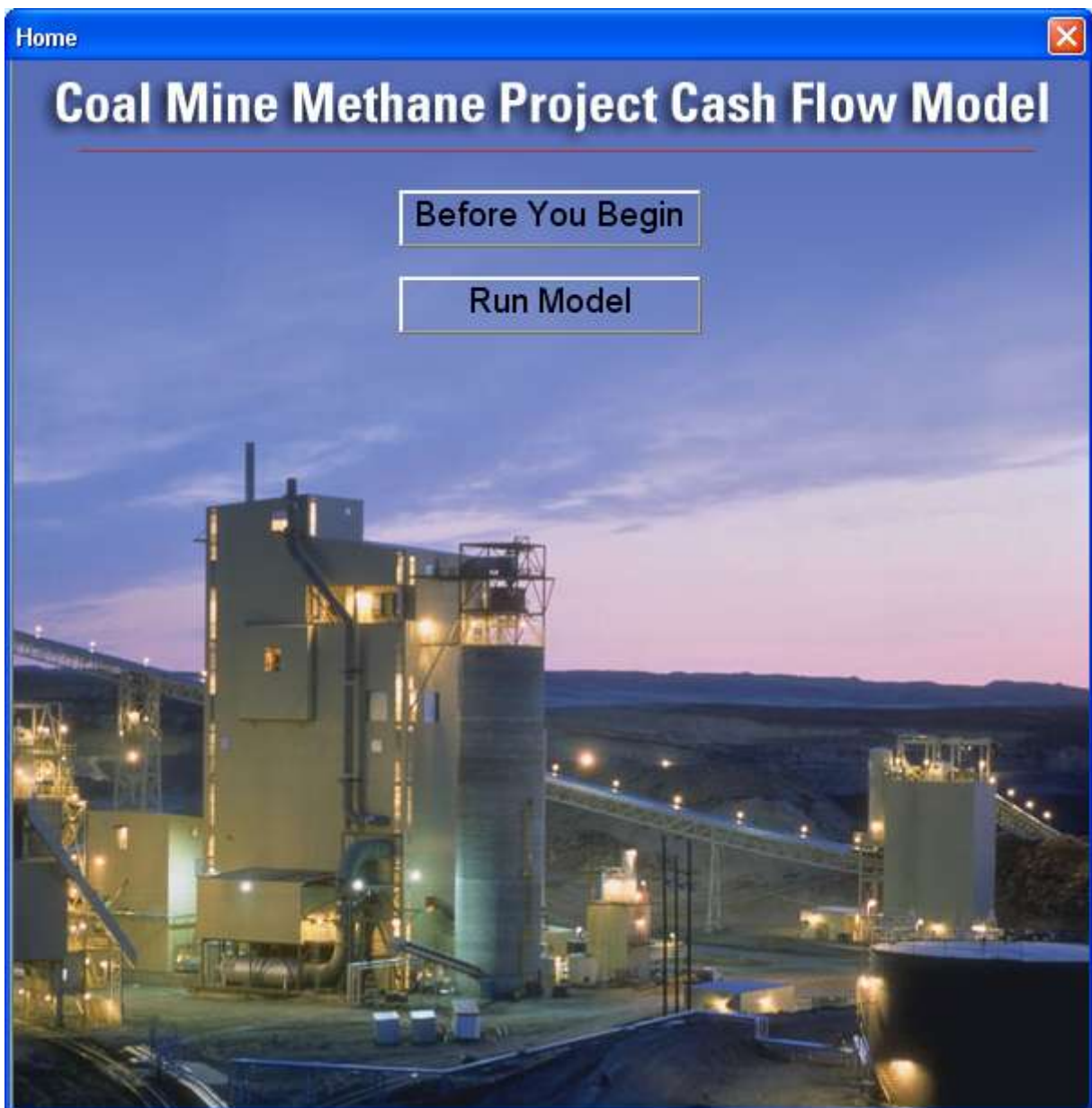

User's Manual for the Coal Mine Methane Project Cash Flow Model

(Version 2)



