine. Drainage is not necessary for the L_6 and L_3 seams which have gas contents of 28 m^3/t and 15 m^3/t, respectively. Drainage is accomplished using cross-measure boreholes drilled into the roof of the L_4 and L_7 seams. The efficiency of satellite gob gas drainage in seam L_7 is 52-69% and 47-70% in seam L_4. A gas gathering system with vacuum pumps pulls the gas to the surface. The methane content in the captured surface mixture varies from 30 to 70% with an average of 35-40%, which enables its utilization.

DTEK reports the following flow and concentration measurements for different sections of the L_4 and L_7 seams:

- Gas production from KV 1 of the eastern longwall of seam L_4 in block 2 is 14-30 m^3 min. with CH_4 concentration 50-75%.
- Gas production from KV 4 of the western longwall of seam L_4 in block 2 is 8-17 m^3 min. with CH_4 concentration 40-55%.
- Gas production from KV 10 of the western longwall of seam L_4 in block 3 is 17-28 m^3 min. with CH_4 concentration 43-55%.
- Gas production from KV 2 of the western longwall of seam L_7 in block 5 is 20-33 m^3 min. with CH_4 concentration 40-70%.
- Gas production from KV 12 of the western longwall of seam L_7 in block 3 is 20-27 m^3 min. with CH_4 concentration 50-75%.

Surface well drainage is not currently used at the Komsomolets Donbassa Mine. An attempt was made around 1998 to drill vertical boreholes, but the experiment failed due to problems completing the well.

Degassing the seams using vertical boreholes is challenging not only because of geological conditions but also due to mining advance rates. The seam nearest to surface, the L_7, advances at more rapid rate than the L_4. Therefore, surface pre-drainage wells and surface gob vent boreholes must be shut-in prior to mine-through of the L_7. The alternative is to drill and complete wells leaving pillars around each borehole in each of the mined seams. In fact, this method is used in the United States with the pillar dimensions being 80 ft x 80 ft (25m x 25m). Otherwise, continued degassing of the lower coal seams must rely on in-mine drainage using cross-measure boreholes, short cross-panel horizontal boreholes or long-hole directionally drilled boreholes.

4.2 Modeling Pre-Drainage

The objectives of this pre-feasibility study are to (i) perform an initial assessment of the technical and economic viability of pre-drainage in the new reserve addition from the two gassiest seams (L_7 and L_4) and the rock layers adjacent to the seams, and (ii) compare the forecasted gas production from pre-drainage to the forecasted gas production from surface gob gas wells. The gas production profiles generated for both the pre-drainage and surface gob well development scenarios form the basis of the economic analyses performed in Section 7 of this report.

To accomplish the first objective, ARI working with KD mine staff defined a “study area” in the reserve addition. ARI then constructed a reservoir model designed to simulate ten-year gas and water production volumes from pre-drainage wells located in the study area. The results of the reservoir simulation in the study area are then extrapolated to the entire reserve addition.

The following sections of the report discuss the construction of the vertical borehole pre-drainage model using the reservoir modeling software package, COMET3®, the input parameters used to populate the reservoir simulation model, and the simulation results.

4.2.1 COMET3® Model

The reservoir model was constructed using ARI's proprietary reservoir simulator, COMET3®. The model is a two-layer model constructed to calculate gas and water production for the study area. The model was designed to simulate production from the L_7 and L_4 seams using vertical pre-drainage wells drilled from the surface. A total of three simulations were run with three separate well spacing cases: 20 acres (8 hectares), 40 acres (16 hectares), and 80 acres (32 hectares) per well. The model was run for 10 years in order to simulate gas and water production rates and cumulative production volumes from the study area.

4.2.1.1 Study Area

The study area for the simulation study was designated by DTEK and encompasses an area roughly 2100 m in length by 600 m in width. Figure 4-1 and Figure 4-2 illustrate the location of the study area in relation to the mine workings of the L_7 and L_4 seams, respectively. Mining of the L_7 seam is at a more advanced stage of development than the L_4 seam. As a result, a portion of the L_7 seam directly adjacent to the study area is designated as "mined out or active mining", which will be treated as a no-flow barrier in the simulations to account for coal being removed during mining.

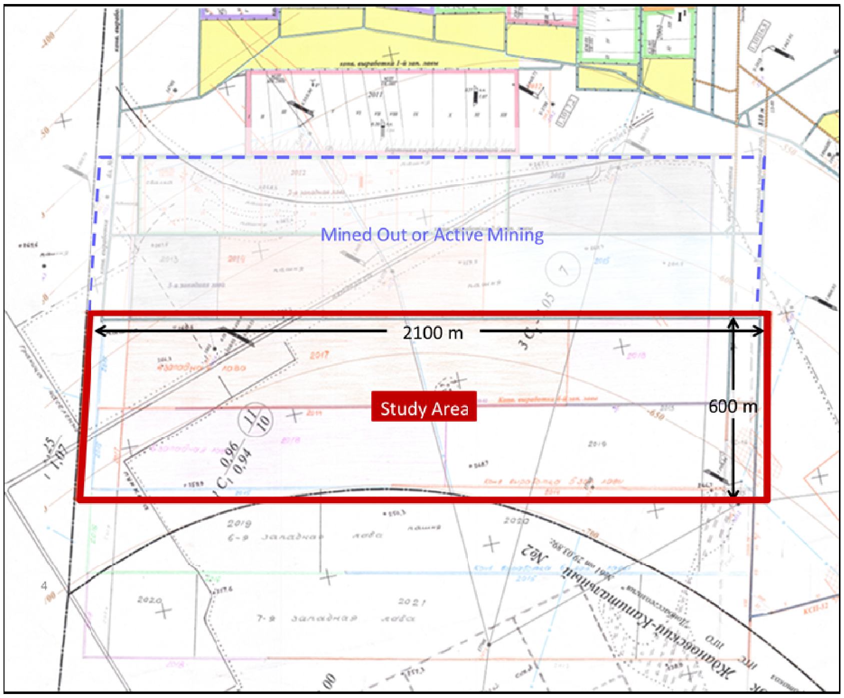

Figure 4-1: Mine Map Showing L_7 Seam Study Area

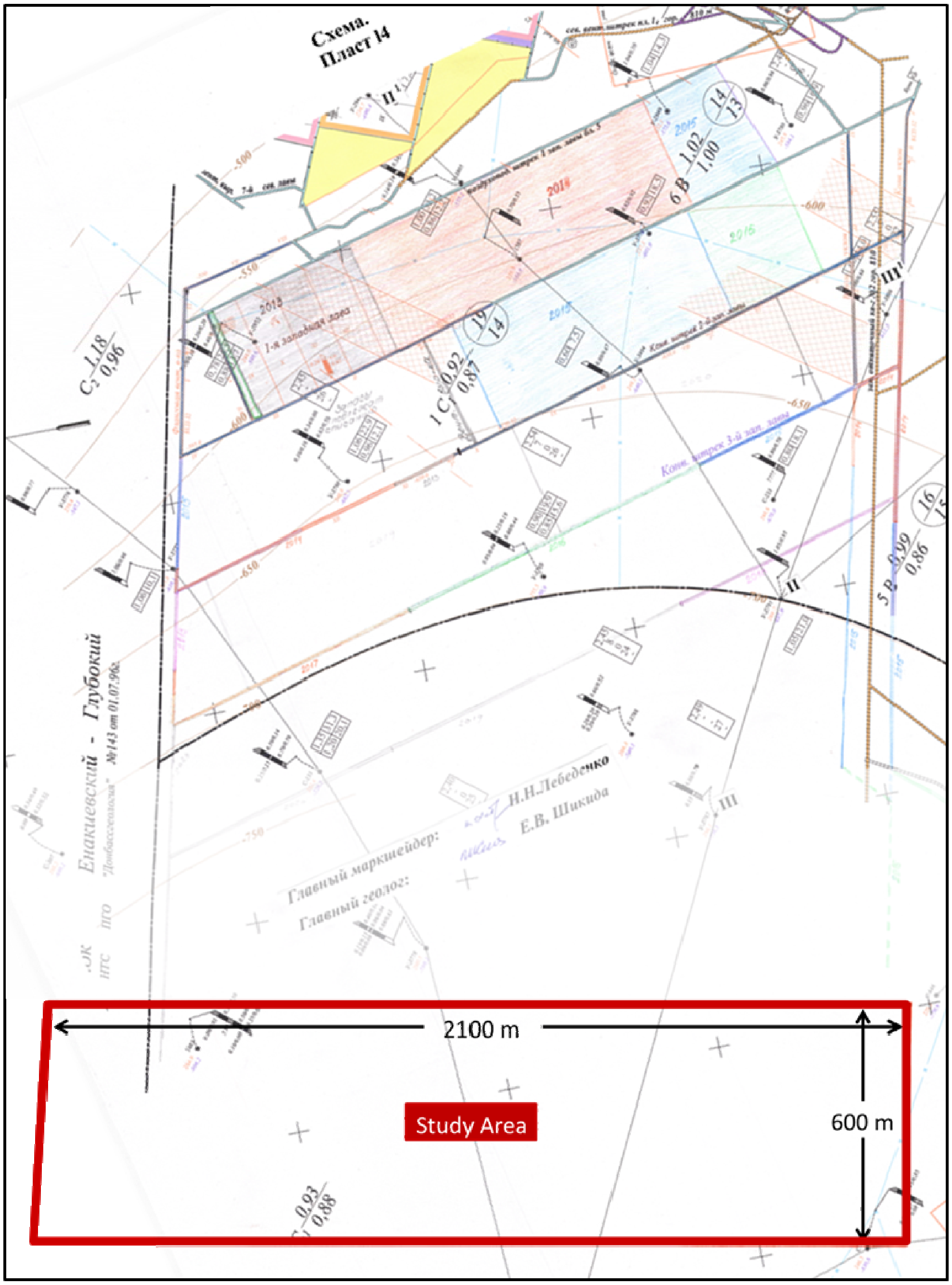

Figure 4-2: Mine Map Showing L_4 Seam Study Area

4.2.1.2 Model Layout for Simulation Study

Based on the size and location of the study area, a model grid was created in COMET3® consisting of 70 grid-blocks in the x-direction, 42 grid-blocks in the y-direction, and 2 grid-blocks in the z-direction. The total area modeled is roughly 3500 ac (1400 ha), which includes the 310 ac (124 ha) study area as well as a boundary area to account for migration of gas and water from adjacent coal seams. The model layout of the study area is shown in Figure 4-3, and a 3-dimensional representation of the study area as depicted in COMET3® is presented in Figure 4-4. It should be noted that the study area is comprised of two longwall panels.

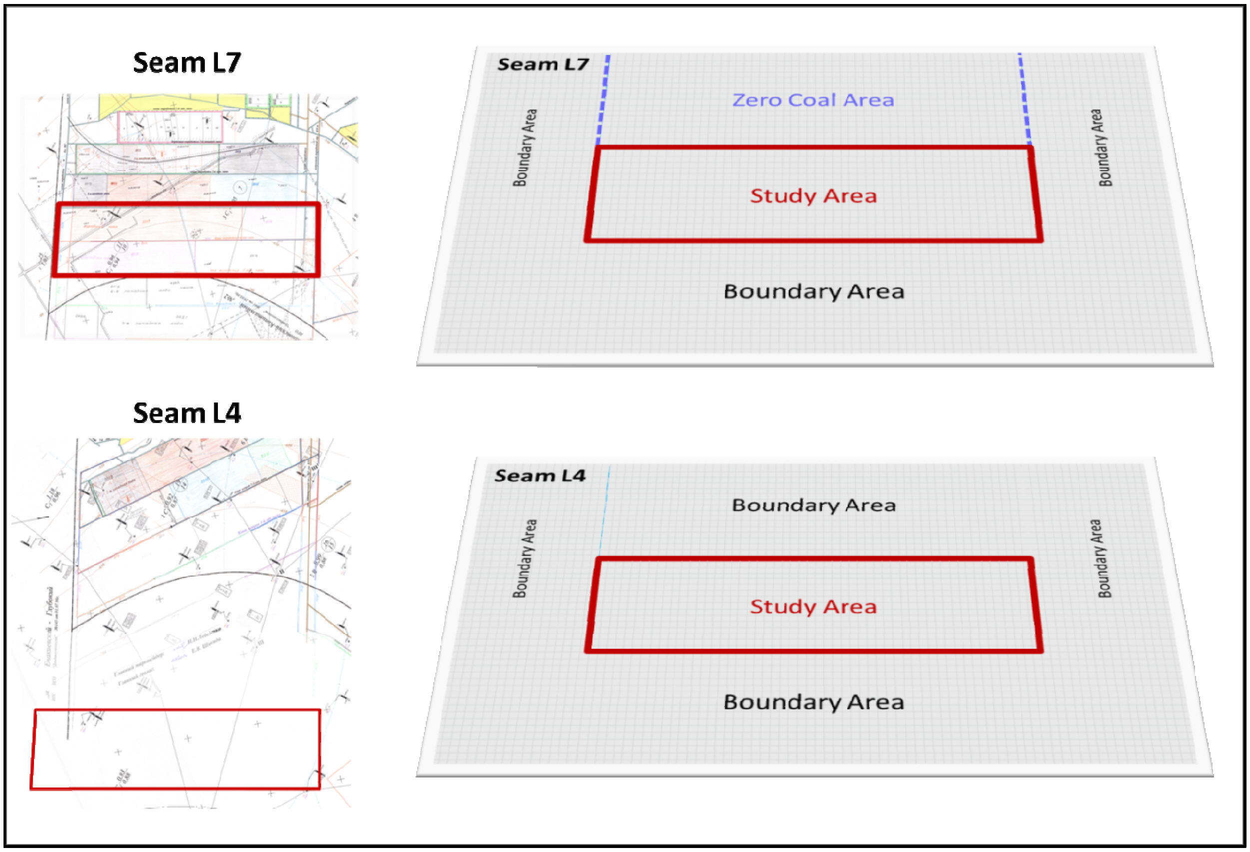

Figure 4-3: Model Layout of Study Area

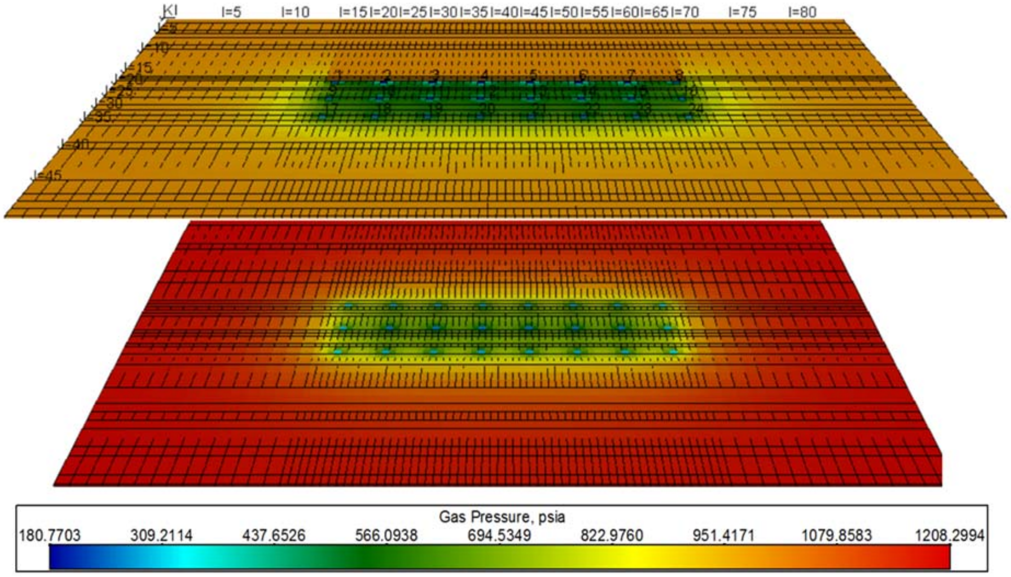

Figure 4-4: 3D Representation of Study Area as Shown in COMET3®

4.2.2 Model Preparation & Runs

The input data used to populate the reservoir model were obtained primarily from the geologic and reservoir data provided by DTEK. Any unknown reservoir parameters were obtained from analogs within the Donetsk Basin, when available, and from other coal formations that are most analogous to those found in the Donetsk Region, such as primarily Permo-Carboniferous local basins in neighboring countries like Poland and the Czech Republic. The input parameters used in the COMET3® reservoir simulation study are presented in Table 4-2. A brief discussion of the most important reservoir parameters is provided in this section of this report.

Parameter	Value	Units	Comments
Target Seam(s)	L7 & L4		
Coal Depth			
Seam L7	2297	ft	From DTEK mine maps
Seam L4	2789	ft	From DTEK mine maps
Coal Thickness			
Seam L7	3.28	ft	From DTEK data
Seam L4	3.28	ft	From DTEK data
Coal Density	1.6	g/cc	Analog
Pressure Gradient	0.433	psi/ft	Assumes hydrostatic gradient
Initial Reservoir Pressure			
Seam L7	995	psi	Calculated from midpoint depth of seam and pressure gradient
Seam L4	1208	psi	Calculated from midpoint depth of seam and pressure gradient
Desorption Pressure			
Seam L7	995	psi	Calculated from isotherm; assumes fully saturated conditions
Seam L4	1208	psi	Calculated from isotherm; assumes fully saturated conditions
Initial Water Saturation	50	%	Assumption
Permeability	0.1	mD	Analog; assumes Kx = Ky
Vertical Permeability	0	mD	Analog
Porosity	1	%	Analog
Sorption Time	24	days	Analog
Fracture Spacing	9	in	From DTEK data
Langmuir Volume - CH_4	865	scf/ton	Analog; synthetic isotherm
	43	scf/cf	Conversion for input into COMET
Langmuir Pressure - CH_4	339	psi	Analog; synthetic isotherm
Initial Gas Content			
Seam L7	645	scf/ton	Calculated from isotherm and initial reservoir pressure
Seam L4	675	scf/ton	Calculated from isotherm and initial reservoir pressure
Well Operation	120(40)	BWPD(psi)	Wells nodes pumped off at max pump rate of 120 BWPD to min BHP of 40 psi
Skin	-4		Assumes wells are hydraulically fractured

Table 4-2: COMET3® Reservoir Simulation Input Data, Komsomolets Donbassa Mine

4.2.2.1 Permeability

Coal bed permeability, as it applies to production of methane from coal seams, is a result of the natural cleat (fracture) system of the coal and consists of face cleats and butt cleats (see Figure 4-5). This natural cleat system is sometimes enhanced by natural fracturing caused by tectonic forces in the basin.

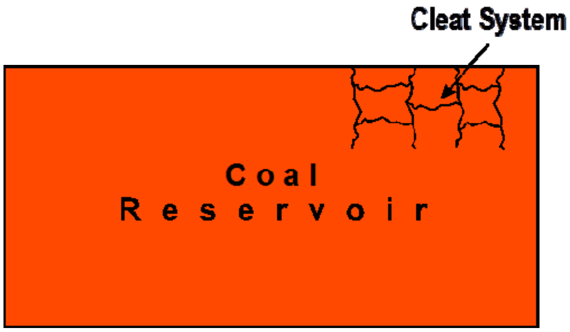

Figure 4-5: Natural Cleat Fracture System

The permeability resulting from the fracture systems in the coal is called "absolute permeability" and it is a critical input parameter for reservoir simulation studies. Absolute permeability data for the coal seams in the study area were not provided, but permeability measurements taken from exploration core holes in the Donetsk Basin were available. Based on extensive work conducted by numerous coal mines in the Donetsk region, the permeability of the coal seams appears to be low, on the order of 0.1 mD or less. This value is consistent with permeability measurements derived from other Eastern European coal basins which generally indicate permeability values of less than 1.0 mD in the coal seams. For the study area, horizontal permeability of 0.1 mD and vertical permeability of 0 mD were assumed.

4.2.2.2 Langmuir Volume and Pressure

Laboratory measured Langmuir volumes and pressures for the study area were not available. Therefore, it was necessary to construct a synthetic isotherm based on gas content data. Gas content has been measured in cores taken from many coal exploration core holes throughout the Donetsk Basin.[17] The gas content data in units of scf (standard cubic feet)/ton were plotted versus pressure. Pressure was derived by applying a pressure gradient of 0.433 psi/ft to the reported depth of each respective coal seam from the cores. A curve was then fit to the data points using the Langmuir equation, as shown below.

$$C = (VL \times P) / (PL + P)$$

Where:
C is gas concentration (scf/ton)
VL is Langmuir volume (scf/ton)
PL is Langmuir pressure (psia); and
P is pressure (psia)

The resulting Langmuir volume and pressure is 865 scf/ton (24.49 m3/ton) and 339 psia, respectively, and this synthetic isotherm was used in lieu of laboratory measured data. The isotherm derived by this methodology is shown in Figure 4-6.

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[17] Coal Mine Methane in Ukraine, Opportunities for Production and Investment in the Donetsk Coal Basin, U.S. Environmental Protection Agency, January 2001.

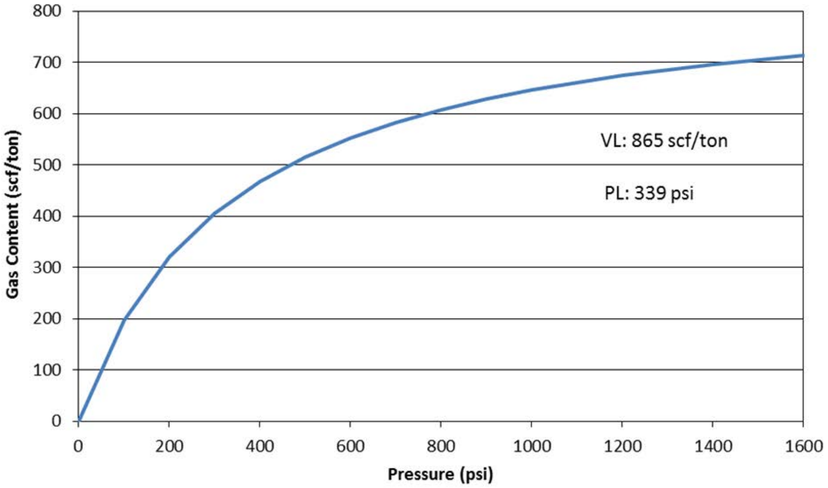

Figure 4-6: Methane Isotherm Used in Simulation

For the Langmuir volume, COMET3® utilizes units of standard cubic feet of gas per cubic foot (scf/cf) of bulk volume for coal. Assuming a coal density of 1.6 g/cc, the Langmuir volume of 865 scf/ton converts to 43.2 scf/cf for use in COMET3®.