January 2011

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1.0 Introduction

Welcome to the Coal Mine Methane Project Cash Flow Model, Version 2.0. The U.S. Environmental Protection Agency's Coalbed Methane Outreach Program (CMOP) designed the model to help you—a coal mine owner/operator, project developer, or other interested party—evaluate the potential economic viability of recovering and beneficially using coal mine methane in one of eight ways from gob wells, abandoned mine drainage wells or mine ventilation air. Version 2.0 of the model upgrades the previous version by adding the capability to investigate the benefits of oxidizing methane in mine ventilation air in exchange for marketable carbon credits.

The model was NOT DESIGNED for conducting a detailed economic analysis or for designing a coalbed methane project. A detailed feasibility assessment should be conducted by qualified professionals experienced in coalbed methane recovery and use, prior to preparing a system design, initiating construction, purchasing materials, or entering into agreements to provide or purchase energy from a coal mine methane project. To start your search for a project developer or for a service or equipment provider in the CMM industry, visit the CMOP Network Contacts list (www.epa.gov/cmop/networkcontacts.html).

CMOP is a voluntary outreach program with a mission to promote the profitable recovery and use of coal mine methane (CMM), a greenhouse gas more than 20 times as potent as carbon dioxide. By working cooperatively with coal companies and related industries, CMOP helps to address barriers to using CMM instead of emitting it to the atmosphere. In turn, these actions mitigate climate change, improve mine safety and productivity, and generate revenues and cost savings.

Input and Output

The model was designed for users who have readily accessible data specific to a coal mine, but who do not necessarily have the data, experience, or knowledge to evaluate a coal mine methane project.

The user will be required to enter data specific to a coal mine and coal mine methane (CMM) project needs. For data related to the CMM project technology, EPA has provided an extensive set of default values that eliminate the need to be familiar with CMM technologies. You can override defaults if you have more specific data.

Using the combination of user-provided and default parameters, the model calculates the discounted cash flow, discounted Net Present Value, and the Internal Rate of Return for the project.

The model's output includes the following:

- Capital cost
- Operating cost
- Size of the project
- Sellable renewable energy credits

-
- Economic value
 - Internal Rate of Return (IRR)
 - Net Present Value (NPV)
 - Cash flow

Contact:

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2.0 Getting Started

This User's Manual is organized to follow the model input screens. Follow the instructions below to open and use the model. Once you have the model up and running, the User's Manual leads you through the data input screens and model output screens. You will learn how to print or save results. Finally, you can check Section 4 to learn more about the model's assumptions for each project type.

Open the Model

Use a PC running a recent Microsoft Windows Operating System and Excel. For example, use Microsoft Windows XP and Vista Operating Systems and Excel 2003 or Excel 2007. Do not use a non-Microsoft Windows Operating System.

Save the model to your local drive. Do not open the model until you have changed the attributes and Security Settings as described below.

Attributes. Before opening the model, right click on the file name. Select **Properties**. On the **General** tab, check **Read-only** under Attributes. This prevents you from accidentally corrupting the file. Click **Apply** to implement your change.

Security. Before opening the model, open Excel and set the Security Level.

- In Excel 2003, go to the **Tools** menu and select **Options**. On the **Options** window select the **Security** tab, then click on the **Macro Security...** button. Select either the **Medium** or **Low** options. Click **OK** to save your changes.
- In Excel 2007, click on the **Office Button**. Select **Excel Options...** at the bottom right. Select **Trust Center** from the left-hand menu, then select **Trust Center Settings**. Select **Macro Settings** from the left-hand menu. Select the button **Disable all macros with notification**. Select **OK** to save your changes.

Open the model the same as you would open any Excel spreadsheet.

- In Excel 2003, select **Enable Macros** if prompted by the Security Warning Window. The Macros do not contain viruses. If you choose **Disable Macros**, then you will not be able to run the model.
- In Excel 2007, a Security Warning appears in the opened spreadsheet file. Next to the Security Warning, click on **Options...** Select the button **Enable this content**. Click on **OK** to save your changes.

Screen Resolution: If you cannot view the entire data entry screen, then you must change the screen resolution on your computer monitor:

- In Windows 2000, right click on the Desktop and select **Properties**. Select the **Settings** tab. Set the Screen resolution to no less than 1024 x 768.

-
- In Windows XP, right click on the Desktop and select **Properties**. Select the **Settings** tab. Set the Screen resolution to no less than 1024 x 768.
 - In Windows Vista, right click on the Desktop and select **Personalize**. Select **Display Settings**. Set the Screen resolution to no less than 1024 x 768.

Use the Model

Although the model is constructed as an Excel spreadsheet, you operate the model from Visual Basic screens. When choosing a scenario on the first screen, select the scenario and the source of gas to continue to the following data input screens.

In the data input screens, data for the specific scenario can be either user-provided or default data. Complete each field on all four tabs of the data input screen. Use the **<<Back** and **Next>>** buttons to return to previous tabs to edit your data. Once you have completed all fields, the **Calculate** button becomes available. Select **Calculate** and the model generates a **Preliminary Report**.

Select **Units Help** at any time for definitions of units in the model.

Note that the model generally provides a range of values rather than specific default values. If you enter a value outside of the recommended range, you will receive a warning. However, the model will use your value if you choose not to change it.

3.0 Quick-Start Example Calculation

This section leads you through a quick-start example calculation to evaluate the feasibility of a coal mine methane project. The screens shown in this section represent data that have been entered for a coal mine that is exploring a pipeline gas project. This quick-start example leads you to the report that appears at the end of this section.

Start

Coal Mine Methane Project Cash Flow Model

← Go Back

1. Select a methane end use scenario for cash flow analysis: **Scenario Help**

- Coal Drying
- Flaring - Enclosed
- Flaring - Open
- Mine Boilers
- On-site Electricity Generation - Engine
- Pipeline Gas
- Stand-alone VAM Oxidizer
- Supplemented VAM Oxidizer

2. What is the source of the supplemental methane?

- abandoned mine methane
- gob gas methane

3. Select a flare type if flares are to be included in the project:

- no flare
- open flare
- enclosed flare

Continue

Start

Start by selecting one of the eight project types. Click on the **Scenario Help** button to learn more about each scenario. (See further details about each scenario in Section 4.)

Depending on the scenario selected, you will be presented with additional questions about the source of methane for the project. Note for abandoned mine methane (AMM) and gob gas methane, the model assumes wells are drilled from the surface. For ventilation air methane (VAM) oxidation, the ventilation air is ducted from the evasee to the VAM oxidizer that is located near-by. Also note that the model does not apply to pre-mine drainage.

The coal drying, mine boilers and supplemented VAM scenarios allow you to select a backup flare. If the project cannot fully utilize the available CMM, then the unused CMM can be burned in a flare to recover additional carbon credits.

If a flare is part of the project, choose whether the flare is open or enclosed. An open flare is a combustion device for burning gases, consisting of a burner that is mounted such that the flame is "open" and is not shielded. An enclosed flare is a combustion device for

burning gases, consisting of a burner that is mounted such that the flame is shielded or enclosed in a stack.

Pipeline Gas

Gas Collection | Gas Availability | User-Defined Inputs | Default Parameters

Gathering & Delivery System Parameters	Amount / Units	Recommended Values
What is the cost of satellite compressors?	1000 \$/HP	[1,000]
What is the distance from the drainage area to the onsite project?	21000 ft	[21,000]
What is the cost of installing header pipe from the drainage area?	40 \$/ft	[40]
What are the compressor and blower efficiencies?	0.035 HP/mcfd	[0.02-0.07]
What is the mining rate?	12000 ft/yr	[12,000]
What is the spacing between drainage wells?	1000 ft	[1,000]

Do you want to include the drainage well and drainage blower development costs in this cost analysis? Yes No

What is the cost of well-head blowers?	1000 \$/HP	[1,000]
What is the mine depth?	1000 ft	[1,000]
What is the drilling cost?	140 \$/ft	[140]
What is the fraction of this project's drainage system cost that will be included in the analysis?	100 %	[100]

Note: The drainage system cost is based on supplying only the portion of available drainage gas that is needed by the project. However, the user can elect to allocate only a percentage of this cost to the project. See the Users Manual for additional information.