4.2.2.3 Gas Content

Data provided by DTEK indicate initial gas contents of the coal seams ranging from 894 scf/ton to 1157 scf/ton. However, it is not clear whether the data provided are derived from gas desorption analysis or if they represent specific emissions (i.e., methane emitted per ton of coal mined). Gas content value of 645 scf/ton and 675 scf/ton were used in the simulation study for the L_7 and L_4 seams, respectively. These values are taken from the isotherm at the corresponding initial reservoir pressure of each seam.

4.2.2.4 Relative Permeability

The flow of gas and water through coal seams is governed by permeability, of which there are two types, depending on the amount of water in the cleats and pore spaces. When only one fluid exists in the pore space, the measured permeability is considered absolute permeability. Absolute permeability represents the maximum permeability of the cleat and natural fracture space in coals and in the pore space. However, once production begins and the pressure in the cleat system starts to decline due to the removal of water, gas is released from the coals into the cleat and natural fracture network. The introduction of gas into the cleat system results in multiple fluid phases (gas and water) in the pore space, and the transport of both fluids must be considered in order to accurately model production. To accomplish this, relative permeability functions are used in conjunction with specific permeability to determine the effective permeability of each fluid phase.

Relative permeability data for the coal of the study area and the Donetsk Basin in general was not available. Therefore, ARI used a relative permeability data set derived from a production history-matching effort on the Recopol[18] Coalbed Methane (CBM) project in Poland, which we believe to be a

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[18] Development of a field experiment of ECBM in the Upper Silesian coal basin of Poland (RECOPOL) - F. van Bergen, H.J.M. Pagnier, L.G.H. van der Meer, F.J.G. van den Belt and P.L.A. Winthaegen, Netherlands Institute of Applied Geoscience TNO (the Netherlands), P. Krzystolik, Central Mining Institute (Poland)

suitable analogue for the Donetsk Basin. The Recopol project was a pilot project designed to determine whether CO2 could be sequestered in the coal seams. Because of the research nature of the project, a tremendous amount of reservoir data was collected and is available for study. ARI believes that the Recopol data should be somewhat representative of Donetsk Basin coal seams as they are age-equivalent and have experienced similar tectonic histories. However, ARI recognizes that there could be variation between the two coal basins. Figure 4-7 is a graph of the relative permeability curves used in the reservoir simulation of the study area.

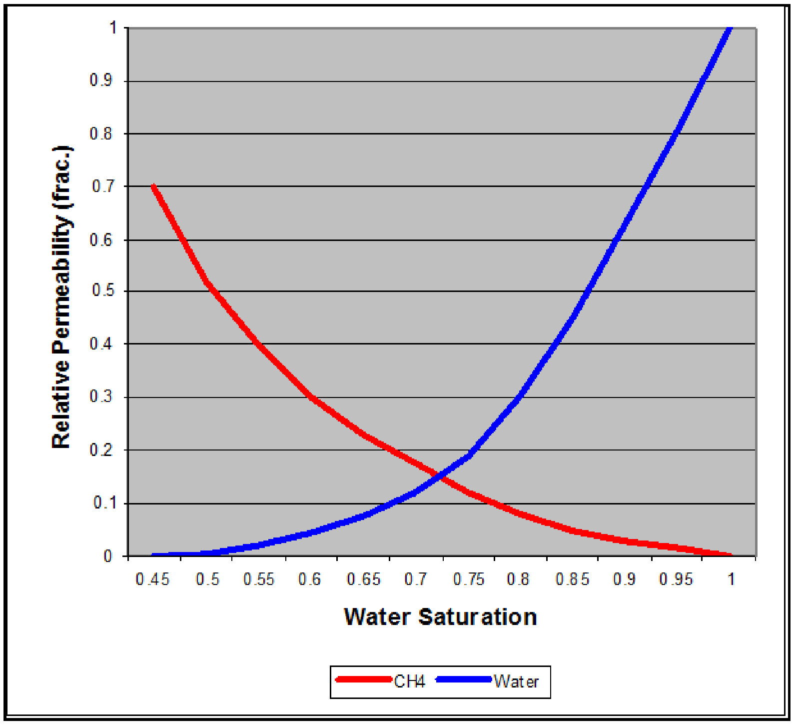

Figure 4-7: Relative Permeability Curve Used in Simulation

4.2.2.5 Reservoir Depth and Thickness

Reservoir depth and thickness for the prospective coal seams within the study area are highlighted in Table 4-3. The model assumes two individual zones, corresponding to the L_7 and L_4 seams, will be hydraulically fractured in each well. The coal thickness is taken to be 3.28 ft for each of the coal seams. The depth to the top of the coal reservoir was assumed to be 2297 ft and 2789 ft for the L_7 and L_4 seams, respectively, as determined from the mine maps provided by DTEK.

Komsomolets Donbassa Mine Reservoir Parameters

Layer (Seam)	Formation Mid Point (ft)	Formation Top (ft)	Formation Thick (ft)	Mid Point Formation Pressure (psia)
Layer 1 (L7)	2,298.3	2296.7	3.28	995.2
Layer2 (L4)	2,790.5	2788.9	3.28	1,208.3

Table 4-3: Depth and Thickness of Study Area at Komsomolets Donbassa Mine

4.2.2.6 Reservoir and Desorption Pressure

The initial reservoir pressure for each seam is calculated by multiplying the mid-point depth by the pressure gradient of 0.433 psi/ft to yield reservoir pressures of 995 psi and 1208 psi for the L_7 and L_4 seams, respectively (Table 4-3). Because the coal seams are assumed to be saturated with respect to gas, desorption pressure is set equal to the initial reservoir pressure for each seam.

4.2.2.7 Porosity and Initial Water Saturation

For the coal seams in the study area a porosity value of 1% and initial water saturation of 50% were used in the model. Since porosity values for the coal seams in the study area were not available, a value of 1% was used in the simulations, which corresponds to the porosity values determined through reservoir simulation history matching for the Recopol[19] project in Poland. The cleat and natural fracture system in the reservoir was assumed to be 50% water saturated. This assumption is based on the presence of active dewatering operations in conjunction with coal mining adjacent to the study area.

4.2.2.8 Sorption Time

Sorption time is defined as the length of time required for 63% of the gas in a sample to be desorbed. In this study a 24 day sorption time was used, which is consistent with the coals in the region. Production rate and cumulative production forecasts are typically relatively insensitive to sorption time.

4.2.2.9 Fracture Spacing

A fracture spacing of 9 inches was used in the simulations, which was derived from the average value of cleat spacing provided by DTEK. In COMET3®, fracture spacing is only used for calculation of diffusion coefficients for different shapes of matrix elements and it does not materially affect the simulation results.

4.2.2.10 Well Spacing

In the United States, where the natural gas industry is well developed, operators typically develop relatively tight sandstones (i.e., 1 mD or less) on spacing patterns of 60 ac (24 ha) or less. Spacing on the order of 40-80 ac (16 – 32 ha) is common, with some operators going down to spacing as tight as 10 ac (4 ha). Due to the low permeability present at the study area, the decision was made to run the reservoir simulations on three spacing cases of 60 ac, 40 ac, and 20 ac. Figure 4-8 shows the number and location of wells for each of the spacing cases as modeled.

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[19] Development of a field experiment of ECBM in the Upper Silesian coal basin of Poland (RECOPOL) - F. van Bergen, H.J.M. Pagnier, L.G.H. van der Meer, F.J.G. van den Belt and P.L.A. Winthaegen, Netherlands Institute of Applied Geoscience TNO (the Netherlands), P. Krzystolik, Central Mining Institute (Poland)

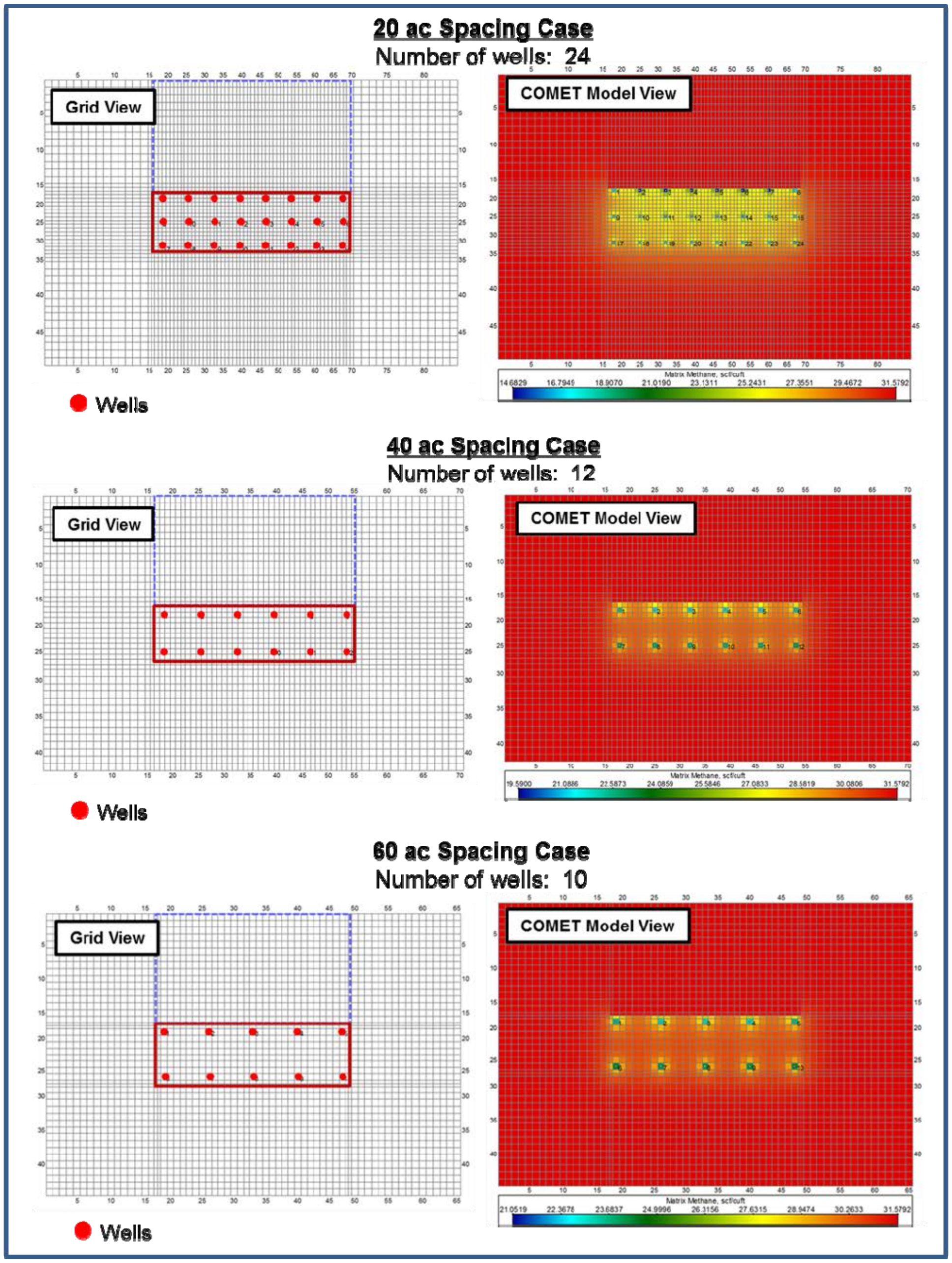

Figure 4-8: Illustration of Wells and Locations by Spacing Case

4.2.2.11 Completion and Stimulation

Vertical wells are projected to be drilled and completed to a depth of roughly 2800 ft (853 m) and completed in two stages corresponding to the L_7 and L_4 seams. Nearly all coal seams require some type of stimulation in order to initiate and sustain economic gas production. For modeling purposes, a skin value of -4 is assumed.

4.2.2.12 Well Operation

In the current study, wells were pumped at a maximum pump rate for each layer of 120 BWPD (barrels of water per day) to a minimum bottomhole pressure of 40 psi. In coal mine methane operations, low well pressure is required to achieve maximum gas content reduction. The wells were allowed to produce for a total of 10 years.

4.2.3 Pre-Drainage Model Results

As noted previously, three reservoir models were created to simulate gas production for the study area located at the Komsomolets Donbassa mine. Each of the models was run for a period of 10 years and the resulting gas production profiles and reduction in methane of the coal seams are highlighted in the following sections.

4.2.3.1 Gas Production Profiles for Study Area

Simulated gas production rate and cumulative gas production for the L_7 and L_4 seams for each of the three scenarios (20 acre spacing, 40 acre spacing, and 60 acre spacing) are shown in Figure 4-9 through Figure 4-14 and a summary of pre-drainage simulation results for the study area is presented in Table 4-4.

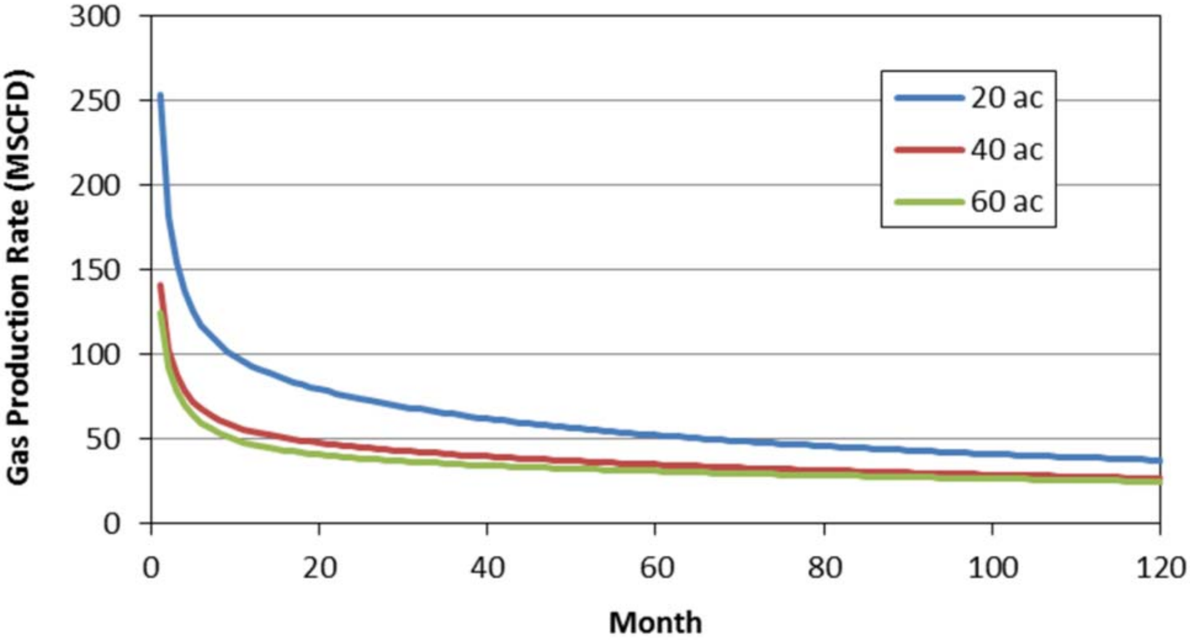

Figure 4-9: Simulated Gas Production Rate for the L_7 Seam

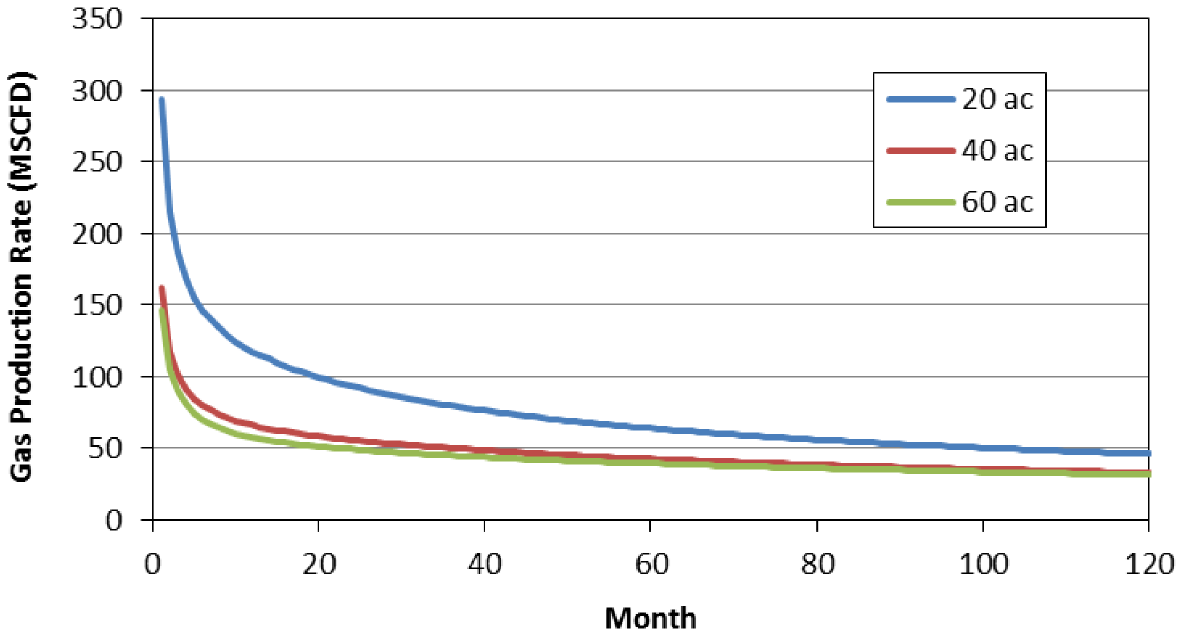

Figure 4-10: Simulated Gas Production Rate for the L_4 Seam

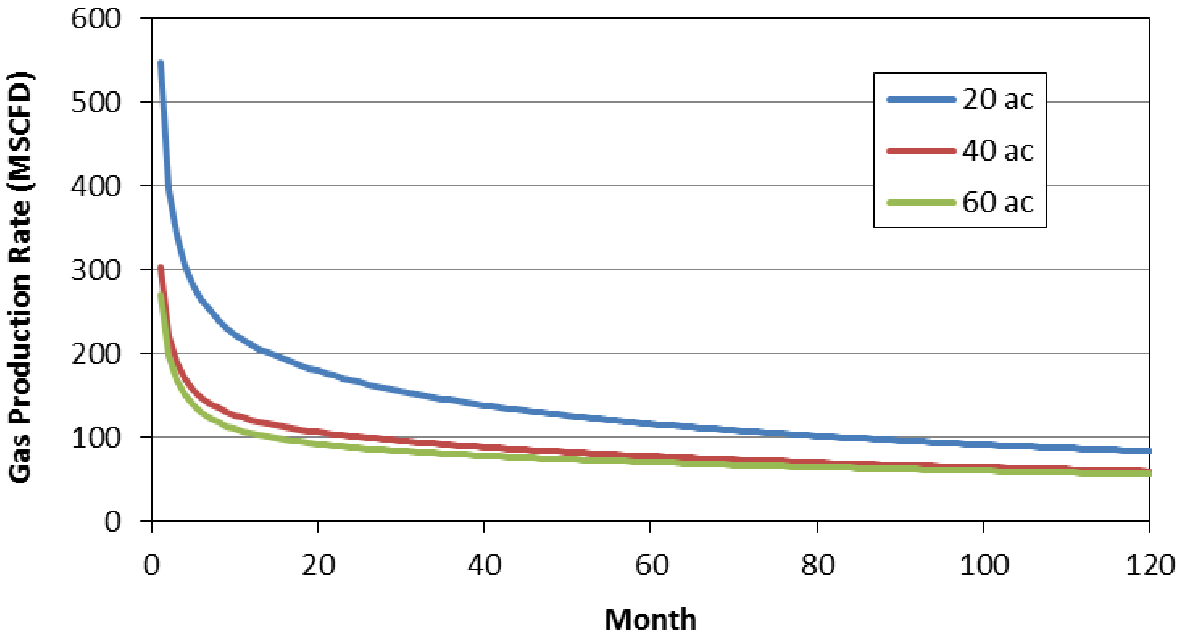

Figure 4-11: Simulated Gas Production Rate for the Study Area (L_7 & L_4 Seams Combined)

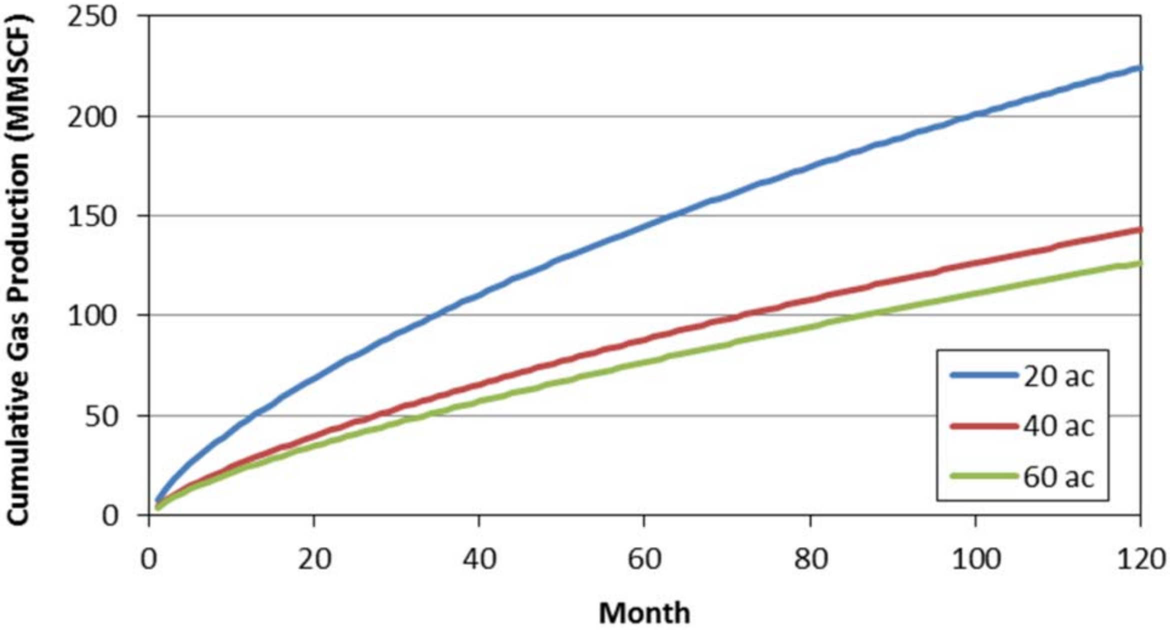

Figure 4-12: Simulated Cumulative Gas Production for the L_7 Seam

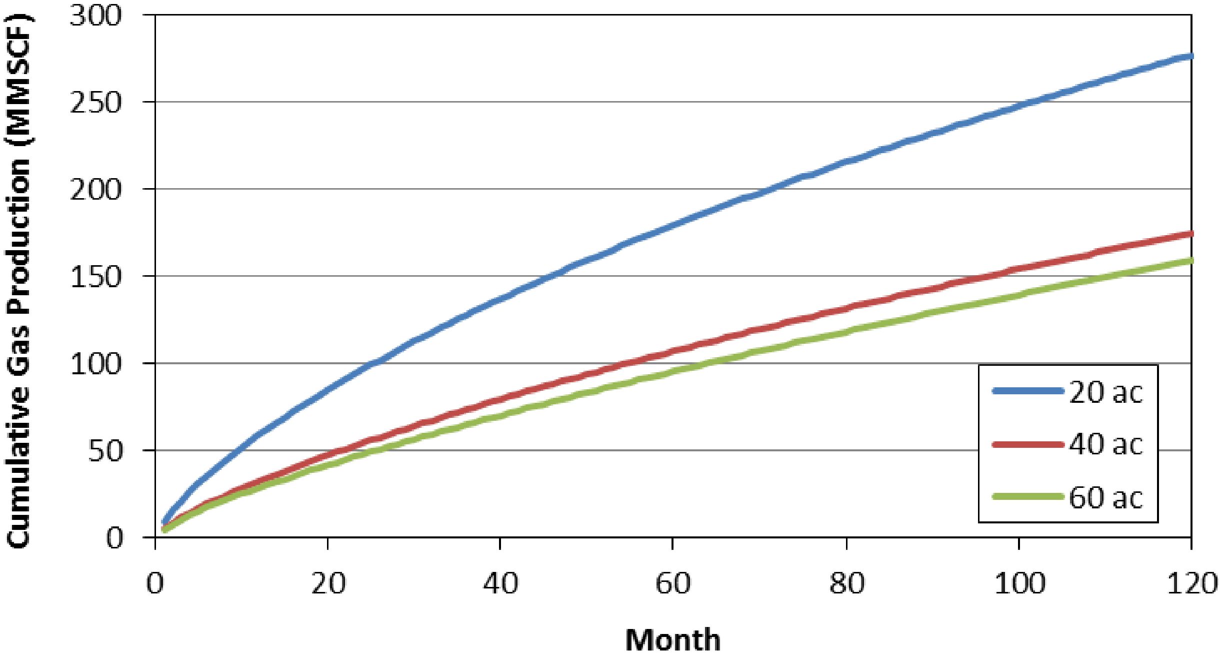

Figure 4-13: Simulated Cumulative Gas Production for the L_4 Seam

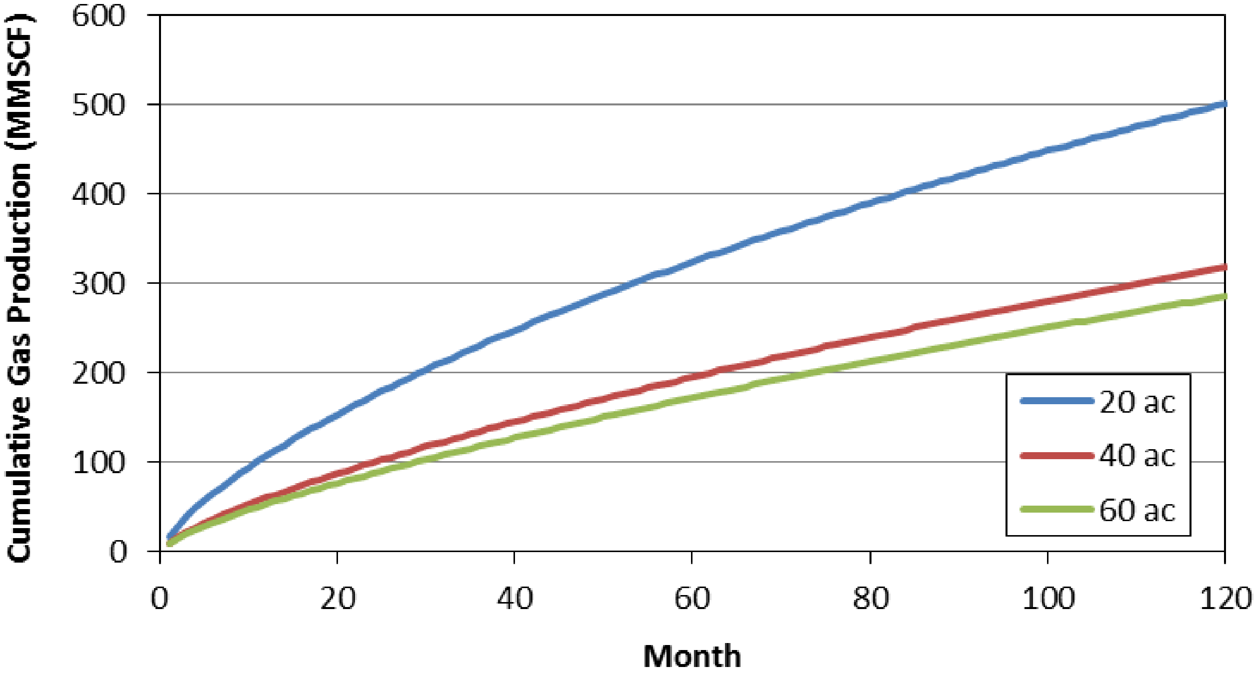

Figure 4-14: Simulated Cumulative Gas Production for the Study Area (L_7 & L_4 Seams Combined)

Well Spacing	ac	20	20	20	40	40	40	60	60	60
Producing Seam(s)		L7	L4	L7+L4	L7	L4	L7+L4	L7	L4	L7+L4
Total Wells Drilled	wells	24	24	24	12	12	12	10	10	10
Peak Gas Rate	MSCFD	254	293	547	141	163	304	125	146	271
Cumulative Gas Production										
1 Year	MMSCF	48	59	107	27	32	60	24	29	53
3 Year	MMSCF	103	128	231	61	74	134	53	65	118
5 Year	MMSCF	129	159	324	77	94	195	67	83	172
10 Year	MMSCF	224	277	502	143	175	318	127	159	286
Methane Concentration	%	98%	98%	98%	98%	98%	98%	98%	98%	98%
CH4-In-Place	BCF	1.40	1.47	2.87	1.40	1.47	2.87	1.40	1.47	2.87
Recovery Factor (10-Yr)	%	16%	18%	17%	10%	12%	11%	9%	11%	10%

Table 4-4: Summary of Pre-Drainage Simulation Results for the Study Area

As expected, the 20 ac (8 ha) spacing case produces the most gas due to the greater number of wells drilled within the study area. However, due to the low permeability of the coal seams in the study area, only 17% of the methane-in-place is recovered from both seams after 10 years of production.

4.2.3.2 Gas Content of Coal Seams in Study Area

According to mine data provided by DTEK, the L_7 and L_4 seams are the gassiest coal seams mined. DTEK currently employs gas drainage in the L_7 and L_4 seams using cross-measure boreholes drilled into the roof of the L_4 and L_7 seams. One of the benefits of pre-drainage is the reduction of methane content in the coal seams prior to mining. Figure 4-15 and Figure 4-16, show the simulated reduction in in-situ gas content for the L_7 and L_4 seam, respectively, within the Study Area.

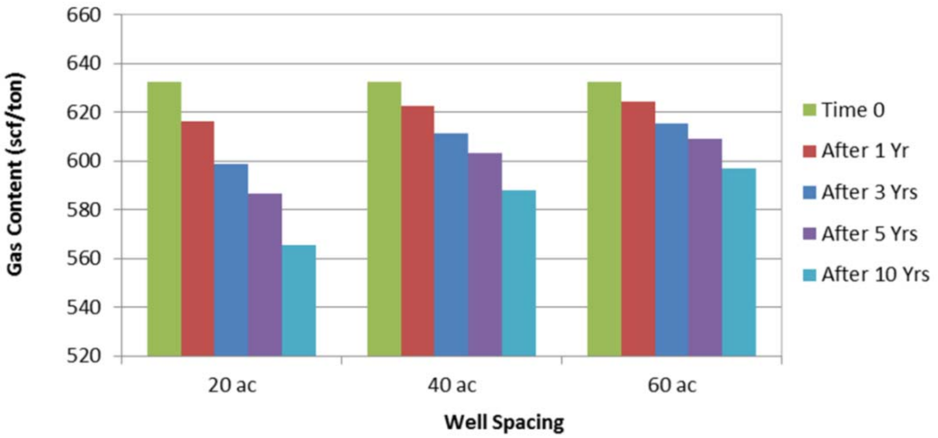

Figure 4-15: Simulated Reduction in In-Situ Gas Content for the L_7 Seam within the Study Area

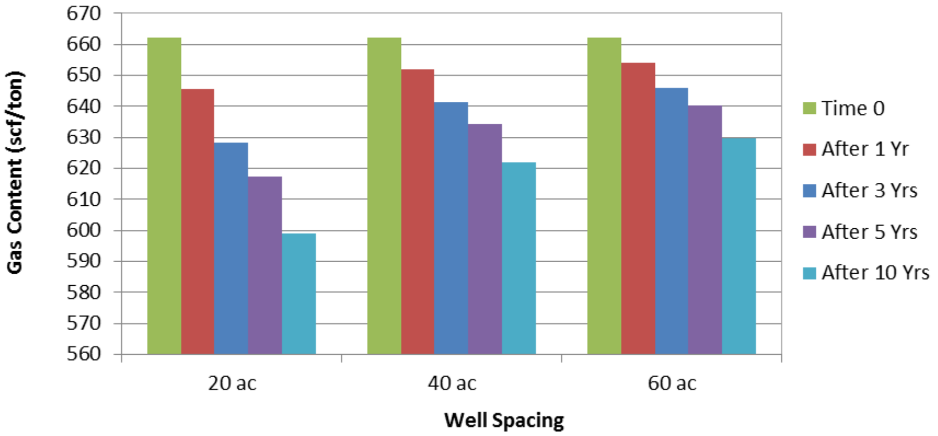

Figure 4-16: Simulated Reduction in In-Situ Gas Content for the L_4 Seam within the Study Area

Again, due to the closer well spacing, the greatest reduction in gas content within the coal seams is associated with the 20 ac (8 ha) spacing case. Despite 10 years of production, the amount of gas recovered is low, mainly due to the low permeability. Down-spacing of the wells or the use of long, in-seam wells drilled from underground could potentially increase the recovery percentages. However, any increase in gas recovery must be weighed against the added cost for a greater number, or more expensive, wells.

4.3 Modeling Surface Gob Gas Production

To model surface gob gas production from longwall panels at the Komsomolets Donbassa mine, the Methane Control and Prediction (MCP) model was used.[20]

4.3.1 Methane Control and Prediction Model

The Methane Control and Prediction (MCP) software suite was developed by the National Institute for Occupational Safety and Health / Office of Mine Safety and Health Research (NIOSH/OMSHR) to help address various issues related to methane control in longwall coal mines in the U.S. and other countries. This software suite contains numerous models designed to predict total and desorbable gas content coals, coal measure rock and mechanical properties, mine ventilation emissions, degasification system selection, roadway development methane inflow, and gob venthole production performance.

To model a longwall panel within the study area, the Gob Gas Venthole (GGV) Performance Prediction model for working depths exceeding 1,000 ft in active panels with advancing faces was used. This model is designed to predict GGV performance in order to maximize production rates, determine methane concentrations, improve mining safety, and produce pipeline-quality gas. The model provides output as GGV total gas production rate and methane concentration in the produced gas stream. The model output is based on venthole location, mining parameters, borehole location with respect to panel and surface terrain, and exhauster pressure. The specific input parameters used to model GGV production from a longwall panel in the study area are discussed in the following section of this report.

4.3.2 Gob Gas Model Preparation and Runs

Table 4-5 summarizes the input parameters for the GGV performance prediction model. Each parameter is discussed in more detail below[21]. A schematic diagram showing the GGV model layout is presented in Figure 4-17.

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[20] Methane Control and Prediction (MCP) Model, Version: 2.0. NIOSHTIC2 Number: 20038036. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, September 2010. Available http://www.cdc.gov/niosh/mining/works/coversheet1805.html

[21] Description of input parameters modified from Help Documentation for Methane Control and Prediction (MCP) Software Suite – Version 2.0 by Dr. C. Özgen Karacan.

Parameter	Value	Unit	Comment
Coal rank	LV-MV		Sub-Bit., HV, or LV-MV
Slotted casing length	300.6	ft	NIOSH MCP Model v2.0; mean value
Distance (from surface) to slotted casing top	2510.2	ft	Calculated
Face passed borehole location	variable	ft	Calculated
Face linear advance rate	12.5	ft/day	DTEK
Surface elevation	869.1	ft	DTEK
Average overburden	2854.5	ft	DTEK
Slotted casing diameter	9.1	inch	NIOSH MCP Model v2.0; mean value
Slotted casing distance from top of coal	43.7	ft	NIOSH MCP Model v2.0; mean value
Distance of GGV to tailgate	283	ft	Assumption
Distance of GGV from start of panel	variable	ft	Assumption
Panel length	5741.8	ft	DTEK
Panel width	820.3	ft	DTEK
Atmospheric pressure	26.2	inch Hg	NIOSH MCP Model v2.0; mean value
	12.9	psi	Conversion
Average exhauster vacuum	-49.3	inch water	NIOSH MCP Model v2.0; mean value
	-1.8	psi	Conversion
Gas content of overlying formations	0	scf/ton	Assumes no overlying coal
Surface subsidence	3.1	ft	NIOSH MCP Model v2.0; mean value

Table 4-5: Input Parameters for Gob Gas Venthole Performance Prediction Model

4.3.2.1 Coal Rank

Coal rank represents the level of maturation reached in a coal seam and generally increases with increasing depth. For modeling purposes, a coal rank of low-volatile bituminous was used[22]. Most longwall mines, as well as most commercial coalbed methane projects, operate in bituminous coalbeds. The coals in the subbituminous to low-volatile bituminous range usually provide high gas content and natural permeability. Mining coals of this rank, particularly medium- to low-volatile bituminous coals, potentially liberate high amounts of gas into the ventilation system.

4.3.2.2 Slotted Casing Length

Vertical gob wells are drilled in advance of mining to a depth above the working coal seam. Gob wells are normally cased and cemented to a point just above the uppermost coal seam or gas-bearing stratum believed capable of liberating gas as a result of longwall mining. The lower portion of the well is either left uncased as an open hole completion, or is lined with slotted casing to maintain borehole integrity while allowing gas flow to the well.[23] The slotted liner is not cemented in place, but hung from the bottom of the casing. A slotted casing length of 300.6 ft (91.6 m) was assumed in the model. This value is the mean value from the database employed in developing the MCP model, which is assumed to be representative of conditions in the study area.

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[22] Coal Mine Methane in Ukraine: Opportunities for Production and Investment in the Donetsk Coal Basin. Prepared for U.S. Environmental Protection Agency (EPA) by Partnership for Energy and Environmental Reform (PEER), January 2001.

[23] U.S. Environmental Protection Agency (USEPA). Coal Mine Methane Recovery: A Primer. EPA-430-R-09-013 prepared under Task Orders No. 13 and 18 of USEPA Contract EP-W-05-067 by Advanced Resources, Arlington, USA, September 2009.

4.3.2.3 Distance (From Surface) to Slotted Casing Top

For modeling purposes, the distance from the surface to the top of the slotted casing was input at 2510.2 ft (765.1 m). This value was calculated by subtracting the slotted casing length (300.6 ft) and slotted casing distance from the top of the coal seam (43.7 ft) from the average overburden (2854.5 ft).

4.3.2.4 Face Passed Borehole Location

GGV production begins only after the longwall face advances past the borehole location. The distance between each borehole and the face will vary depending on the well location with respect to the start of the panel and the face linear advance rate (see below). As a result, the face passed borehole location input value was calculated for each well on a monthly basis and then input into the model as needed.

4.3.2.5 Face Linear Advance Rate

GGV production performance during longwall mining is closely related to face-advance rate, which enhances fractures and increases permeability due to dynamic deformation and subsidence. It is usually the case that higher face-advance rates result in lower hydraulic conductivity in the fractures, suggesting a possible impact on venthole performance. Face advance also creates an extensively fractured methane reservoir from which the gob-gas ventholes can produce gas. A faster face-advance rate causes a larger percentage of the panel to subside and creates a larger fractured reservoir within a given time period compared to a slower face-advance rate. A daily face-advance rate of 12.5 ft (3.8 m) per day was used in the GGV model, which was provided by DTEK.

4.3.2.6 Surface Elevation

The surface elevation of each GGV was assumed to be 869.1 ft, (265 m) as provided by DTEK.

4.3.2.7 Average Overburden

The depth of the mined coal seam or the overburden to the longwall mine affects the methane content of coal seams and the disturbances created in the overlying strata during mining. For coals of the same rank, gas content generally increases with increasing depth. Increasing gas content usually increases the gas emissions in the mine. Overburden depth also impacts the degree of caving in the overlying strata as the longwall panel advances. If panel width is greater than the overburden, the panel is considered "supercritical," and thus the caving will be more complete after mining compared to a situation where the panel width is less than overburden depth. This situation may potentially affect the methane reservoir and permeability pathways in the overlying strata and may promote reconsideration of some of the design parameters for gob vent boreholes. The value used in the GGV model for overburden depth is 2854.5 ft (870 m) as provided by DTEK.

4.3.2.8 Slotted Casing Diameter

Casing diameter is used in calculating GGV performances. Generally, increasing the gob gas venthole casing diameter increased cumulative methane production from the subsided strata. A casing diameter of 9.1 inches (23.1 cm) was entered into the model. This is the mean value from the database employed in developing the MCP model, which is assumed to be representative of conditions in the study area.

4.3.2.9 Slotted Casing Distance from Top of Coal

Casing-setting depth, with respect to the top of the mined coal seam, may play an important role in the amount and concentration of methane captured. A distance of 43.7 ft (13.3 m) from the bottom of the slotted casing to the top of the coalbed was used as an input in the model. This is the mean value from the database employed in developing the MCP model, which is assumed to be representative of conditions in the study area.

4.3.2.10 Distance of GGV to Tailgate

According to the MCP model documentation, the location of a the GGV with respect to the panel tailgate is generally calculated based on the subsidence profiles that are expected during mining operations in order to locate the ventholes in tension zones, where most fractures are open, to ensure maximum production from the fractured strata instead of in the centerline location which is in compression due to subsidence and recompaction of the longwall gob. As a result, the GGVs were assumed to be 283 ft (86.3 m) from the tailgate.

4.3.2.11 Distance of GGV from Start of Panel

According to the MCP model documentation, the location of the GGVs with respect to the panel start is calculated based on the subsidence profiles expected during mining operations in order to locate the ventholes in tension zones. The distances from the start of the panels and the distances between the ventholes along the panel are based on maximizing productivity, on the expected drainage radius of the ventholes, and on the emissions in the mines. In general, the holes on the ends of the panels (especially the ones at the start end) are the highest-quantity and longest-duration producers. This is attributed to enhanced mining-induced fractures on the ends of the panels where the overburden strata are in tension on three sides due to the support of the surrounding pillars. As shown in Figure 4-17, the location of the first GGV is assumed to be 283 ft (86.3 m) from the start of the longwall panel, and the distance between each subsequent GGV is assumed to be 1320 ft (402 m), which corresponds to a 40 ac (16 ha) well spacing pattern.

4.3.2.12 Panel Length and Width

The increasing size of longwall panels (i.e., width and length) usually affects coal production and methane emissions due to the exposure of the mining environment to wider faces and to a larger area of fractured strata. If not captured effectively, additional gas emissions from a larger area of fractured formations can enter the mining environment and may create unsafe operating conditions. Thus, as the size of the panel increases, the expected increase in emissions must be controlled by effective degasification methods. The size of the panel as modeled is 5741.8 ft (1750 m) in length by 820.3 ft (250 m) in width. The panel dimensions were provided by DTEK.

4.3.2.13 Atmospheric Pressure

It is known that atmospheric pressure is an important factor for gas emission and production, especially from uncovered sources (i.e., when the gas source is in direct communication with the atmosphere). For uncovered gas sources, there may be a strong inverse relationship between barometric pressure and methane emissions. However, this situation can be very different for closed underground sources because they will not have direct contact with the atmosphere. Due to the absence of this data for the study area, atmospheric pressure was assumed to be 26.2 inch-HG for modeling purposes. This is the mean value from the database employed in developing the MCP model, which is assumed to be representative of conditions in the study area.

4.3.2.14 Average Exhauster Vacuum

A vacuum applied to the gob gas wellheads stimulates methane migration into the ventholes from the surrounding strata and prevents flow reversals into the mine. However, this advantage may be lost over time as there is a tendency for mine air to be drawn into the gob area and dilute the methane. A higher suction pressure has a positive but relatively small effect on drawing gas from overlying strata into the venthole. There is a limit to the amount by which the capture efficiency of a venthole can be increased by means of higher vacuum pressures. Higher suction pressure causes higher air leakage into the well and reduces the purity of methane. For the GGV model, an exhauster vacuum pressure of -49.3 inch-water was assumed. This is the mean value from the database employed in developing the MCP model, which is assumed to be representative of conditions in the study area.

4.3.2.15 Gas content of Overlying Formations

Major coal seams within the slotted interval can contribute to the amount and concentration of methane captured. In the current study, no overlying coal seams were assumed to be present; therefore, the gas content of overlying formations was input as 0 scf/ton into the model.

4.3.216 Surface Subsidence

Coal seam extraction can lead to subsidence at the surface. While all the seams between a longwall and the surface will be disturbed, only gas within a de-stressed arch enters the workings. For modeling purposes, surface subsidence was assumed to be 3.1 ft (1 meter). This is the mean value from the database employed in developing the MCP model, which is assumed to be representative of conditions in the study area.

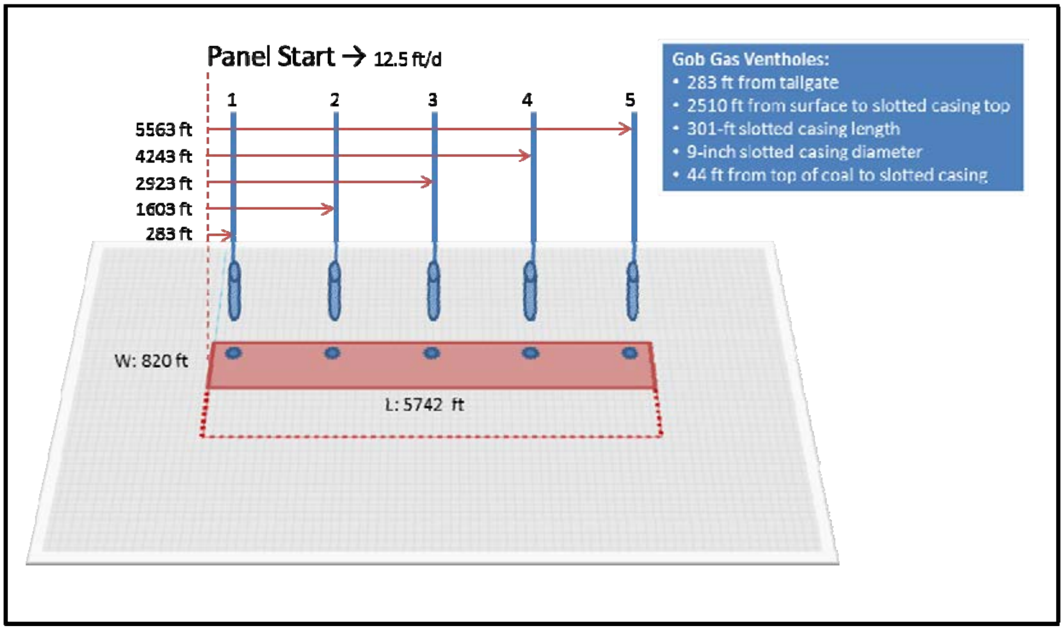

Figure 4-17: Schematic Diagram of Gob Model Layout

4.3.3 Gob Gas Model Results

With a linear face advance rate of 12.5 ft/d and a longwall panel length of 5742 ft, a single panel can be mined through in 460 days, or roughly 15 months. A series of gob gas model runs were made for each of the five proposed GGV locations. For each well, total gas production rate (SCFM) and methane concentration (%CH_4) were calculated on a monthly basis according to the borehole location with respect to the position of the advancing face. Since gob wells can continue producing even after the panel over which they are located is mine through, the life of each well was assumed to be 18 months. In practice, the life of a GGV is largely determined by the gas volume and methane concentration of the produced gas.