<< Back | Next >> | Calculate | Select New Scenario | Units Help

Gas Collection

For AMM, gob gas and supplemented VAM, the model uses the input from the **Gas Collection** tab to obtain information on the system that gathers and delivers the coal mine drainage gas to the project.

Gathering and Delivery System Parameters

The first six questions address the system used to gather and convey the coal mine drainage gas to the project. The costs for this portion of the system are included in the project cost and feasibility analysis. Collection piping and a compressor station are the primary components of this system.

To estimate mining rate in feet per year (ft/yr) when you know only the mining rate in tons per year (tons/yr), use the following equation:

$$\text{ft/yr} = (\text{tons/yr} * 2,000\text{lb/ton}) / (60 \text{ lb/ft}^3 * \text{height of mined panel} * \text{width of mined panel})$$

Drainage System Parameters

The drainage system includes the drainage wells and drainage blowers used to bring the drainage gas to the surface. You can choose to include (**Yes** button) or exclude (**No** button) the drainage well and drainage blower development costs in the project cost analysis.

For example, if your coal mine does not have a drainage system in place, you will likely want to include these costs to give a better overall picture of the project. However, if the mine already has a drainage system in place for reasons such as safety, then you could exclude these costs and focus the analysis on the additional costs of just the energy recovery project.

When you select **Yes**, the model uses your drainage system inputs to cost the appropriate drainage system. If you select **No**, these data entry fields are inactivated. If you select **Yes**, you may choose the percentage of the project's drainage system to include in the analysis—from 1 to 100%. For example, choose 50% if you want the model to factor in only half the cost of the mine's drainage system.

When data entry is complete, select **Next >>** to go to the next tab.

Gas Availability Parameters	Amount / Units	Recommended Values
What do you expect the CMM drained per day to be?	1500 mcf/d	[See footnote.]
What is the fraction of CMM available after losses?	95 %	[80-99]
What percent methane is the drained gas?	85 %	

The project will use 100% of the available CMM.

Note: CMM flow is just the methane flow, not the total gas flow. If no drainage system is currently in place, the expected drained CMM flow can be estimated as 20% to 60% of the current VAM flow. Typically gassy mines in the United States have an actual or expected drained CMM flow of between 500 and 1500 mcf/day.

<< Back Next >> Calculate Select New Scenario Units Help

Gas Availability

The model uses the input from the **Gas Availability** tab to determine if enough gas is available for the project or if the project will have excess gas. The required data input for this tab varies with each scenario. Note that throughout the model, CMM flow refers to only the flow of coal mine methane in the gas and not the total drainage gas flow.

Each scenario has a minimum methane concentration, below which it will not perform optimally. If the methane concentration is below the minimum that manufacturers recommend for the scenario you have selected, the model provides a warning. However, the model will run the calculations with your value if you choose not to change to a scenario type that is compatible with your mine's methane concentration.

When you enter data, the model automatically calculates and presents the gas availability in the box located in the middle of the screen. For example, see "The project will use 100% of the available CMM" in the above screen capture.

For the mine boilers and coal drying scenarios, which are assumed to be using existing equipment, there may be insufficient CMM to meet the equipment needs. The remaining fuel demand is assumed to be supplied by whatever fuel they currently use. In other cases, the available gas may exceed the boiler or dryer's gas requirements. If flares are not chosen to burn this excess gas, then the gas is available for other projects. Data on the excess flow could be entered into other model runs to determine whether an additional project is feasible.

Guidance is provided in the lower portion of the screen on a common method for estimating CMM flow when no measure of CMM flow is available. When data entry is complete, select **Next >>** to go to the next tab.