The gob gas production profile for a single panel extends beyond the 15 month mining period to 32 months in total. According to Karacan[24], comparison of mining and after-mining periods of production generally shows that the production rate decline is faster after the corresponding panel is completed. As a result, production for each well beyond active mining of the panel was assumed to decline at twice the rate experienced during the final month of active mining; methane concentration of produced gas from each well was assumed to stay constant during post-mining production. The gob gas production rates by well, as modeled for a single longwall panel, are shown in Figure 4-18, while gob gas methane concentration is presented in Figure 4-19.

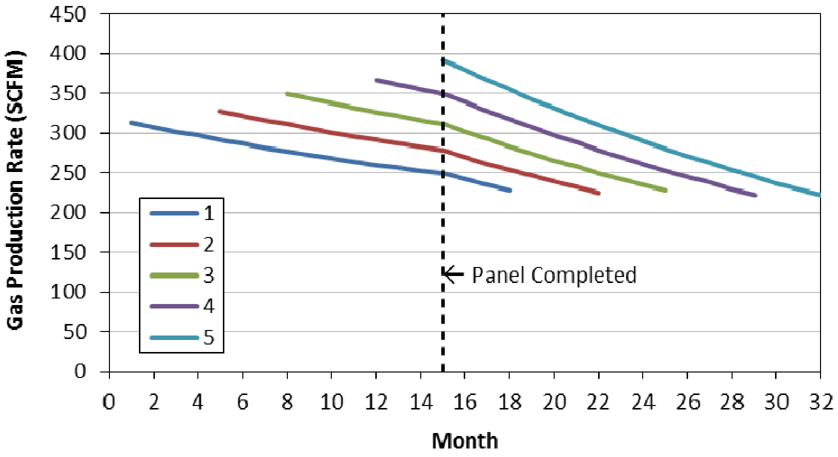

Figure 4-18: Gob Gas Production Rate by Well for Single Longwall Panel

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[24] Forecasting gob gas venthole production performances using intelligent computing methods for optimum methane control in longwall coal mines by C. Özgen Karacan. National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Research Laboratory, Pittsburgh, PA 15236, USA

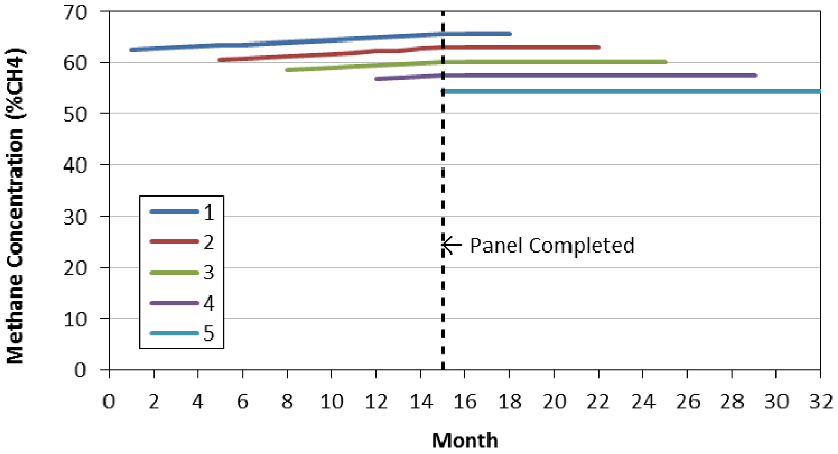

Figure 4-19: Gob Gas Methane Concentration by Well for Single Longwall Panel

As observed from the data in Figure 4-18, each borehole initially produces at a higher gas rate and then declines as time increases. The first boreholes in each panel typically produce the highest methane percentage, which can be observed in Figure 4-19.

4.4 Comparison of Pre-Drainage and Gob Wells

The results from modeling pre-drainage and gob wells can be compared in order to determine the most effective degasification strategy for the study area. As noted previously, the study area is comprised of two longwall panels. In order to perform an accurate comparison, the gob model results were extrapolated to include production from a second longwall panel with mining initiated in month 16, allowing one month for longwall equipment to be moved to the second panel. Figure 4-20 presents gas production rates and cumulative gas production data for both pre-drainage and gob gas wells for the study area. The production profiles for pre-drainage are the same as those presented in section 4.2.3, but they are provided again here for ease of comparison. A tabular summary of the data can be found in Table 4-6.

The results show gob gas production volumes are greater than any of the pre-drainage cases. Gob wells produce more than two times as much methane from the study area as compared to the best pre-drainage case (i.e., 20 acre spacing case) despite using less than half as many wells.

When comparing gob gas production to the results from the 60 acre pre-drainage case (10 wells each), the difference in methane production is even more pronounced with methane production from gob wells over four times that of pre-drainage wells. The recovery factor of the in-place methane resource in the study area ranges from 10% to 17% for pre-drainage, while gob gas recovery exceeds 90%.

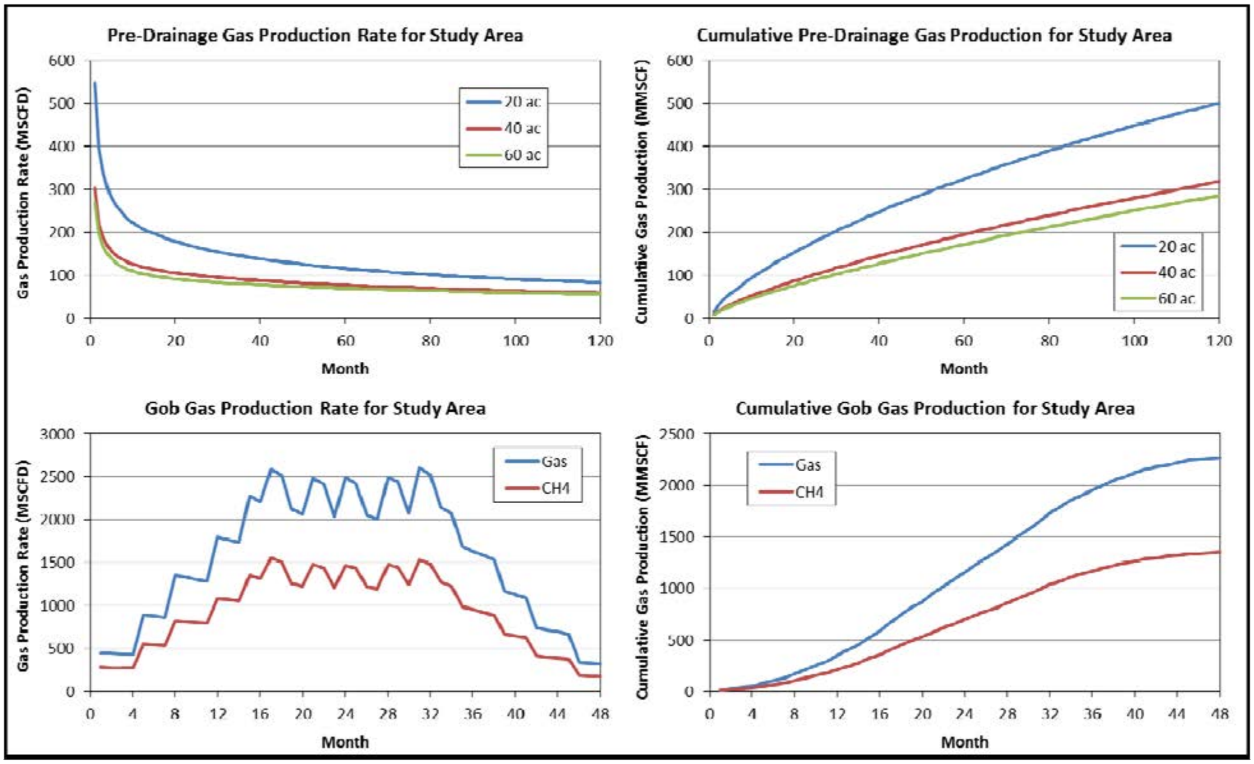

Figure 4-20: Comparison of Pre-Drainage and Gob Gas Modeling Results for the Study Area

Production Case		PD-20ac	PD-40ac	PD-60ac	Gob
Producing Seam(s)		L7+L4	L7+L4	L7+L4	L7
Total Wells Drilled	wells	24	12	10	10
Peak Gas Rate	MSCFD	547	304	271	2607
Cumulative Gas Production	MMSCF	502	318	286	2270
CH4 Concentration	%	98%	98%	98%	59%
Cumulative CH4 Production	MMSCF	491	311	280	1349
CH4-In-Place	BCF	2.87	2.87	2.87	1.40
Recovery Factor	%	17%	11%	10%	96%

Table 4-6: Summary of Pre-Drainage and Gob Gas Modeling Results for the Study Area

5.0 Market Information

5.1 Energy Commodity Markets

The primary markets available for a CMM utilization project at the Komsomolets Donbassa mine are power generation using internal combustion engines, flaring and boilers. DTEK is specifically targeting power generation for this project.

In addition to these end uses, vehicle fuel in the form of liquefied natural gas (LNG) or compressed natural gas (CNG) would also be technically feasible with a successful pre-drainage program, but the capital and operating costs are high making such projects difficult to justify economically. Sale to natural gas pipelines is neither a technically nor economically viable option.

With respect to electricity markets, the Mine's power demand is 24.9 MW and total electricity consumption is roughly 270 million kWh, providing ample opportunity to offset power purchases with on-site generated electricity from CMM. Although the CMM-based power could be used on-site, DTEK would like to sell the power to the electricity grid.

As of July 2013 the average rate of electricity at the mine is UAH 0.7952/kWh (net of VAT), equivalent to US$0.0978/kWh at current exchange rates. The mine does not pay a standby (demand) charge, but does have a rate structure where it pays differentiated rates depending on the time of day:

Time of Day	Rate (UAH)	Rate (USD)
Peak	UAH 1.33594/kWh	$ 0.1642/kWh
s/Peak	UAH 0.81110/kWh	$0.0997/kWh
Night	UAH 0.27832/kWh	$0.0342/kWh

*all rates net of VAT

5.2 Environmental Attributes

Markets for environmental attributes include carbon markets such as the European Union Emissions Trading Scheme and the project-based emissions trading under the Kyoto Protocol, renewable energy markets, green energy markets, and feed-in-tariffs and other subsidies.

Carbon markets today are generally not viable. Although Ukraine has 13 CMM projects registered as Joint Implementation projects with an additional two projects being considered for registration, the Kyoto markets have effectively crashed with offsets selling for under US$1 per metric tonne of CO_2 equivalent, well below transaction and other administrative costs. At this time, there is no indication that prices in the Kyoto markets will shift significantly; therefore, a value for the carbon is unlikely to drive project development.

5.3 Legislative and Regulatory Environment

CMM capture and use is a priority for the Ukrainian central government and the Donetsk Regional State Administration, but some barriers continue to present:

- All mineral rights belong to the State in Ukraine, although they are leased to private operators. Coal production licenses automatically authorize coal producers to extract and emit or utilize CMM, but there is no easy transfer of ownership.[25] In addition, details on mineral reserves and resources may be considered state secrets in some cases, making it difficult for non-state actors to obtain necessary data. In addition, the release of this information could have serious legal consequences for those responsible for distributing such information.
- In June 2009, coal mine legislation was enacted that provides a tax exemption for Ukrainian CMM projects. Starting in 2010 and continuing through January 2020, profits from the production and use of CMM earned by Ukrainian enterprises will no longer be subject to taxation.[26] However, there have been some changes to the legislation recently and the impact of these changes is not clear. The impact of a separate piece of legislation taxing methane emissions from mines and its impact on CMM projects is also not clear.
- The Verkhovna Rada passed a law on green electricity tariffs in 2008 that provides incentives for electricity produced from alternative sources but there is no language that specifically applies to CMM.

6.0 Opportunities for Gas Use

With additional gas availability expected in the reserve addition, DTEK has stated its intent to use the gas for power production. The KD mine has already installed two CMM-fired boilers and two flares, each with 5 MW_{th} flaring capacity, on-site. The flares and boilers are both located at ventilation shaft #3, and are part of a Clean Development Mechanism (CEM) project registered by the United Nation's CDM Executive Board in 2008. Through the end of June 2012, 416,891 carbon credits from gas utilization/destruction at the KD mine in the form of Emission Reduction Units (ERUs) were issued by the Clean Development Mechanism Executive Board (CDM EB) of the United Nations Framework Convention on Climate Change. The flares are not currently operational, however, due to a lack of demand and very low prices for ERUs. Still, the boilers and flares stand ready to accept CMM for use. Although revenues from carbon markets are not expected to play a major role in project economics in the near term, greenhouse gas emissions should still be monitored. In addition to the flares and boilers, DTEK is also planning a 3 MW power project based on existing CMM production using Cummins engines. The project is being co-developed for the KD Mine in partnership with a project developer. The project would be located at Shaft #3 also.

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[25] Evans, Meredydd and Volha Roshchanka, Pacific Northwest National Laboratory *Energizing the Electricity Market for Coal Mine Methane*. March 2013. GMI Expo. Vancouver, Canada

[26] Global Methane Initiative "Ukraine Country Profile"

Based on ARI’s gas supply forecasts, the Mine could be capable of producing as much as 4.6 MW from the new mining area. In addition, the project should also be integrated with at least one flare so that the flare can destroy excess methane or methane emissions during project construction or when the power plant is idled for maintenance.

7.0 Project Economics and Economic Analysis

7.1 Project Area and Development Scenario

In order to assess the economic viability of the two degasification options presented throughout this report, it is necessary to define the project scope and schedule. Based on the mine maps provided by DTEK, a total of four longwall panels (two included in the original study area) are scheduled to be mined over a five-year period beginning in 2017. These are the only longwall panels identified on the mine maps provided, and it is assumed the project area will be limited to these four panels only. Figure 7-1 is a map showing the proposed project area and the mine progression by year (panels are named A through D). With four panels mined over five years, it is assumed that each panel takes 1.25 years (15 months) to mine. Delineation work for the L_7 seam is currently being conducted and is expected to be completed by the end of 2015. Coal production is scheduled to begin in 2017 and continue through the end of 2021. The specifics for the proposed pre-drainage and the gob gas projects are detailed in the next two sections of this report.

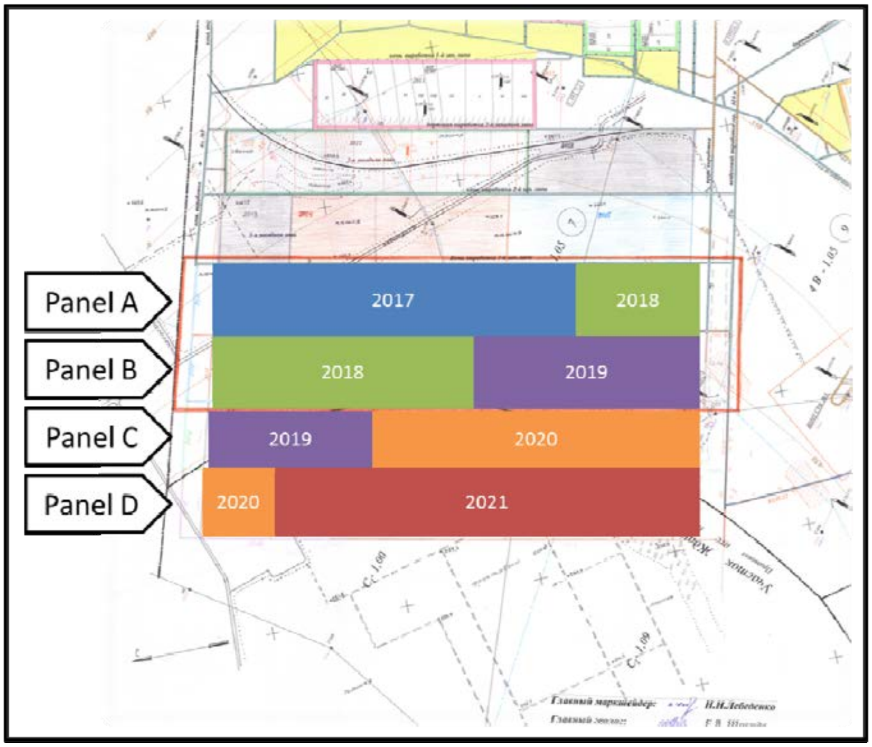


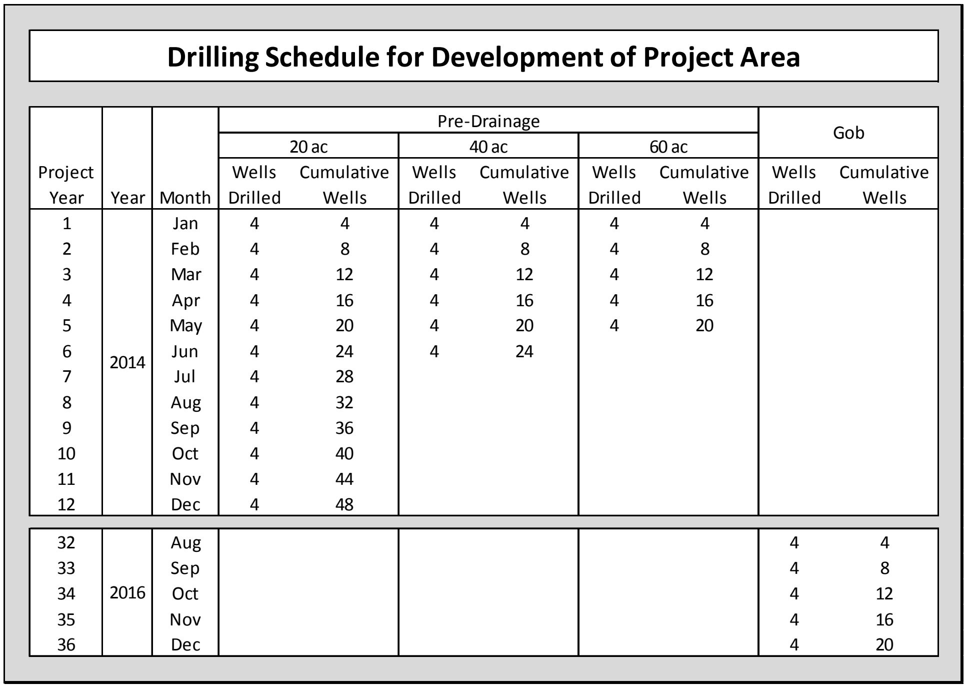
Figure 7-1: Mine Map Showing Project Area and Mine Progression by Year

7.1.1 Pre-Drainage Project Development

The proposed pre-drainage project will target both the L_7 and L_4 seams with vertical boreholes drilled from the surface. It is assumed drilling of wells and gas production commences in January of 2014 at a rate of four wells per month (see Table 7-1). Wells will continue to produce until each well is shut-in as the L_7 seam is mined through, eliminating pre-drainage from seams below the L_7 from that point forward. The project will conclude when the last panel is mined through at the end of 2021; total project life is 96 months from project start.

7.1.2 Gob Gas Borehole Project Development

The proposed gob gas project will target the L_7 seam only. Gob gas boreholes will be drilled from the surface to just above the coal seam. Since gas production from gob wells is initiated only after the longwall face advances past the borehole, it is assumed gob gas production will not begin until 2017 corresponding to the start of mining. However, the gob wells are assumed to be drilled prior to the start of mining. Utilizing the same drilling schedule as before, four wells per month, drilling will start five years prior to mining (see Table 7-1). Each panel is assumed to take 15 months to mine, with each well producing for a total of 18 months. Since the life of some wells extends beyond the period of active mining, the project will not conclude until the end of May 2023; total project life is 113 months from project start.



Drilling Schedule for Development of Project Area

			Pre-Drainage						Gob	
			20 ac		40 ac		60 ac			
Project Year	Year	Month	Wells Drilled	Cumulative Wells	Wells Drilled	Cumulative Wells	Wells Drilled	Cumulative Wells	Wells Drilled	Cumulative Wells
1	2014	Jan	4	4	4	4	4	4		
2		Feb	4	8	4	8	4	8		
3		Mar	4	12	4	12	4	12		
4		Apr	4	16	4	16	4	16		
5		May	4	20	4	20	4	20		
6		Jun	4	24	4	24				
7		Jul	4	28						
8		Aug	4	32						
9		Sep	4	36						
10		Oct	4	40						
11		Nov	4	44						
12		Dec	4	48						
32	2016	Aug							4	4
33		Sep							4	8
34		Oct							4	12
35		Nov							4	16
36		Dec							4	20

Table 7-1: Drilling Schedule for Development of Project Area

7.2 Gas Production Forecast

Gas production forecasts were developed using type curves for pre-drainage wells as shown in Figure 7-2. Figure 7-3 shows the total gas production rate for the production area and the number of pre-drainage wells. Figure 7-4 provides the simulated production from gob wells and the number of operating gob wells during the production period. Table 7-2 presents a cumulative production forecast for the production area using 20 acre, 40 acre and 60 acre spacings in the L_4 and L_7 seams and roughly 60 acre spacing in the L_7 gob. The results reflect the findings for effectiveness of pre-drainage wells versus gob wells for the study area. Gob wells could reduce gas in place by as much as 96% (according to the MCP model) compared with 5%-11% employing pre-drainage.