User-Defined Input Parameters	Amount / Units	Recommended Values
Scenario Name (up to 40 characters):	Pipeline Gas Run #1a	
What is the planned project operational lifetime?	15 years	[10 - 20]
What is the loan term?	7 years	[5 - project lifetime]
What interest rate is charged for the loan?	6 %	[Prime plus 1-3%]
What is the developer's equity share in the project?	20 %	[0-100]
What percent of CMM is consumed by prime-mover use?	10 %	[10]
What is the carbon credit unit sale price?	3.00 \$/tonne CO2E	[\$2.00-\$8.00]
What is the distance to the natural gas pipeline?	35000 ft	
What is the cost of electric power used by the project?	70 \$/MWh	[\$50-\$90]
What is the price of the methane sold to the pipeline?	8 \$/mmBtu(HHV)	[\$5.00-\$12.00]
What is the installed cost of high pressure line from project to natural gas pipeline?	55 \$/ft	

User-Defined Inputs

The **User-Defined Inputs** screen collects the key user inputs required by the model to conduct the economic analysis.

Name your scenario using up to 40 characters. When you **Print** your scenario, the **Scenario Name** appears at the top of the report. When you **Save** the model run, the **Scenario Name** is the default name for the file. Note that the name of the scenario type does not appear in the output report automatically and you will not be able to identify the end-use type unless you specify it in the **Scenario Name**.

Input for the **User-Defined Inputs** tab will vary greatly from user to user and project to project. Thus, the model generally provides a range of values rather than specific default values. You will receive a warning if you enter a value outside of the recommended range, but the model will use your value if you choose not to change it.

When data entry is complete, you have enough data to calculate the economic viability of your project. When you select **Calculate** from the User-Defined input tab, the model automatically uses the default data from the **Default Parameters** tab for calculations. However, you should review the default parameters to determine if any are appropriate for your specific project. If you want to edit the **Default Parameters**, then select from the **Default Parameters** tab and edit the data.

Pipeline Gas

Gas Collection | Gas Availability | User-Defined Inputs | **Default Parameters**

Default Parameters	Amount / Units	Recommended Values
What is the inflation rate?	<input type="text" value="2.5"/> %	[2.5]
What is the real discount rate?	<input type="text" value="12"/> %	[12]
What are the royalty, severance tax, and negotiation fees?	<input type="text" value="20"/> %	[20]
What is the contingency factor?	<input type="text" value="5"/> %	[5]
How many hours per year will the project operate?	<input type="text" value="8000"/> hrs/year	[7500-8300]
What is the annual escalation rate for carbon credits?	<input type="text" value="2"/> %	

Restore Default Values

<< Back | Next >> | Calculate | Select New Scenario | Units Help

Default Parameters

The **Default Parameters** tab generally contains economic parameters that are typically independent of the project or mine.

Since many of these parameters may not be familiar to users, EPA has provided a full set of default parameters. However, users can override the default parameters. Selecting **Restore Default Values** restores the EPA-provided values.

From the **Default Parameters** input screen, you can select **<<Back** to review or edit your data in other tabs. You can also **Select New Scenario** to restart the model for a new scenario. However, all data entered for the current scenario will be lost.

When data entry is complete, select **Calculate** and the model generates a **Preliminary Report**.

Preliminary Report

The financial estimates for your project are shown below. Select the View/Print report to generate a presentation-quality report of this analysis, including a bar graph showing the Net Cash Value of the project.

Available CMM for Other Projects	0 mcf/d
Total capital cost	7,877,000 \$
Total annual cost	2,877,000 \$/year
Equity percent	20 %
Equity amount	1,575,000 \$
Loan amount	6,302,000 \$
Interest rate	6 %
Carbon credits earned per year	175,983 tonne/year
Carbon credit unit value	3.00 \$/tonne CO2E
Internal rate of return (IRR)	9.36 %
Net present value	-516,000 \$
Real discount rate	12 %
Quantity of exported Methane	390,720 Mcf/year

Buttons: View/Print Report, Show Cash Flows, Select New Scenario, Modify Inputs, Save Scenario

Preliminary Report

The **Preliminary Report** presents the financial estimates for your project. From the preliminary report screen, you can **View/Print Report**, **Show Cash Flows**, **Select New Scenario**, **Modify Inputs**, or **Save Scenario**.