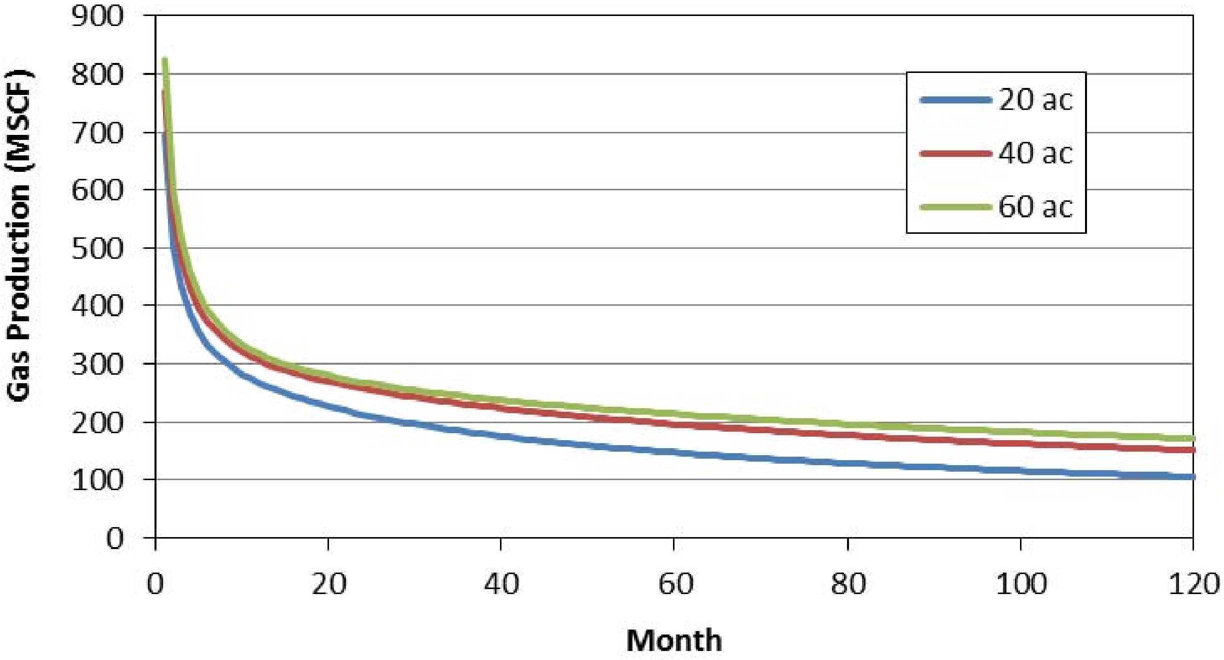


Figure 7-2: Single-Well Type Curves Used to Forecast Pre-Drainage Gas Production for the Project Area

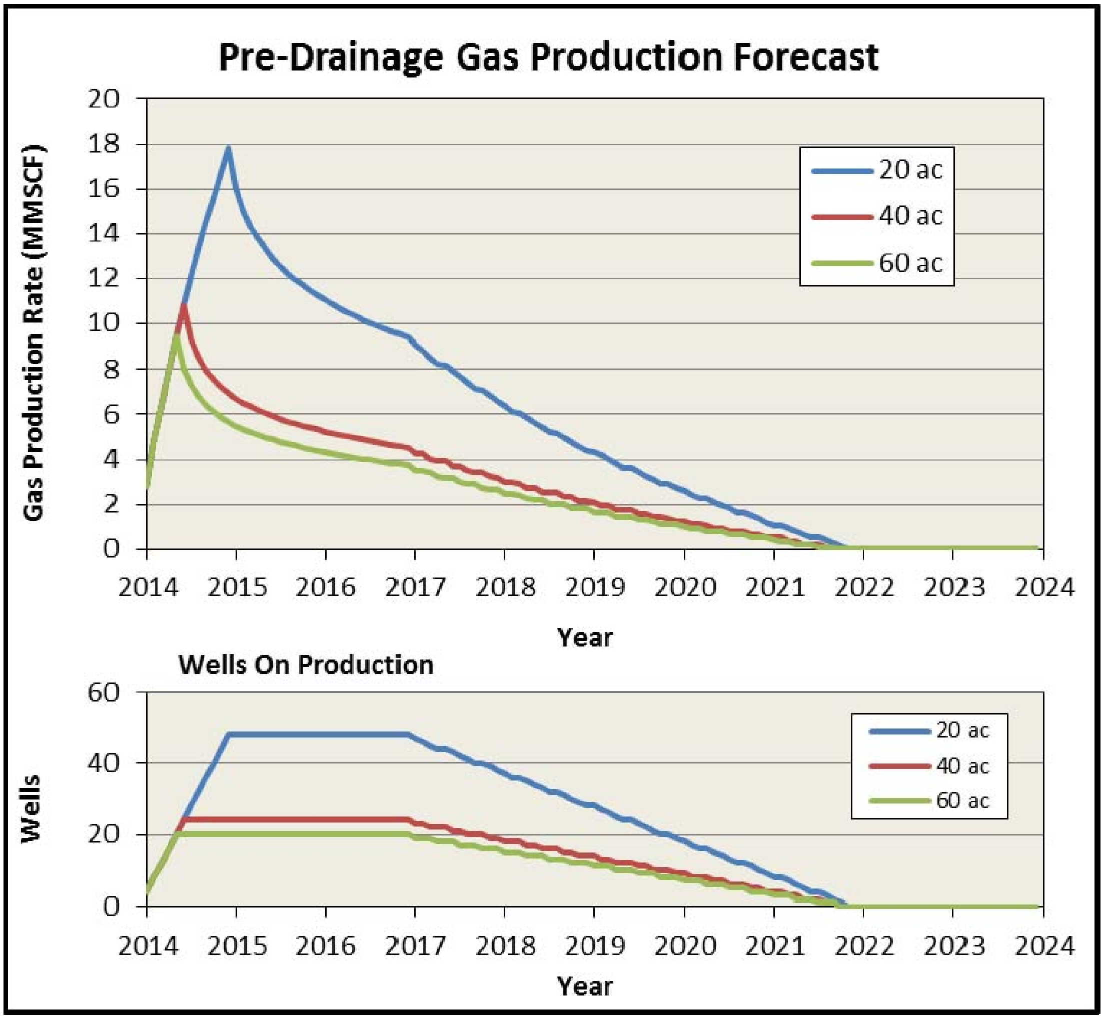


Figure 7-3: Pre-Drainage Gas Production Forecast for Project Area

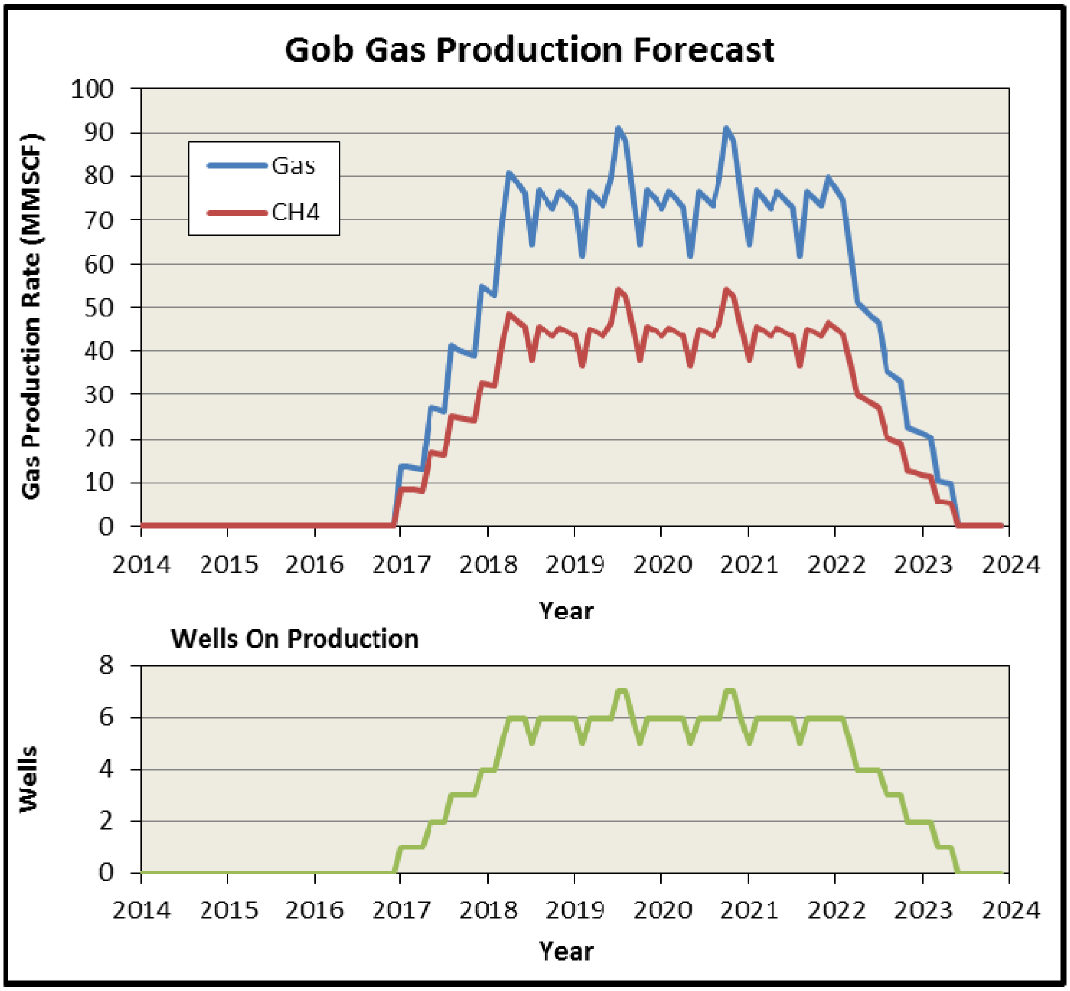


Figure 7-4: Gob Gas Production Forecast for Project Area

Production Case		PD-20ac	PD-40ac	PD-60ac	Gob
Producing Seam(s)		L7+L4	L7+L4	L7+L4	L7
Total Wells Drilled	wells	48	24	20	20
Peak Gas Rate	MSCFD	585	356	312	2988
Cumulative Gas Production	MMSCF	640	328	275	4540
CH4 Concentration	%	98%	98%	98%	59%
Cumulative CH4 Production	MMSCF	626	321	269	2699
CH4-In-Place	BCF	5.74	5.74	5.74	2.80
Recovery Factor	%	11%	6%	5%	96%

Table 7-2: Summary of Gas Production Forecast Results for Project Area

7.3 Economic Analysis

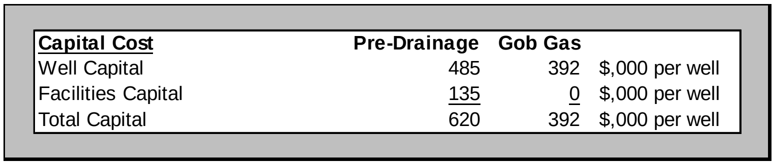
7.3.1 Economic Assessment Methodology

For each of the proposed project development scenarios, project economics were calculated for the upstream portion (i.e., gas production) and the downstream portion (i.e., electricity production). A breakeven gas price was calculated in the upstream segment where the present value of cash outflows is equivalent to the present value of cash inflows using a discounted rate of 10%. The breakeven gas price was then used in the downstream segment to calculate the fuel cost for the power plant. Likewise, a breakeven power sales price was calculated for the downstream segment, which can be compared to the current price of electricity observed at the mine to determine the economic feasibility of a power project at the mine.

7.3.2 Upstream (Gas Production) Economic Assumptions and Results

Advanced Resources has developed cost estimates for the goods and services required for the development of the project area located at the Komsomolets Donbassa mine. These cost estimates are based on a combination of known local costs provided by a panel of Ukrainian experts, known average development costs of analogous projects in the U.S., and other publically available sources.[27] The capital cost assumptions, operating cost assumptions, and physical and financial factors used in the evaluation of upstream economics are provided in Table 7-3, Table 7-4 and Table 7-5, respectively. The economic results for the proposed 20-acre pre-drainage, 40-acre pre-drainage, 60-acre pre-drainage, and gob gas projects are summarized in Figure 7-5, Figure 7-6, Figure 7-7 and Figure 7-8, respectively. The breakeven gas price as calculated for each development scenario is shown in Table 7-6.

The cost of vertical pre-drainage is prohibitively expensive. Based on the gas production achieved, the cost is estimated to be between US$81.77 and US$85.37 per MMBtu (million British thermal units), roughly equivalent to $2,887 - $3,014 per thousand cubic meters. In contrast, the breakeven cost of producing gob gas through surface boreholes is $5.89/MMBtu ($210 per thousand m^3).



Capital Cost	Pre-Drainage	Gob Gas	
Well Capital	485	392	$,000 per well
Facilities Capital	135	0	$,000 per well
Total Capital	620	392	$,000 per well

Table 7-3: Capital Cost Assumptions for Evaluation of Upstream Economics

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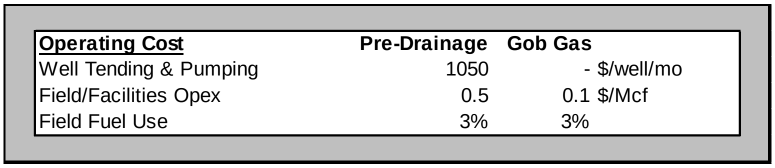
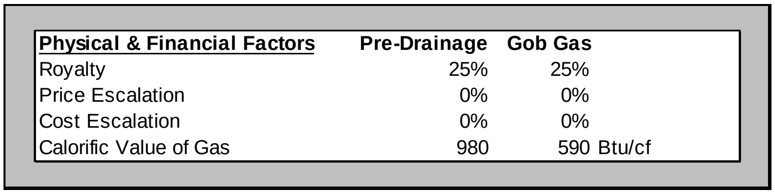
[27] Coal Mine Methane Development in the Donetsk Region, Ukraine. Prepared for Donetsk Regional Administration and U.S. Trade and Development Agency; prepared by Advanced Resources International, Inc. Arlington, VA USA in association with Ecometan; State Regional Geological Enterprise "Donetskgeologiya"; Bazhanov Mine and South Donbass #3 Mine; May, 2008.
User's Manual for the Coal Mine Methane Project Cash Flow Model (Version 2). USEPA Coalbed Methane Outreach Program, January 2011.



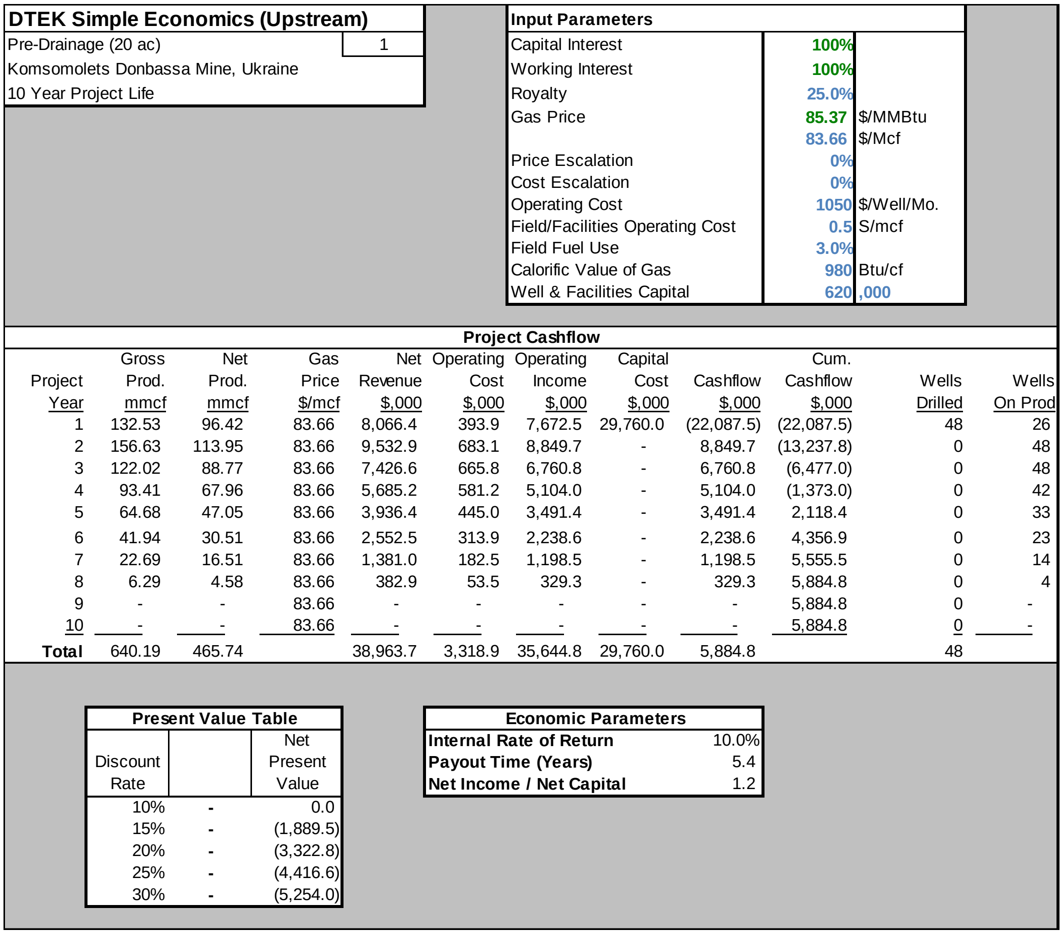
Operating Cost	Pre-Drainage	Gob Gas	
Well Tending & Pumping	1050	-	$/well/mo
Field/Facilities Opex	0.5	0.1	$/Mcf
Field Fuel Use	3%	3%	

Table 7-4: Operating Cost Assumptions for Evaluation of Upstream Economics



Physical & Financial Factors	Pre-Drainage	Gob Gas	
Royalty	25%	25%	
Price Escalation	0%	0%	
Cost Escalation	0%	0%	
Calorific Value of Gas	980	590	Btu/cf

Table 7-5: Physical and Financial Factors for Evaluation of Upstream Economics



DTEK Simple Economics (Upstream)	
Pre-Drainage (20 ac)	1
Komsomolets Donbassa Mine, Ukraine	
10 Year Project Life	

Input Parameters		
Capital Interest	100%	
Working Interest	100%	
Royalty	25.0%	
Gas Price	85.37	$/MMBtu
	83.66	$/Mcf
Price Escalation	0%	
Cost Escalation	0%	
Operating Cost	1050	$/Well/Mo.
Field/Facilities Operating Cost	0.5	S/mcf
Field Fuel Use	3.0%	
Calorific Value of Gas	980	Btu/cf
Well & Facilities Capital	620	,000

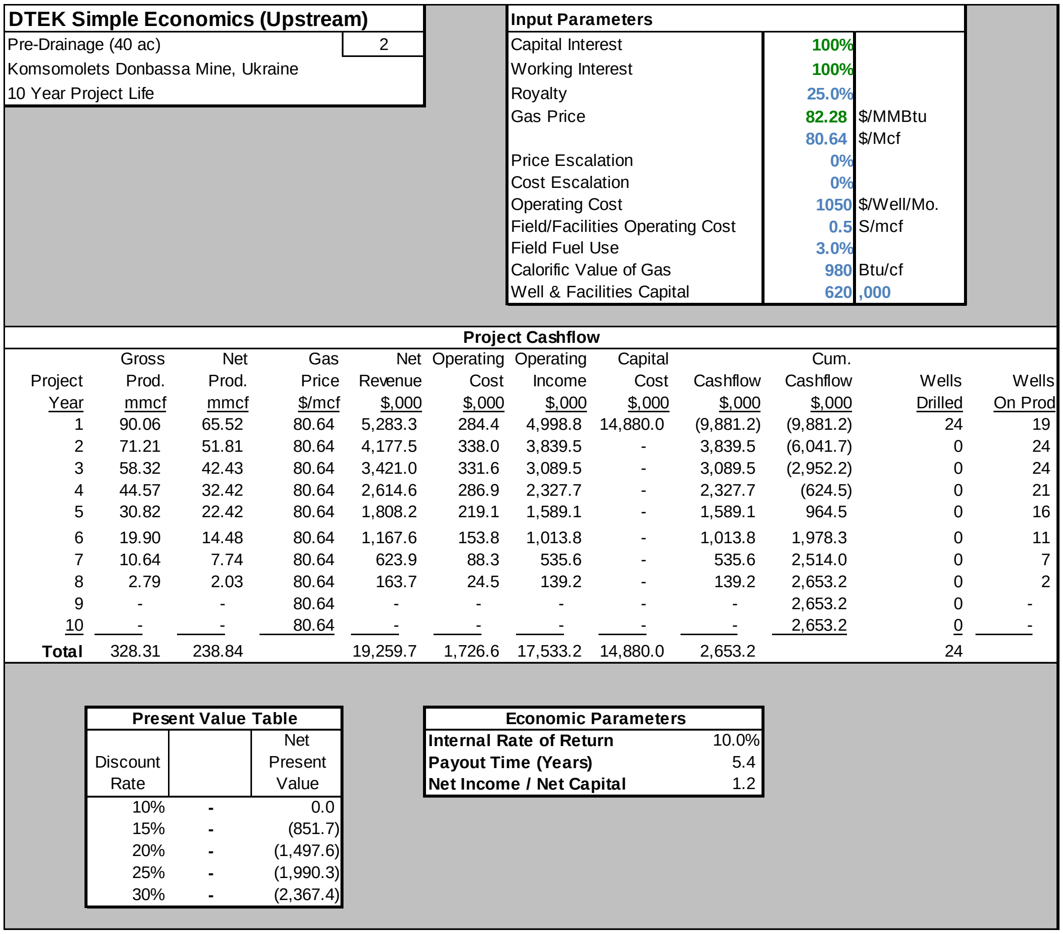
Project Cashflow

Project Year	Gross Prod. mmcf	Net Prod. mmcf	Gas Price $/mcf	Net Revenue $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Wells Drilled	Wells On Prod
1	132.53	96.42	83.66	8,066.4	393.9	7,672.5	29,760.0	(22,087.5)	(22,087.5)	48	26
2	156.63	113.95	83.66	9,532.9	683.1	8,849.7	-	8,849.7	(13,237.8)	0	48
3	122.02	88.77	83.66	7,426.6	665.8	6,760.8	-	6,760.8	(6,477.0)	0	48
4	93.41	67.96	83.66	5,685.2	581.2	5,104.0	-	5,104.0	(1,373.0)	0	42
5	64.68	47.05	83.66	3,936.4	445.0	3,491.4	-	3,491.4	2,118.4	0	33
6	41.94	30.51	83.66	2,552.5	313.9	2,238.6	-	2,238.6	4,356.9	0	23
7	22.69	16.51	83.66	1,381.0	182.5	1,198.5	-	1,198.5	5,555.5	0	14
8	6.29	4.58	83.66	382.9	53.5	329.3	-	329.3	5,884.8	0	4
9	-	-	83.66	-	-	-	-	-	5,884.8	0	-
10	-	-	83.66	-	-	-	-	-	5,884.8	0	-
Total	640.19	465.74		38,963.7	3,318.9	35,644.8	29,760.0	5,884.8		48	

Present Value Table		
Discount Rate		Net Present Value
10%	-	0.0
15%	-	(1,889.5)
20%	-	(3,322.8)
25%	-	(4,416.6)
30%	-	(5,254.0)

Economic Parameters	
Internal Rate of Return	10.0%
Payout Time (Years)	5.4
Net Income / Net Capital	1.2

Figure 7-5: Economic Results for 20 Ac Pre-Drainage Project



DTEK Simple Economics (Upstream)	
Pre-Drainage (40 ac)	2
Komsomolets Donbassa Mine, Ukraine	
10 Year Project Life	

Input Parameters		
Capital Interest	100%	
Working Interest	100%	
Royalty	25.0%	
Gas Price	82.28	$/MMBtu
	80.64	$/Mcf
Price Escalation	0%	
Cost Escalation	0%	
Operating Cost	1050	$/Well/Mo.
Field/Facilities Operating Cost	0.5	S/mcf
Field Fuel Use	3.0%	
Calorific Value of Gas	980	Btu/cf
Well & Facilities Capital	620	,000

Project Cashflow

Project Year	Gross Prod. mmcf	Net Prod. mmcf	Gas Price $/mcf	Net Revenue $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Wells Drilled	Wells On Prod
1	90.06	65.52	80.64	5,283.3	284.4	4,998.8	14,880.0	(9,881.2)	(9,881.2)	24	19
2	71.21	51.81	80.64	4,177.5	338.0	3,839.5	-	3,839.5	(6,041.7)	0	24
3	58.32	42.43	80.64	3,421.0	331.6	3,089.5	-	3,089.5	(2,952.2)	0	24
4	44.57	32.42	80.64	2,614.6	286.9	2,327.7	-	2,327.7	(624.5)	0	21
5	30.82	22.42	80.64	1,808.2	219.1	1,589.1	-	1,589.1	964.5	0	16
6	19.90	14.48	80.64	1,167.6	153.8	1,013.8	-	1,013.8	1,978.3	0	11
7	10.64	7.74	80.64	623.9	88.3	535.6	-	535.6	2,514.0	0	7
8	2.79	2.03	80.64	163.7	24.5	139.2	-	139.2	2,653.2	0	2
9	-	-	80.64	-	-	-	-	-	2,653.2	0	-
10	-	-	80.64	-	-	-	-	-	2,653.2	0	-
Total	328.31	238.84		19,259.7	1,726.6	17,533.2	14,880.0	2,653.2		24	

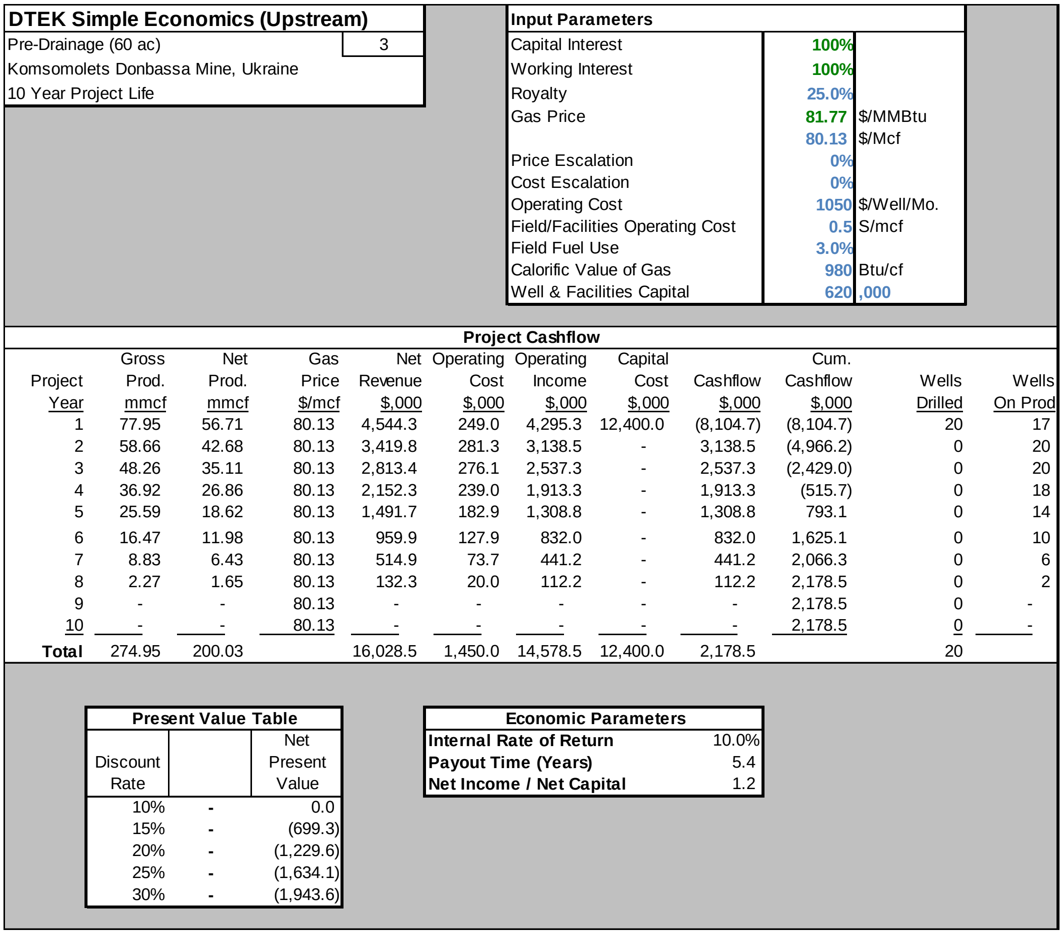
Present Value Table

Discount Rate		Net Present Value
10%	-	0.0
15%	-	(851.7)
20%	-	(1,497.6)
25%	-	(1,990.3)
30%	-	(2,367.4)

Economic Parameters

Internal Rate of Return	10.0%
Payout Time (Years)	5.4
Net Income / Net Capital	1.2

Figure 7-6: Economic Results for 40 Ac Pre-Drainage Project



DTEK Simple Economics (Upstream)

Pre-Drainage (60 ac)	3
Komsomolets Donbassa Mine, Ukraine	
10 Year Project Life	

Input Parameters		
Capital Interest	100%	
Working Interest	100%	
Royalty	25.0%	
Gas Price	81.77	$/MMBtu
	80.13	$/Mcf
Price Escalation	0%	
Cost Escalation	0%	
Operating Cost	1050	$/Well/Mo.
Field/Facilities Operating Cost	0.5	S/mcf
Field Fuel Use	3.0%	
Calorific Value of Gas	980	Btu/cf
Well & Facilities Capital	620	,000

Project Cashflow

Project Year	Gross Prod. mmcf	Net Prod. mmcf	Gas Price $/mcf	Net Revenue $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Wells Drilled	Wells On Prod
1	77.95	56.71	80.13	4,544.3	249.0	4,295.3	12,400.0	(8,104.7)	(8,104.7)	20	17
2	58.66	42.68	80.13	3,419.8	281.3	3,138.5	-	3,138.5	(4,966.2)	0	20
3	48.26	35.11	80.13	2,813.4	276.1	2,537.3	-	2,537.3	(2,429.0)	0	20
4	36.92	26.86	80.13	2,152.3	239.0	1,913.3	-	1,913.3	(515.7)	0	18
5	25.59	18.62	80.13	1,491.7	182.9	1,308.8	-	1,308.8	793.1	0	14
6	16.47	11.98	80.13	959.9	127.9	832.0	-	832.0	1,625.1	0	10
7	8.83	6.43	80.13	514.9	73.7	441.2	-	441.2	2,066.3	0	6
8	2.27	1.65	80.13	132.3	20.0	112.2	-	112.2	2,178.5	0	2
9	-	-	80.13	-	-	-	-	-	2,178.5	0	-
10	-	-	80.13	-	-	-	-	-	2,178.5	0	-
Total	274.95	200.03		16,028.5	1,450.0	14,578.5	12,400.0	2,178.5		20	

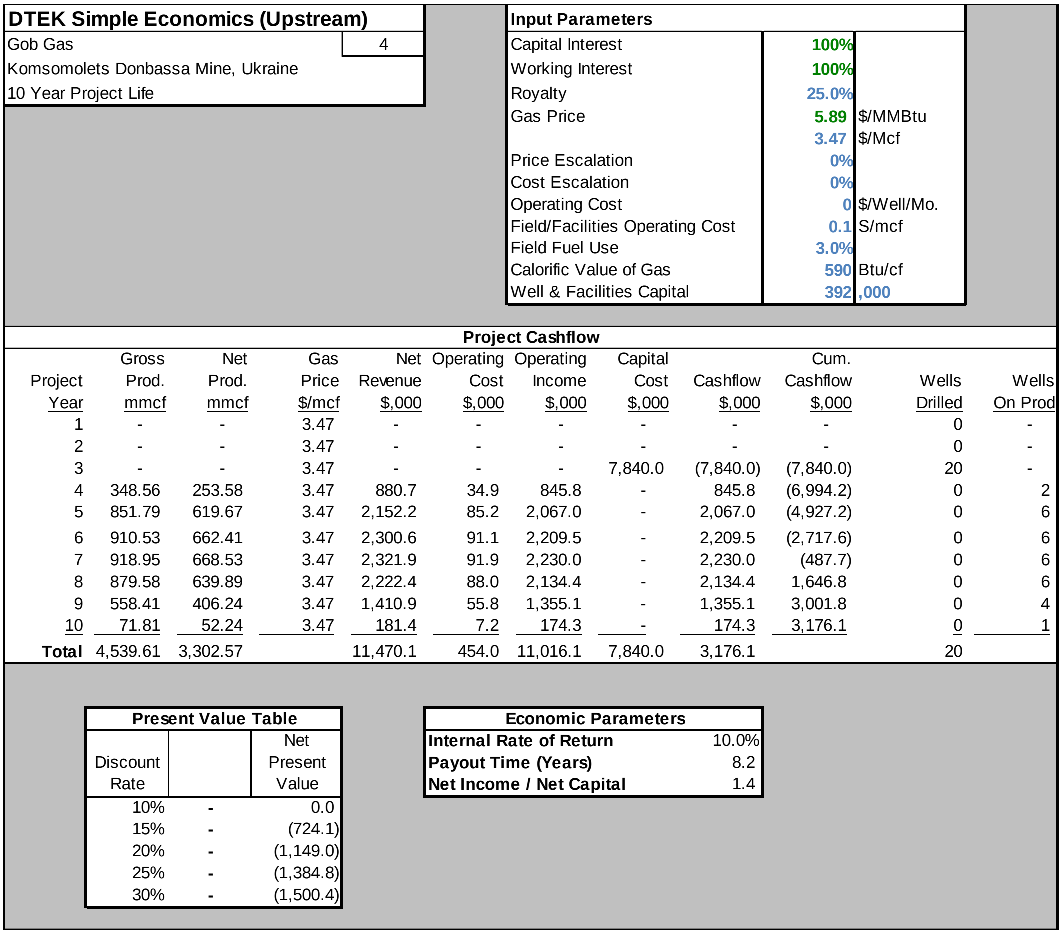
Present Value Table

Discount Rate		Net Present Value
10%	-	0.0
15%	-	(699.3)
20%	-	(1,229.6)
25%	-	(1,634.1)
30%	-	(1,943.6)

Economic Parameters

Internal Rate of Return	10.0%
Payout Time (Years)	5.4
Net Income / Net Capital	1.2

Figure 7-7: Economic Results for 60 Ac Pre-Drainage Project



DTEK Simple Economics (Upstream)	
Gob Gas	4
Komsomolets Donbassa Mine, Ukraine	
10 Year Project Life	

Input Parameters		
Capital Interest	100%	
Working Interest	100%	
Royalty	25.0%	
Gas Price	5.89	$/MMBtu
	3.47	$/Mcf
Price Escalation	0%	
Cost Escalation	0%	
Operating Cost	0	$/Well/Mo.
Field/Facilities Operating Cost	0.1	S/mcf
Field Fuel Use	3.0%	
Calorific Value of Gas	590	Btu/cf
Well & Facilities Capital	392	,000

Project Cashflow

Project Year	Gross Prod. mmcf	Net Prod. mmcf	Gas Price $/mcf	Net Revenue $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Wells Drilled	Wells On Prod
1	-	-	3.47	-	-	-	-	-	-	0	-
2	-	-	3.47	-	-	-	-	-	-	0	-
3	-	-	3.47	-	-	-	7,840.0	(7,840.0)	(7,840.0)	20	-
4	348.56	253.58	3.47	880.7	34.9	845.8	-	845.8	(6,994.2)	0	2
5	851.79	619.67	3.47	2,152.2	85.2	2,067.0	-	2,067.0	(4,927.2)	0	6
6	910.53	662.41	3.47	2,300.6	91.1	2,209.5	-	2,209.5	(2,717.6)	0	6
7	918.95	668.53	3.47	2,321.9	91.9	2,230.0	-	2,230.0	(487.7)	0	6
8	879.58	639.89	3.47	2,222.4	88.0	2,134.4	-	2,134.4	1,646.8	0	6
9	558.41	406.24	3.47	1,410.9	55.8	1,355.1	-	1,355.1	3,001.8	0	4
10	71.81	52.24	3.47	181.4	7.2	174.3	-	174.3	3,176.1	0	1
Total	4,539.61	3,302.57		11,470.1	454.0	11,016.1	7,840.0	3,176.1		20	

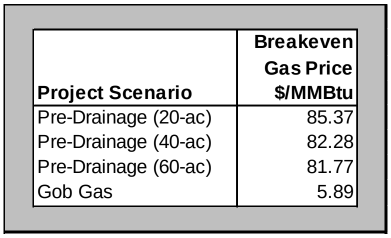
Present Value Table

Discount Rate		Net Present Value
10%	-	0.0
15%	-	(724.1)
20%	-	(1,149.0)
25%	-	(1,384.8)
30%	-	(1,500.4)

Economic Parameters

Internal Rate of Return	10.0%
Payout Time (Years)	8.2
Net Income / Net Capital	1.4

Figure 7-8: Economic Results for Gob Gas Project



Project Scenario	Breakeven Gas Price $/MMBtu
Pre-Drainage (20-ac)	85.37
Pre-Drainage (40-ac)	82.28
Pre-Drainage (60-ac)	81.77
Gob Gas	5.89

Table 7-6: Breakeven Gas Price as Calculated in Upstream Evaluation

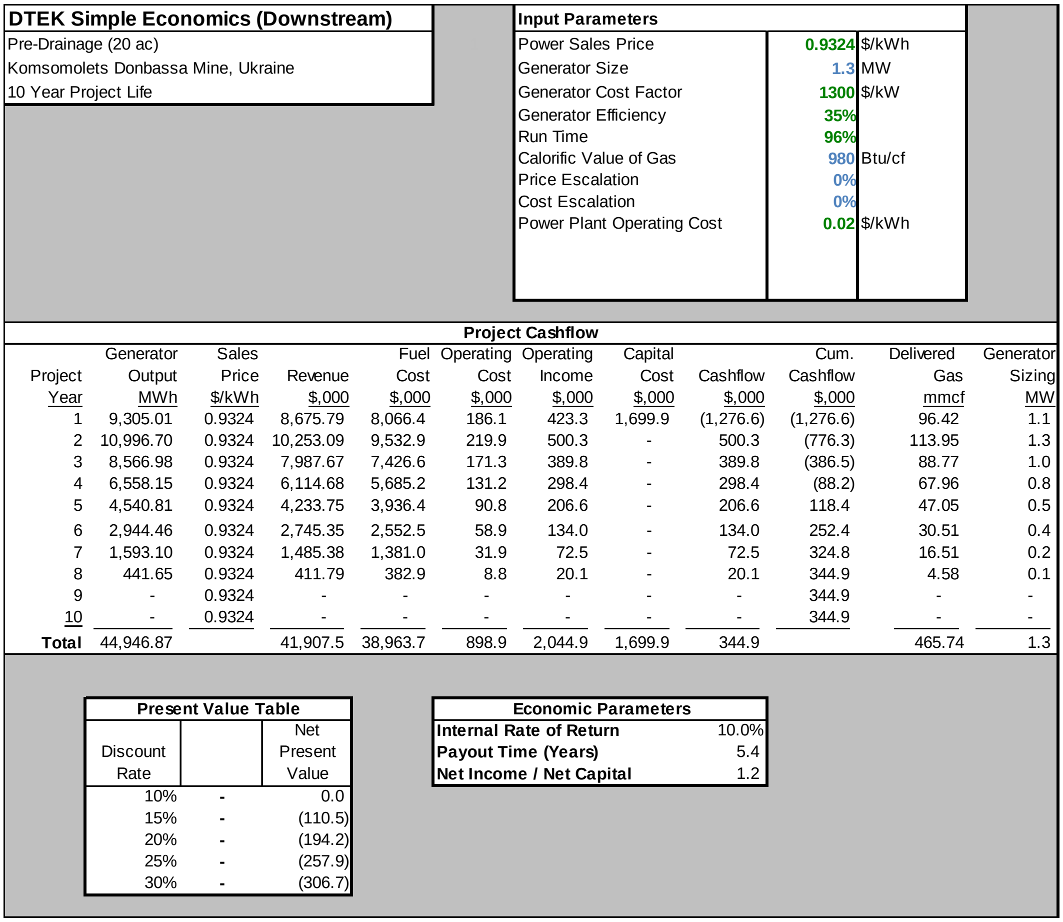
7.3.3 Downstream Economic Assumptions and Results

The assumptions used to assess the economic viability of the power project are presented in Table 7-7. The economic results for the proposed 20-acre pre-drainage, 40-acre pre-drainage, 60-acre pre-drainage, and gob gas projects are summarized in Figure 7-9, Figure 7-10, Figure 7-11 and Figure 7-12, respectively. The breakeven power sales price as calculated for each development scenario is shown in Table 7-8. At $0.12/kWh inclusive of the cost of methane drainage, a power project combined with gob wells could be potentially economic, especially considering the additional benefits of methane degasification in terms mine safety and increasing the advance rate for longwall.

Although power combined with pre-drainage appears very expensive, removing the cost of mine degasification from downstream economics as a sunk cost would significantly reduce the marginal cost of power. However, gas production from pre-drainage wells is so low that it can only sustain a very small power project. Even using 20 ac (8 ha) spacing, there is only enough gas to support 1.3 MW of power production. Gob well production will support 4.6 MW of electricity generation.

Power Plant Assumptions	
Generator Cost Factor	1300 $/kW
Generator Efficiency	35%
Run Time	96%
Power Plant Operating Cost	0.02 $/kWh

Table 7-7: Power Plant Assumptions for Evaluation of Downstream Economics



DTEK Simple Economics (Downstream)

Pre-Drainage (20 ac)
Komsomolets Donbassa Mine, Ukraine
10 Year Project Life

Input Parameters		
Power Sales Price	0.9324	$/kWh
Generator Size	1.3	MW
Generator Cost Factor	1300	$/kW
Generator Efficiency	35%	
Run Time	96%	
Calorific Value of Gas	980	Btu/cf
Price Escalation	0%	
Cost Escalation	0%	
Power Plant Operating Cost	0.02	$/kWh

Project Cashflow

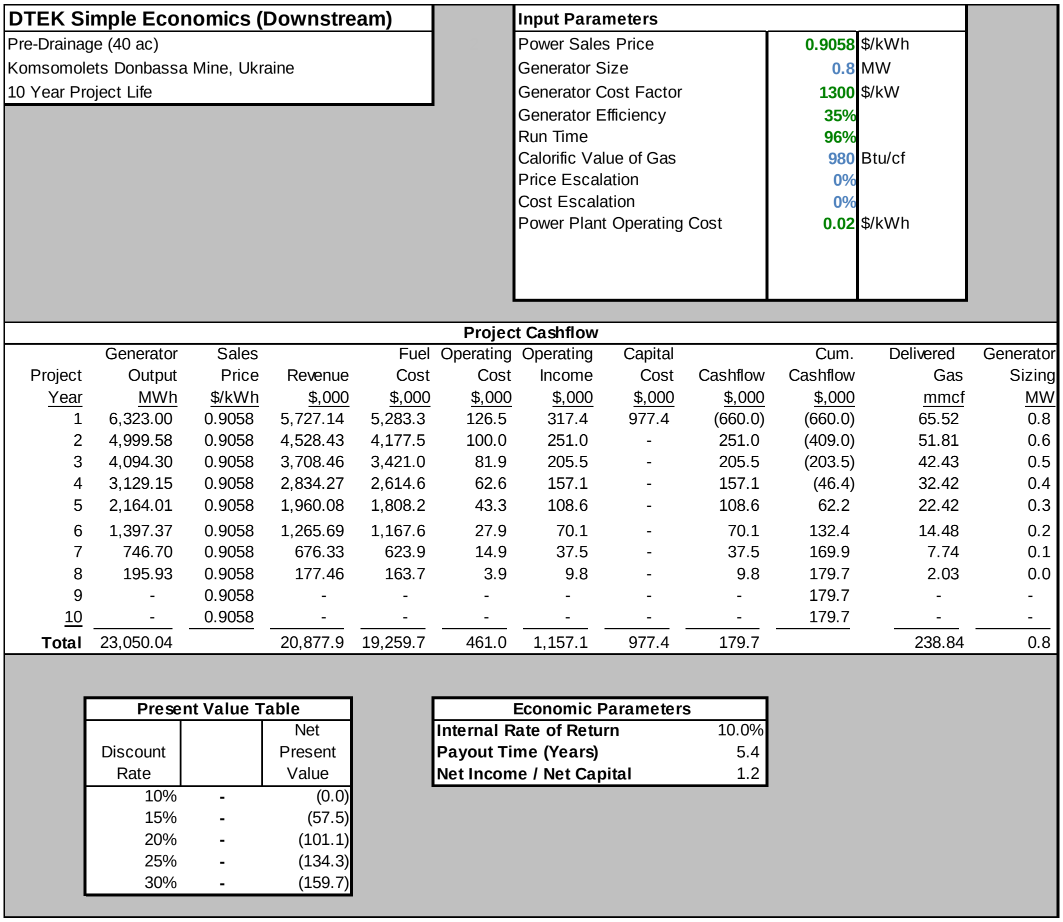
Project Year	Generator Output MWh	Sales Price $/kWh	Revenue $,000	Fuel Cost $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Delivered Gas mmcf	Generator Sizing MW
1	9,305.01	0.9324	8,675.79	8,066.4	186.1	423.3	1,699.9	(1,276.6)	(1,276.6)	96.42	1.1
2	10,996.70	0.9324	10,253.09	9,532.9	219.9	500.3	-	500.3	(776.3)	113.95	1.3
3	8,566.98	0.9324	7,987.67	7,426.6	171.3	389.8	-	389.8	(386.5)	88.77	1.0
4	6,558.15	0.9324	6,114.68	5,685.2	131.2	298.4	-	298.4	(88.2)	67.96	0.8
5	4,540.81	0.9324	4,233.75	3,936.4	90.8	206.6	-	206.6	118.4	47.05	0.5
6	2,944.46	0.9324	2,745.35	2,552.5	58.9	134.0	-	134.0	252.4	30.51	0.4
7	1,593.10	0.9324	1,485.38	1,381.0	31.9	72.5	-	72.5	324.8	16.51	0.2
8	441.65	0.9324	411.79	382.9	8.8	20.1	-	20.1	344.9	4.58	0.1
9	-	0.9324	-	-	-	-	-	-	344.9	-	-
10	-	0.9324	-	-	-	-	-	-	344.9	-	-
Total	44,946.87		41,907.5	38,963.7	898.9	2,044.9	1,699.9	344.9		465.74	1.3

Present Value Table

Discount Rate		Net Present Value
10%	-	0.0
15%	-	(110.5)
20%	-	(194.2)
25%	-	(257.9)
30%	-	(306.7)

Economic Parameters	
Internal Rate of Return	10.0%
Payout Time (Years)	5.4
Net Income / Net Capital	1.2

Figure 7-9: Economic Results for Power Project Utilizing Pre-Drainage (20-ac) Gas



DTEK Simple Economics (Downstream)
Pre-Drainage (40 ac)
Komsomolets Donbassa Mine, Ukraine
10 Year Project Life

Input Parameters		
Power Sales Price	0.9058	$/kWh
Generator Size	0.8	MW
Generator Cost Factor	1300	$/kW
Generator Efficiency	35%	
Run Time	96%	
Calorific Value of Gas	980	Btu/cf
Price Escalation	0%	
Cost Escalation	0%	
Power Plant Operating Cost	0.02	$/kWh

Project Cashflow

Project Year	Generator Output MWh	Sales Price $/kWh	Revenue $,000	Fuel Cost $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Delivered Gas mmcf	Generator Sizing MW
1	6,323.00	0.9058	5,727.14	5,283.3	126.5	317.4	977.4	(660.0)	(660.0)	65.52	0.8
2	4,999.58	0.9058	4,528.43	4,177.5	100.0	251.0	-	251.0	(409.0)	51.81	0.6
3	4,094.30	0.9058	3,708.46	3,421.0	81.9	205.5	-	205.5	(203.5)	42.43	0.5
4	3,129.15	0.9058	2,834.27	2,614.6	62.6	157.1	-	157.1	(46.4)	32.42	0.4
5	2,164.01	0.9058	1,960.08	1,808.2	43.3	108.6	-	108.6	62.2	22.42	0.3
6	1,397.37	0.9058	1,265.69	1,167.6	27.9	70.1	-	70.1	132.4	14.48	0.2
7	746.70	0.9058	676.33	623.9	14.9	37.5	-	37.5	169.9	7.74	0.1
8	195.93	0.9058	177.46	163.7	3.9	9.8	-	9.8	179.7	2.03	0.0
9	-	0.9058	-	-	-	-	-	-	179.7	-	-
10	-	0.9058	-	-	-	-	-	-	179.7	-	-
Total	23,050.04		20,877.9	19,259.7	461.0	1,157.1	977.4	179.7		238.84	0.8

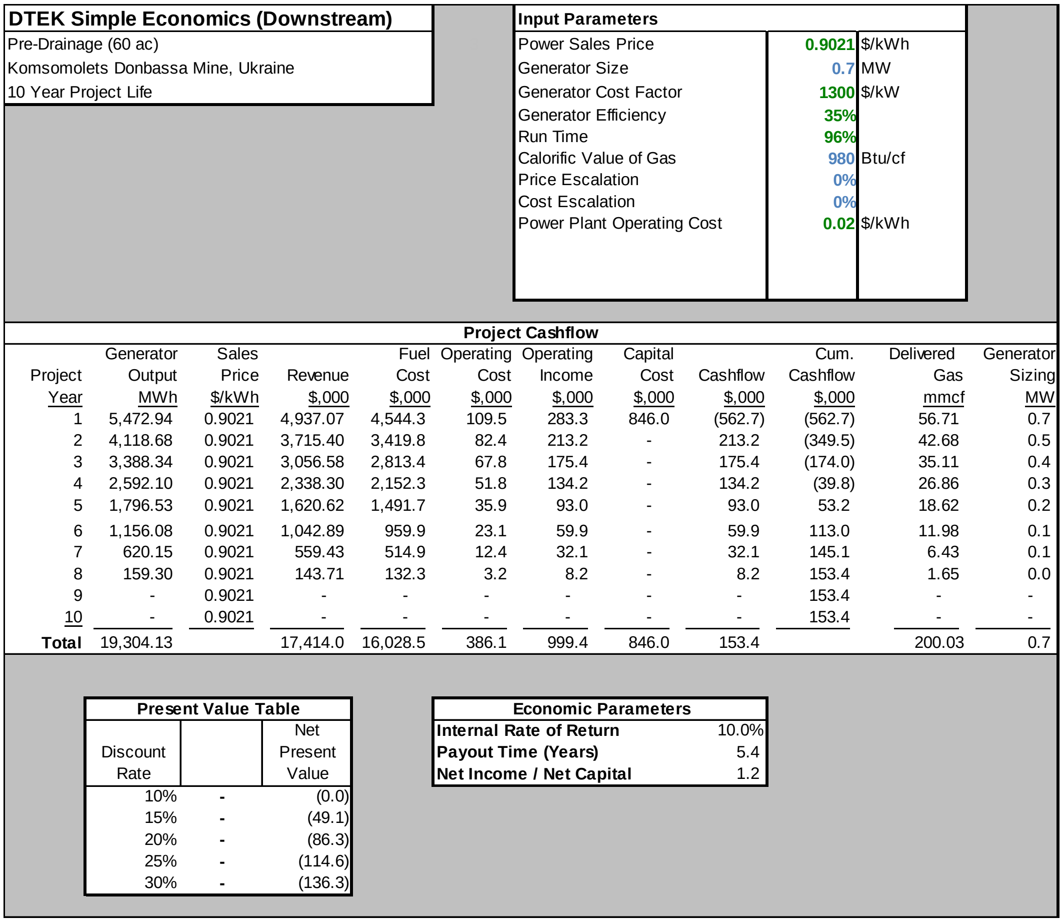
Present Value Table

Discount Rate		Net Present Value
10%	-	(0.0)
15%	-	(57.5)
20%	-	(101.1)
25%	-	(134.3)
30%	-	(159.7)

Economic Parameters

Internal Rate of Return	10.0%
Payout Time (Years)	5.4
Net Income / Net Capital	1.2

Figure 7-10: Economic Results for Power Project Utilizing Pre-Drainage (40-ac) Gas



DTEK Simple Economics (Downstream)

Pre-Drainage (60 ac)
Komsomolets Donbassa Mine, Ukraine
10 Year Project Life

Input Parameters		
Power Sales Price	0.9021	$/kWh
Generator Size	0.7	MW
Generator Cost Factor	1300	$/kW
Generator Efficiency	35%	
Run Time	96%	
Calorific Value of Gas	980	Btu/cf
Price Escalation	0%	
Cost Escalation	0%	
Power Plant Operating Cost	0.02	$/kWh

Project Cashflow

Project Year	Generator Output MWh	Sales Price $/kWh	Revenue $,000	Fuel Cost $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Delivered Gas mmcf	Generator Sizing MW
1	5,472.94	0.9021	4,937.07	4,544.3	109.5	283.3	846.0	(562.7)	(562.7)	56.71	0.7
2	4,118.68	0.9021	3,715.40	3,419.8	82.4	213.2	-	213.2	(349.5)	42.68	0.5
3	3,388.34	0.9021	3,056.58	2,813.4	67.8	175.4	-	175.4	(174.0)	35.11	0.4
4	2,592.10	0.9021	2,338.30	2,152.3	51.8	134.2	-	134.2	(39.8)	26.86	0.3
5	1,796.53	0.9021	1,620.62	1,491.7	35.9	93.0	-	93.0	53.2	18.62	0.2
6	1,156.08	0.9021	1,042.89	959.9	23.1	59.9	-	59.9	113.0	11.98	0.1
7	620.15	0.9021	559.43	514.9	12.4	32.1	-	32.1	145.1	6.43	0.1
8	159.30	0.9021	143.71	132.3	3.2	8.2	-	8.2	153.4	1.65	0.0
9	-	0.9021	-	-	-	-	-	-	153.4	-	-
10	-	0.9021	-	-	-	-	-	-	153.4	-	-
Total	19,304.13		17,414.0	16,028.5	386.1	999.4	846.0	153.4		200.03	0.7

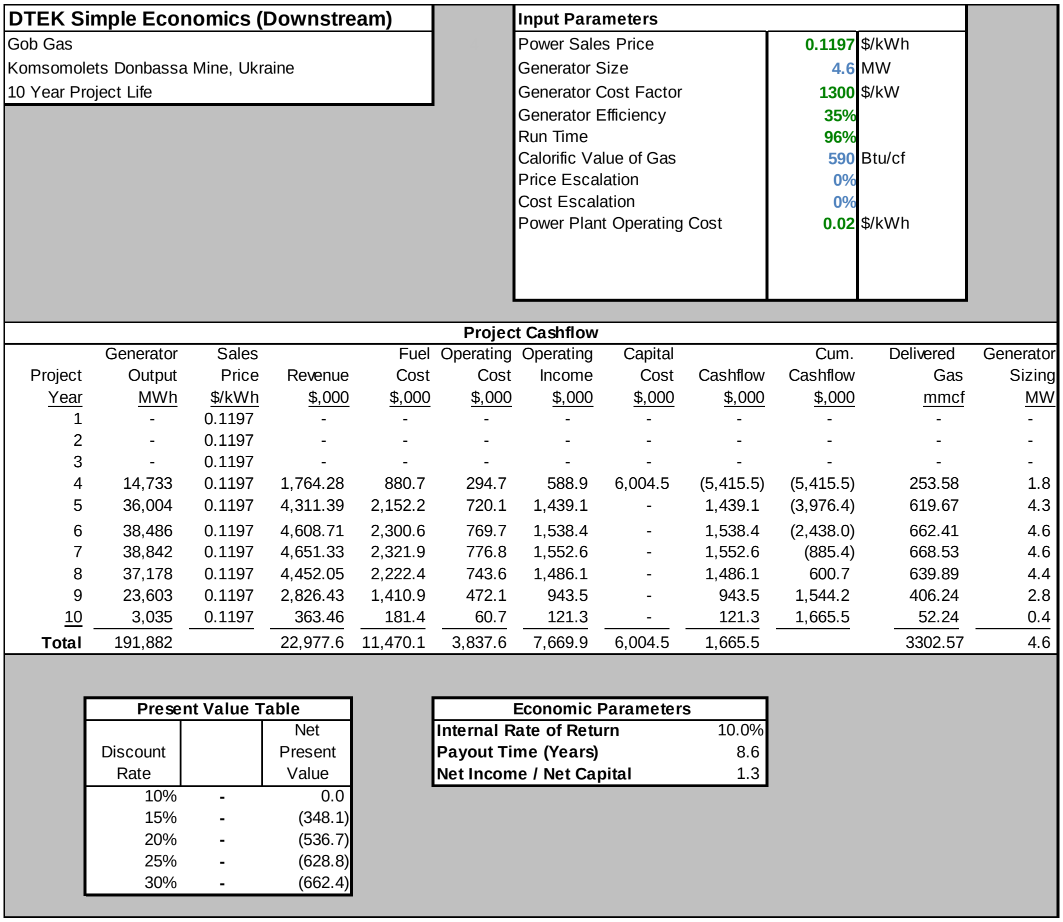
Present Value Table

Discount Rate		Net Present Value
10%	-	(0.0)
15%	-	(49.1)
20%	-	(86.3)
25%	-	(114.6)
30%	-	(136.3)

Economic Parameters

Internal Rate of Return	10.0%
Payout Time (Years)	5.4
Net Income / Net Capital	1.2

Figure 7-11: Economic Results for Power Project Utilizing Pre-Drainage (60-ac) Gas



DTEK Simple Economics (Downstream)

Gob Gas
Komsomolets Donbassa Mine, Ukraine
10 Year Project Life

Input Parameters		
Power Sales Price	0.1197	$/kWh
Generator Size	4.6	MW
Generator Cost Factor	1300	$/kW
Generator Efficiency	35%	
Run Time	96%	
Calorific Value of Gas	590	Btu/cf
Price Escalation	0%	
Cost Escalation	0%	
Power Plant Operating Cost	0.02	$/kWh

Project Cashflow

Project Year	Generator Output MWh	Sales Price $/kWh	Revenue $,000	Fuel Cost $,000	Operating Cost $,000	Operating Income $,000	Capital Cost $,000	Cashflow $,000	Cum. Cashflow $,000	Delivered Gas mmcf	Generator Sizing MW
1	-	0.1197	-	-	-	-	-	-	-	-	-
2	-	0.1197	-	-	-	-	-	-	-	-	-
3	-	0.1197	-	-	-	-	-	-	-	-	-
4	14,733	0.1197	1,764.28	880.7	294.7	588.9	6,004.5	(5,415.5)	(5,415.5)	253.58	1.8
5	36,004	0.1197	4,311.39	2,152.2	720.1	1,439.1	-	1,439.1	(3,976.4)	619.67	4.3
6	38,486	0.1197	4,608.71	2,300.6	769.7	1,538.4	-	1,538.4	(2,438.0)	662.41	4.6
7	38,842	0.1197	4,651.33	2,321.9	776.8	1,552.6	-	1,552.6	(885.4)	668.53	4.6
8	37,178	0.1197	4,452.05	2,222.4	743.6	1,486.1	-	1,486.1	600.7	639.89	4.4
9	23,603	0.1197	2,826.43	1,410.9	472.1	943.5	-	943.5	1,544.2	406.24	2.8
10	3,035	0.1197	363.46	181.4	60.7	121.3	-	121.3	1,665.5	52.24	0.4
Total	191,882		22,977.6	11,470.1	3,837.6	7,669.9	6,004.5	1,665.5		3302.57	4.6

Present Value Table

Discount Rate		Net Present Value
10%	-	0.0
15%	-	(348.1)
20%	-	(536.7)
25%	-	(628.8)
30%	-	(662.4)

Economic Parameters

Internal Rate of Return	10.0%
Payout Time (Years)	8.6
Net Income / Net Capital	1.3

Figure 7-12: Economic Results for Power Project Utilizing Gob Gas

Project Scenario	Breakeven Power Price $/kWh
Pre-Drainage (20-ac)	0.932
Pre-Drainage (40-ac)	0.906
Pre-Drainage (60-ac)	0.902
Gob Gas	0.120

Table 7-8: Breakeven Power Sales Price as Determined in Downstream Evaluation

8.0 Conclusions & Recommendations and Next Steps

As a pre-feasibility study, this document is intended to provide a high level analysis on the technical feasibility and economics of the KD Mine gas drainage and utilization project.

The analysis performed by ARI reveals that surface gob gas ventholes are likely to be the most effective method for degasification of the coal seams at the Komsomolets Donbassa mine. The recovery efficiency is significantly higher for the gob wells in comparison to the low recovery efficiencies and the high remaining gas in place that ARI reservoir simulation showed for pre-mine drainage.

The focus of this study was the L_7 and L_4 coal seams because these seams require degassing and the study area was defined for both seams. A multi-seam completion that includes the L_3 and L_6 seams would improve the economics for pre-drainage but only to a very limited degree.

The most effective gas drainage program for the Komsomolets Donbassa Mine is likely to be a combination of gob gas ventholes drilled form the surface combined with in-mine cross measure boreholes, for which the Komsomolets Donbassa Mine has significant experience implementing and operating. Another alternative is to employ long-hole in-mine directional drilled wells. A pilot project using long hole directional drilling sponsored by the United States Department of Labor in cooperation with the Ukraine Department of Labor Safety demonstrated that the technology could be successful in Ukraine. Another option could be to attempt surface-to-inseam directional drilling (SID). This technique is used in the United States and Australia in coal seams and in the U.S., Canada, Australia and other countries for shale gas development. However the costs to drill SID wells are very high.

In terms of utilization, a decision to use surface gob wells instead of pre-mine drainage should not impact the decision to use the CMM produced at the mine for power generation. In contrast, gas availability increases substantially with gob wells. And gas engines and flares can be designed to operate at concentrations as low as 30% methane presenting an ideal solution of use of gob gas.

Should DTEK and the Komsomolets Donbassa Mine wish to continue consideration of surface gob well or pre-mine drainage, ARI recommends the following steps:

Step 1: Refine Pre-feasibility Analysis

Review the data and determine if more detailed and accurate data are required or are necessary. In addition, it will be beneficial to obtain more accurate costing information including costs for drilling and completion in Donetsk for gob gas wells and pre-drainage wells in the Donetsk region and installed capital costs and operating costs for packaged gas engines in Ukraine.

Step 2: Detailed Engineering & Design

If the results of the refined prefeasibility study are promising, the next step is to move forward with detailed engineering and design for a pilot well program.

Step 3: Pilot Well Program

The pilot well program would likely take the form of one or more 5-well clusters drilled on a fairly tight spacing (40 acres or less). Contiguous well patterns are important indicators of full-scale production potential because they quickly achieve efficient dewatering of the continued well, an important criterion for coalbed methane production.

Detailed plans should be developed for all phases of the drilling program including drilling, completion, stimulation, artificial lift, water disposal, and production operations.

Step 4: Full Feasibility Study including Field Development Plan

The results of the project will inform the development of a full feasibility study. In addition to further defining the elements of the pre-feasibility study including the project economics, the feasibility study should include reservoir simulation and data analysis to support the construction of the Full Field Development Plan.

APPENDIX A – SITE GEOLOGY

Geological characteristics

The methane impacting mining operations originates principally from the coal seams rather than the adjacent strata. According to DTEK and KD Mine geologists and engineers, studies of the porosity and permeability of the rock (sandstone, limestone, sandy shale) show that the rock is very dense (2.5-2.87 g/cm^3), has low porosity (total – up to 3.8%, open – 1.5-1.9%) and low gas permeability (0.00-0.02 mD) limiting the volume of gas in the pore space. However, numerous local methane accumulations are located in zones of fracturing caused by tectonic faults, flexure bends, or mining activities. But there were no detailed studies of any regularity in the location of such zones of fracturing.

The geology of the area has been explored extensively for a variety of purposes by many organizations. The first geological studies within the area were performed in 1900-1916, followed by additional geological exploration in subsequent years. The last geological exploration was performed between 1985-1992 by the Zapadnoantratsitovskaya Exploration Company. The re-estimation of coal reserves within the Komsomolets Donbassa mine field was developed based on this work.[28]

As part of this study 435 core wells were drilled within the extent of the Komsomolets Donbassa mine with cumulative drilling total of 322,075 meters. The wells were located in 38 cross-sections mainly spaced at 125 – 500 m (the maximum distance is 1250 m between wells). Non-uniform density of the exploration grid is a result of intensive development of the site, poor local conditions and presence of the mining operations. The grid is denser in the central and south-east part of the mine field and less dense in the north-west part.

Re-drilling of the target coal seams was performed with double-core barrel of Alekseyenko system (DTA) and KA-61 core gas collectors. The samples were tested by the chemical laboratory of Artemovsk geological exploration company of Donbassgeologia association and the laboratory of Donetsk expedition of Ukruglegeologia company.

The coal analyses performed for all samples consisted of:

- Analytical moisture – W^a, %
- Ash - A^d, %; total sulphur - S_t^d, %;
- Volatile Matter - V^{daf}, %;

The following parameters were identified for individual samples:

- Calorific value – Q, MJ/kg;
- Volume yield of volatile matter – V_v, cm^3/g;
- Vitrinite reflectance – R_o %;
- Fusainized components sum - $\sum$ОК, %;
- Ultimate composition, coal chemical composition, rank index – log ρ.

Geophysical logging performed in the wells consisted of electrical logging, gamma-ray logging, gamma-

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[28] Approved by the minutes No. 1534 TES of Ukruglegeologia dated 10.12.1992

gamma logging, acoustic logging, and mud logging.

A total of 311,649 meters were logged between the various core holes and the logging coverage of the drilled metrerage is 96.7%. Also the physical and mechanical properties of host rocks were studied and the gas content measured.

Geological structure (stratigraphy, lithology, tectonics)

Within the mine area, Upper and Middle Carboniferous sediments are represented by suites C_3^1, C_2^7 and C_2^6, and are covered by Quaternary deposits, except for minor areas of drainage and hill slopes, where the coal deposits crop out.

Carboniferous deposits contain the typical terrigenous sediments with alternating layers of sand, shale, clay shale, multi-sized sandstones, thin limestones, coal seams and carboniferous shales. Bedding Plane contacts within the mine area vary both in the mine field plane and cross section: there is a smooth transition between the shale layers with various grain size or an area of interlaid thin laminae at the border of lithotype transition. The boundaries between shale and massive sandstones are clearer. Within the thick (m = 11.0-18.0 m) clay shale there are smooth surfaces at 0.8-1.2 m height from the coal seam with no contact in some areas.

In terms of geological structure the area is associated with the western and central parts for Chistyakovo-Snezhnoye syncline represented by a symmetrical fold with abrupt northern slope and shallow southern slope. Its axis gradually deepens in the north-west direction at an angle of $5\text{-}6^0$. The rock dips vary from $5\text{-}17^0$ in the south to $15\text{-}25^0$ in the north. Westwards, the dip angles grow to 47^0, while in the axial part the angles are 2-8 degrees. The relatively smooth bedding of carboniferous rocks is disrupted by minor amplitude (0.05-3.0 m) folds and bedding structures.

Table 1 provides a summary of the thickness and composition of the principal coal layers:

Table 1: Coalbearing Strata of the Komsomolets Donbassa Mine

Suite	Thickness, m	Number of coal seams	Number of commercial seams	Lithological composition of reservoir, %				
				Sandstones	Sand shales	Clay shales	Limestones	Coal
C_3^1	570	10	1	57.9	8.2	31.6	1.4	0.9
C_2^7	709	23	7	25.0	55.9	14.4	3.5	1.2
C_2^6	365	17	6	43.0	45.2	7.2	2.2	2.4
Total				42.0	36.2	18.0	2.3	1.5

Source: Supplied by DTEK

Mining and geologic conditions of operations

Mine reserves are comprised of 9 coal seams: m_9, m_5^1, m_4^1, m_3, L_7, L_6, L_4, L_3, and $L_1^{1в}$. Currently 4 coal seams are mined – L_7, L_6, L_4, L_3.

The mining and geologic conditions of the KD mines operations are relatively favorable for coal production. The coal seams are relatively thin to medium thickness (0.6 – 1.7 m) at depths of 7 - 1600 m depth. The dip of the seams is low, with seam inclination angle is 0 – 35 degrees.

The gas content of the coal seams is between 12 and 40.5 m^3/t of dry, ash-free basis. The rock strata adjacent to the coal seams only hold gas in fractures and other free space, and are believed to contribute only minimally to the mine's gas balance.

Table 2: Hardness Factor and Compressive Resistance for Associated Layers

Rock	Hardness factor within Protodyakonov's scale –f, c.u.	Compressive resistance- $\sigma_{сж}$, MPa
Sandstone	8 – 15	80 – 140
Limestone	9 – 12	95 – 110
Sand shale	6 – 8	65 – 85
Clay shale	3 – 5	35 – 60

Source: DTEK

The host rocks feature medium cavability and unstable roof when mining coal with powered longwalls. Roof control involves full caving. The subsidence of limestone and sandstone is abrupt and is a reservoir for methane accumulation. The extent of caving is 16-18 meters high for the primary roof subsidence increasing to 30-50 m for the primary main roof subsidence. At full longwall production, the area of disturbed rocks increases to 180-200 m above the seam.

One of the main features of Chistyakovo-Snezhnoye industrial region of Donetsk basin is the abrupt change in the reservoir characteristics after disturbance with mining operations. T grade coal and its host rocks are quite dense and have low permeability for gas and water. At the same time the coal and rock formations are very fragile and insensitive to plastic deformations. The impact on the strata after unloading is that they form a large number of open fractures and significantly change the reservoir characteristics. But, there have been no systematic studies or measurements; therefore, representative figures are not available.

The aquifers that impact water influx into the mine workings are associated with carboniferous sandstone and limestones. The underground waters are located in the coal seams and fracture networks and contain chloride-hydro carbonate-sulphate-natrium content. The Komsomolets Donbassa Mine is located in the axial portion of Chistyakovo-Snezhnoye syncline and is in hydraulic communication with the adjacent mines that developed coal seams of the Diamond suite. All closed mines (Donetskaya, Zhitomirskaya, Moskovskaya, Vinnitskaya and No. 222) are located at the edges of the syncline above the technical boundary of Komsomolets Donbassa Mine, and mine water from the closed mines infiltrates the KD mine workings (as a result of direct flow and drainage of aquifers and flooded goafs).

The aquifers are fed by atmospheric precipitation and infiltration. That is why during the flood period there is an increase in water influx from the adjacent mines. The average water influx into the mine workings of the mine is 650 - 1250 m^3/h.

The coal seams are not prone to rock bursts, nor they are prone to self-ignition; the dust is not explosive, threating and dangerous (L_3, L_4).

Komsomolets Donbass Mine – Outburst Potential for Mined Coal Seams

seam	not dangerous	threatening in terms of sudden gas and coal outburst	dangerous in terms of sudden gas and coal outburst	dangerous in terms of arching
L_7	to elevation (-389 m)	from elevation (-389 m)	- from elevation (-700 m)	-
L_6	-	from elevation (-160 m)	- from elevation (-550 m)	-
L_4	to elevation (-389 m)	from elev.(-389 m) to elev. (-645 m)	from elevation (-645 m)	from elevation (-645 m)
L_3	-	-	from depth 418 m	from depth 418 m

Factors that make mining operations difficult include areas of small-amplitude tectonic disturbances with amplitudes ranging from 0.02 to 1.0m. In the faulted areas there is intensive fracturing, coal dilution with clay material, and the presence of multiple interlayers of coaly shale, sometimes splitting of the coal seam into several intervals ('horsetail'). There are also local channel structures with angles of ($5^0 – 10^0 – 0^0 – 7^0$) and partial seam washouts with coal substituted by clay (L_4) or sand (L_6) material to the depth of 0.2-0.4 m.

Characteristics of the mined coal seams

Seam L_3

Coal seam L_3 is dangerous in terms of coal and gas outbursts, in terms of arching, but not dangerous in terms of rock bursts, coal dust is not explosive. The seam produces coal of grade “T”.

Coal seam L_3 has a complex structure, often splitting into four multiple seams. The thickness of interbeds comprised mainly of clay shale varies from 0.05 to 0.35 m. Useful seam thickness is up to 1.80 m, with a total thickness of 2.00 m. From the central to the southern area there is a reduction in seam thickness to 0.7 – 1.55 m.

Within the entire mine field the dip of the coal seam varies from 1 - 28 degrees. The gas content of the seam is 30 - 35 m^3/t on dry, ash-free basis. (A max gas content of 40.5 m^3/t on dry, ash free basis is observed near the north-east field border at 499 m of depth).

Mining of the seam is difficult due to presence of small-amplitude tectonic disturbances (flexure folds, faults, over thrusts) with displacement amplitudes of up to 0.6-1.0 m.

The lithological composition of the coal seam roof and floor is non-uniform within the mine field. The immediate roof contains: limestone - 35%; sand shale-30%; clay shale-20%; and-clay shale-15%.

The roof stability varies depending on lithology: limestone is generally stable, the sandy shale has moderate stability (in case of weak interlayer contact it has low or no stability), and sand-clay shale and clay shale have low stability (very unstable with thickness up to 0.5 m) and are prone to sudden collapse.

The main seam roof is represented by the interlayers of various shales with medium cavability. In the western and south-western parts of the mine field at 8 – 13 m distance there is coal L_3^1 and limestone L_4. There is no connection between coal and limestone; that is why the lower shales cave easily.

The immediate floor contains: sand shale - 60%; clay shale-17%; sand-clay shale - 6%; and sandstone - 17%.

The sand and sandy-clay shales have moderate stability and in case of moisture, they are prone to heaving. The clay shale has low to moderate stability and is prone to heaving. Sandstone in the floor is stable, not prone to heaving. The main floor has thick sand or sandy shale layers and is generally stable.

Seam L_4

Coal seam L_4 is dangerous in terms of sudden gas and coal outburst below the absolute elevation of 389 m, and dangerous in terms of sudden gas and coal outburst and arching below an elevation of 645 m. It is not dangerous in terms of rock bursts, and the coal dust is not explosive. The coal seam mainly has a simple structure, with a typical thickness of 0.95–1.10 m. To the west and south-west the seam thins to 0.7– 0.78 m. Within some areas with the seam splits into two benches with a total thickness of 0.78 – 1.15 m

Within the mine area the dip of coal seam varies from 2 – 30 degrees. The gas content of the seam is 25 - 35 m^3/t on dry, ash free basis. (A max gas content of 36.4 m^3/t on dry, ash free basis is observed near the eastern field border at 331.9 m of depth).

Seam mining is difficult due to:

- wash-outs of the roof (up to 40% of the entire area), the washed-out part of the seam is substituted with re-deposited roof rocks, and the seam thickness is reduced to 0.8 – 0.6 m, sometimes to 0.1 - 0.2 m;

- very weak bedding planes in the immediate roof rocks - clay shale (due to increased fracturing, presence of thin coal layers, carbonized vegetative residues, sliding planes);
- gas-saturated areas of intensive tectonic fracturing, abrupt variations in seam hypsometry.

The lithological composition of the coal seam roof and floor rock is quite uniform within the mine boundary.

The immediate roof contains: clay shale- 52%; sand-clay shale-30%; and sand shale - 18%.

The clay shale is unstable, and in the areas of increased fracturing or small thickness (0.04 – 0.1 m) it is very unstable. Sand-clay shale has no or low stability and sandy shale has low to medium stability.

The main seam roof is composed of easily cavable clay and sand-clay shales and medium cavable sand shales and sandstones ($m \leq 5$ m), above which there is limestone (at 8-16 m distance) and sandstone. Sandstone and limestone are hard to cave.

The immediate floor contains: sand shale - 60%; clay shale-30%; sand-clay shale-9%; and sandstone-1%.

Sand and sandy-clay shales have medium stability, are prone to heaving in case of moisture, while clay shales have medium to low stability, and are prone to heaving. Sandstone in the floor is stable and not prone to heaving. The main floor contains shales with underlying sandstone and is stable.

Seam L_6

Coal seam L_6 can experience sudden gas and coal outburst below elevation 550 m. It is not dangerous in terms of rock bursts and the coal dust is not explosive.

Coal seam L_6 has a relatively continuous structure and covers most of the mine area. The exclusion is in the extreme south-east part of the field and a narrow band along the southern field boundary, where the seam is parted by an over 0.40 m interbed. Within the area of uniform seam coverage, the complex seam structure prevails with thin interlayers (0.05 – 0.10 m). The typical useful thickness is 1.20–1.50 m, while the total thickness is 1.5 – 1.8 m. After separation the upper 0.48 – 1.0 m thick seam part is becomes the main one.

Within the mine area the dip of the coal seam varies from 2 - 10 degrees. The gas content of the seam is about 35 m^3/t on dry, ash free basis (max gas content of 38.6 m^3/t on dry, ash free basis is observed near the south field border at 467 m depth).

Within the mine area there are multiple seam wash-outs in the roof which can range from 60 to 650 m long and 5 – 15m wide. Useful seam thickness within the washed-out area is reduced to 0.5 – 1.1 m and coal is substituted with sand shale or sandstone. The wash-outs are frequently accompanied with micro tectonic effects, abrupt variations in the seam bottom hypsometry. The relatively even bedding of the seam in some areas is complicated with a series of over thrusts that are 50 to 300 m long, with a displacement of 0.05 – 0.8 m.

The lithological composition of the coal seam roof and floor rock is not uniform within the mine area.

The immediate roof contains: sandstone-40%; sand shale- 20%; clay-15%; sand-clay shale - 10%; and limestone-15%.

Rock stability of the roof varies depending on the lithology: sandstone and limestone roof is generally stable, but in areas of increased fracturing and wash-outs they are only moderately stable (and low stability for the clay type of limestone); sandy shale roof has moderate stability (and low stability in case of weak interlayer connection). Sand-clay shale has low stability, and clay shale has poor stability (no stability for thickness up to 0.5 m).

The main roof is composed of thick layers of the same lithotype or interlaid thin shale and sandstone. Sandstone with thickness over 5 m and limestone are hard to cave, while those less than 5 m thick and interlaid rocks or thick shale have medium cavability.

The immediate and main seam floor contains: sand shale - 65%; clay shale - 22%; sand-clay shale - 10%; and sandstone - 3%.

Sand and sandy-clay shales have moderate stability; in case of moisture they are prone to heaving. Clay shale has low and medium stability and is prone to heaving. Sandstone in the floor is stable, not prone to heaving.

Seam L_7

Coal seam L_7 is dangerous in terms of sudden gas and coal outburst below an absolute elevation of 389 m and dangerous in terms of sudden gas and coal outburst below an elevation of 700 m. It is not dangerous in terms of rock bursts and coal dust is not explosive.

The coal seam has a simple structure (except for a small area in the north-west parts of the field, where the structure is complex). The typical thickness of seam L_7 is 1.0 – 1.10 m with a minimum thickness ranging from 0.8 – 0.68 m.

Within the mine area the dip of the coal seam varies from 2 - 24 degrees. The gas content of the seam is 30 - 35 m^3/t on dry, ash free basis. According to DTEK, the maximum gas content of 39.1 m^3/t of dry, ash free mass is observed at 434 m depth.

Mining of the L_7 seam is difficult due to:

- Wash-outs of the roof and glide planes, micro folds, and coal inclusions. The washed out part of the seam is substituted with sandstone, and seam thickness is reduced to 0.8 – 0.6 m, sometimes as little as 0.2 m;
- Lens-shaped sandstone inclusions in the coal seam (sizes up to 0.3 * 12 m);

- Small-amplitude tectonic disturbances (faults over thrusts) with the amplitude of displacement up to 0.6 m, and abrupt seam hypsometry variations;
- Lithological composition of the coal seam roof and bottom rock is non-uniform within the mine field.

The immediate roof contains: clay shale - 50%; sand shale - 40%; sand-clay shale - 8%; and sandstone - 2%.

The roof rock stability is also variable: sandstone is stable, although in the washed-out areas it has low stability; sand and sandy-clay shale has moderate stability (in case of weak interlayer connection it has low stability); and clay shale roof has low to very low stability.

The main roof rocks are similar to lithotypes of the immediate one: Clay, sandy-clay shales and sandstones less than 5 m thick, with medium cavability, and hard to cave areas where sandstone thickness is over 5 m.

The immediate floor rock consists of: sand shale - 75%; clay shale - 15%; sand-clay shale - 5%; and Sandstone - 5%

Sand and sandy-clay shales have high to moderate stability, while the clay shale has low to medium stability and are prone to heaving. Sandstone in the floor is stable and is also not prone to heaving.

The main floor has sand or sandy shale layers and is stable.

Average aggregate water inflow to the mine workings is currently in the range of 980 to 1150 m^3/h. The water yield of the enclosing rock is relatively low (0.2-0.5 m^3/h). In Carboniferous strata, water is normally contained in the sandstone and limestone, and in some cases in fractured sandy shale. There is no water-bearing rock near the coal seam. Ground water is contained in seam fractures and is under pressure. Water flow rates vary due to irregular fracturing. Water inflow at most horizons is from 1 or 2 to 5 m^3/h.

Gas Resources

Overview of Gas Resources

There are nine seams classified as reserves by the company, four of which are being developed: the L_7, L_6, L_4 and L_3 seams; the L_7 is closest to the surface. Coal is mined using seven longwall faces in the four seams, with the L_7 and L_4 seams having the highest gas contents with reported contents of 37.94 m3/t and 53.50 m3/t, respectively.[29]

Average methane releases into the mine workings total 299.84 m^3/min, with ventilation air methane

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[29] Geologic data provided by DTEK

(VAM) flow equaling 229.39 m3/min and gas drainage averaging 70.45 m^3/min. The CH_4 concentration in the gas drainage system averages 35-40%.

The table below shows the regulatory requirements for methane concentrations in Ukrainian mine workings.

Air flow, pipeline	Unacceptable methane concentration, % by volume
Return air from a blind working, chamber, maintained working	Over 1
Return air from a production face, extraction section with no gas meters available	Over 1
Return air from a production face, extraction section with gas meters available	Over 1.3
Return air from a mine-take wing, the mine	Over 0.75
Fresh air to an extraction section, production faces, blind workings and chambers	Over 0.5
Local methane accumulation at blind, extraction and other workings	2 and more
Return air from a mixing chamber	2 and more
Pipelines for the isolated methane drainage with the help of fans (venturi jets)	Over 3.5
Gas drainage pipelines	From 3.5 to 25

The mine maintains three main ventilation units located in the main shaft and ventilation shafts 1 and 3 and employs an exhausting ventilation system. The mine receives 50,000 m^3 of air per minute. The air inflow at each extraction section fluctuates between 1,500 and 2,200 m^3 of air per minute.

The longwalls employ a Y-type ventilation system to manage the higher methane output at the longwall face. In a Y-type ventilation system, fresh air travels toward the longwall face through intake shafts along both sides of a retreat longwall. One source of fresh air is routed across the longwall face intersecting with the other source of fresh air, with the combined mass of air being transported past the gob rather than back down the longwall panel. These systems are often employed where the available airflow is insufficient to dilute the gas emitted from the workings.[30]

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[30] UNECE *Best Practice Guidance* - note: Y-type ventilation systems require higher investment such as driving of an additional roadway, roadside dam (pack wall), and strong support of the roadways remaining open behind the longwall in the goaf.

In addition to mine ventilation, the DTEK employs gas drainage in the L_7 and L_4 seams to degas the mine. Drainage is not necessary for the L_6 and L_3 seams which have gas contents of 28 m3/t and 15 m3/t, respectively. Drainage is accomplished using cross-measure boreholes drilled into the roof of the L_4 and L_7 seams. The efficiency of satellite gob gas drainage in seam L_7 is 52-69% and 47-70% in seam L_4. A gas gathering system with vacuum pumps pulls the gas to the surface. The methane content in the captured surface mixture varies from 30 to 50%, which enables its utilization.

DTEK reports the following flow and concentration measurements for different sections of the L_4 and L_7 seams:

- Gas production from KV 1 of the eastern longwall of seam L_4 in block 2 is 14-30 m ^{3} min. with concentration 50-75%.
- Gas production from KV 4 of the western longwall of seam L_4 in block 2 is 8-17 m ^{3} min. with concentration 40-55%.
- Gas production from KV 10 of the western longwall of seam L_4 in block 3 is 17-28 m ^{3} min. with concentration 43-55%.
- Gas production from KV 2 of the western longwall of seam L_7 in block 5 is 20-33 m ^{3} min. with concentration 40-70%.
- Gas production from KV 12 of the western longwall of seam L_7 in block 3 is 20-27 m ^{3} min. with concentration 50-75%.

Surface well drainage is not currently used at the Komsomolets Donbassa Mine. An attempt was made around 1998 to drill vertical boreholes, but the experiment failed due to problems completing the well.

Degassing the seams using vertical boreholes is challenging not only because of geological conditions but also due to mining advance rates. The seam nearest to surface, the L_7, advances at more rapid rate than the L_4. Therefore, pre-drainage and gob wells must be shut in prior to mine-through of the L_7 or drilling and completion must be designed to allow for the KD Mine to mine through the wells in the L_7 while keeping them intact to continue drainage from the L_4. This would require leaving pillars around each borehole in each of the mined seams. This method is used in the United States with the pillar dimensions being 80 ft x 80 ft (25m x 25m). Otherwise, continued degassing of the lower coal seams must rely on in-mine drainage using cross-measure boreholes, short cross-panel horizontal boreholes or long-hole directionally drilled boreholes.

The tables below provide detailed gas and geologic data for the L_7 and L_4 coal seams that was used as inputs for the COMET model (pre-mine drainage) and the Methane Control and Prediction Model (surface gob gas drainage). In addition data was provided by DTEK for the L_6 and L_3 seams.

Seam L_7			
Parameter	**Units**	**Data Requirement**	
		COAL SEAM	**SANDSTONE LAYER**
Drainage Area	**Hectares**	126	126
Reservoir Thickness	**Meters**	1.0	50
Depth to Reservoirs	**Meters**	873	940
Initial Reservoir Pressure	**kPa**	N/A	N/A
Cleat and Pore Water Saturation	**%**	0.8	1.0
Permeability	**Millidarcy**	N/A	0.00
Porosity	**%**	N/A	1.9-4.0
Pore-Vol. Compressibility	**-**	N/A	
Cleat Spacing	**cm**	15-30	
Langmuir Volume (Coal)	**m^3 / tonne**	1.39	
Langmuir Pressure (Coal)	**kPa**	N/A	
Gas Content (Coal)	**m^3/tonne**	35	
Gas Gravity	**-**	N/A	N/A
Reservoir Temperature Gradient	**degree C / 100m**	2.3	2.3
Water Viscosity	**cp**	N/A	N/A
Sorption Time	**Days**	N/A	

L$_7$ Seam - for gob gas model		
Parameter	**Units**	**Comment**
Percentage of Panel Completed	**%**	ARI will model various percentages
Linear Advance Rate for each panel	**Meters/day**	3.8
Surface Elevation	**Meters**	264.9
Average Overburden in the Pre-Feasibility Study Area from the top of the L7 seam to the surface	**Meters**	870
Casing diameter	**Millimetres**	ARI will input
Distance of Slotted Casing Bottom to the Top of the L7 Seam	**Meters**	ARI will input
Distance of the Boreholes to the Return for the Longwall Panel(s)	**Meters**	ARI will estimate from mine maps unless DTEK has a preference
Distance of the Boreholes from the Longwall Panel Start	**Meters**	ARI will estimate from mine maps unless DTEK has a preference
Planned Longwall Panel Length in the L7 Seam	**Meters**	1750
Planned Panel Width in the L7 Seam	**Meters**	250
Average barometric pressure for the Pre-Feasibility Study Area	**kPa or in Hg**	N/A
Average exhauster vacuum	**In Water Column or other unit**	ARI will estimate from mine maps unless DTEK has a preference

Seam L_6			
Parameter	**Units**	**Data Requirement**	
		COAL SEAM	**SANDSTONE LAYER**
Drainage Area	**Hectares**	126	126
Reservoir Thickness	**Meters**	1.65	55
Depth to Reservoirs	**Meters**	959	1000
Initial Reservoir Pressure	**kPa**	N/A	N/A
Cleat and Pore Water Saturation	**%**	0.8	1.3
Permeability	**Millidarcy**	N/A	0.02
Porosity	**%**	N/A	2.5
Pore-Vol. Compressibility	**-**	N/A	
Cleat Spacing	**cm**	15-30	
Langmuir Volume (Coal)	**m^3 / tonne**	1.42	
Langmuir Pressure (Coal)	**kPa**	N/A	
Gas Content (Coal)	**m^3/tonne**	27.9	
Gas Gravity	**-**	N/A	N/A
Reservoir Temperature Gradient	**degree C / 100m**	2.3	2.3
Water Viscosity	**cp**	N/A	N/A
Sorption Time	**Days**	N/A	

Seam L_4			
Parameter	**Units**	**Data Requirement**	
		COAL SEAM	**SANDSTONE LAYER**
Drainage Area	**Hectares**	126	126
Reservoir Thickness	**Meters**	1.0	12
Depth to Reservoirs	**Meters**	1056	1076
Initial Reservoir Pressure	**kPa**	N/A	N/A
Cleat and Pore Water Saturation	**%**	0.7	0.9
Permeability	**Millidarcy**	N/A	0.01
Porosity	**%**	N/A	3.3
Pore-Vol. Compressibility	**-**	N/A	
Cleat Spacing	**cm**	15-30	
Langmuir Volume (Coal)	**m^3 / tonne**	1.412	
Langmuir Pressure (Coal)	**kPa**	N/A	
Gas Content (Coal)	**m^3/tonne**	36.1	
Gas Gravity	**-**	N/A	N/A
Reservoir Temperature Gradient	**degree C / 100m**	2.3	2.3
Water Viscosity	**cp**	N/A	N/A
Sorption Time	**Days**	N/A	

Seam L_3

Parameter	Units	Data Requirement	
		COAL SEAM	SANDSTONE LAYER
Drainage Area	Hectares	126	126
Reservoir Thickness	Meters	1.7	15
Depth to Reservoirs	Meters	1093	1112
Initial Reservoir Pressure	kPa	N/A	N/A
Cleat and Pore Water Saturation	%	0.8	1.3
Permeability	Millidarcy	N/A	0.01
Porosity	%	N/A	3.3
Pore-Vol. Compressibility	-	N/A	
Cleat Spacing	cm	15-30	
Langmuir Volume (Coal)	m^3 / tonne	1.412	
Langmuir Pressure (Coal)	kPa	N/A	
Gas Content (Coal)	m^3/tonne	35	
Gas Gravity	-	N/A	N/A
Reservoir Temperature Gradient	degree C / 100m	2.3	2.3
Water Viscosity	cp	N/A	N/A
Sorption Time	Days	N/A	