On the **Preliminary Report**, the **Available CMM for Other Projects** represents the volume of gas remaining, if any, that is available after meeting the project's gas needs. Data for the excess gas could be used in a **New Scenario** to determine if an additional project is feasible.

The **Total Capital Cost** is the sum of the initial, one-time cost outlay to install the methane recovery system and the initial, one-time cost outlay to set up the methane utilization system. This includes the cost of the satellite compressor station at the mine, the pipeline that connects the compressor to the gas project, and the cost of end-use equipment at the gas project. This may also include the cost of the blower system if the user chooses to include drainage system parameters in this analysis.

The **Total Annual Cost** is the sum of the annual costs to operate and maintain the methane recovery system and the annual costs to operate and maintain the utilization system. This includes the cost of piping and associated valves and meters necessary to get

the gas from the wellhead to the compressor, and the cost of operating and maintaining the end-use equipment. This may also include the cost of drilling new gob wells if you choose to include drainage system parameters in the analysis, or the cost of relocating the VAM oxidizer if the mine vents are relocated during the life of the project.

Select **View/Print Report** to view the **Preliminary Report** showing your project's financial results, which includes your input as well as cash flow analysis. The hard copy of the report represents your record of this scenario run. Print this report for your files using the print menu. Pages 13 and 14 show an example report for the scenario presented in this manual.

Select **Show Cash Flows** to view the **Cash Flow Report**, which presents the net cash flow over the lifetime of the project—up to 20 years. The Cash Flow Report includes year 0, which is the year to construct the project. Page 15 shows an example cash flow report.

Select **Save Scenario** to save your results to your computer. When you retrieve the saved file, the model opens to the Preliminary Report screen.

Once you have printed or saved the scenario, you can **Modify Inputs** on the current scenario, or you can **Select New Scenario**. If you did not save or print results, you will lose results of the current scenario when you select a new scenario.



Goal Seek

The **Goal Seek** button on the **Preliminary Report** allows you to determine the carbon credit unit value that would be needed to meet your own specific goal for internal rate of return.

For example, the Pipeline Gas Run #1 project that is presented in this manual has an initial net present value of \$-375,000 and initial IRR of 10.10%, as shown in the Preliminary Report on page 11. However, by inputting 13.0% IRR into Goal Seek, the model determines that a carbon credit price of \$3.46 is required to achieve the financial goal. The financial viability improves to a net present value of \$198,000 based on a carbon price of \$3.46 per ton CO₂E.

EPA chose carbon credit price for the goal seek function because that parameter is the most flexible and the one for which you could negotiate or obtain a better value to improve the financial viability of your project.

Coalbed Methane Scenario: Pipeline Gas Run #1



Gathering & Delivery System

What is the cost of satellite compressors?	1000	\$/HP
What is the distance from the drainage area to the onsite project?	21000	ft
What is the cost of installing header pipe from the drainage area?	40	\$/ft
What are the compressor and blower efficiencies?	0.035	HP/mcfd
What is the mining rate?	12000	ft/yr
What is the spacing between drainage wells?	1000	ft

Drainage Well & Blower Development Costs

What is the cost of well-head blowers?	1000	\$/HP
What is the mine depth?	1000	ft
What is the drilling cost?	140	\$/ft
What is the fraction of this project's drainage system cost that will be included in the analysis?	100	%

Gas Availability

What is the source of the coal mine methane?	surface gob gas drainage
Percent Methane in Drainage Gas	85 %
What do you expect the CMM drained per day to be?	1500 mcf/d
What is the fraction of CMM available after losses?	95 %

User-Defined Inputs

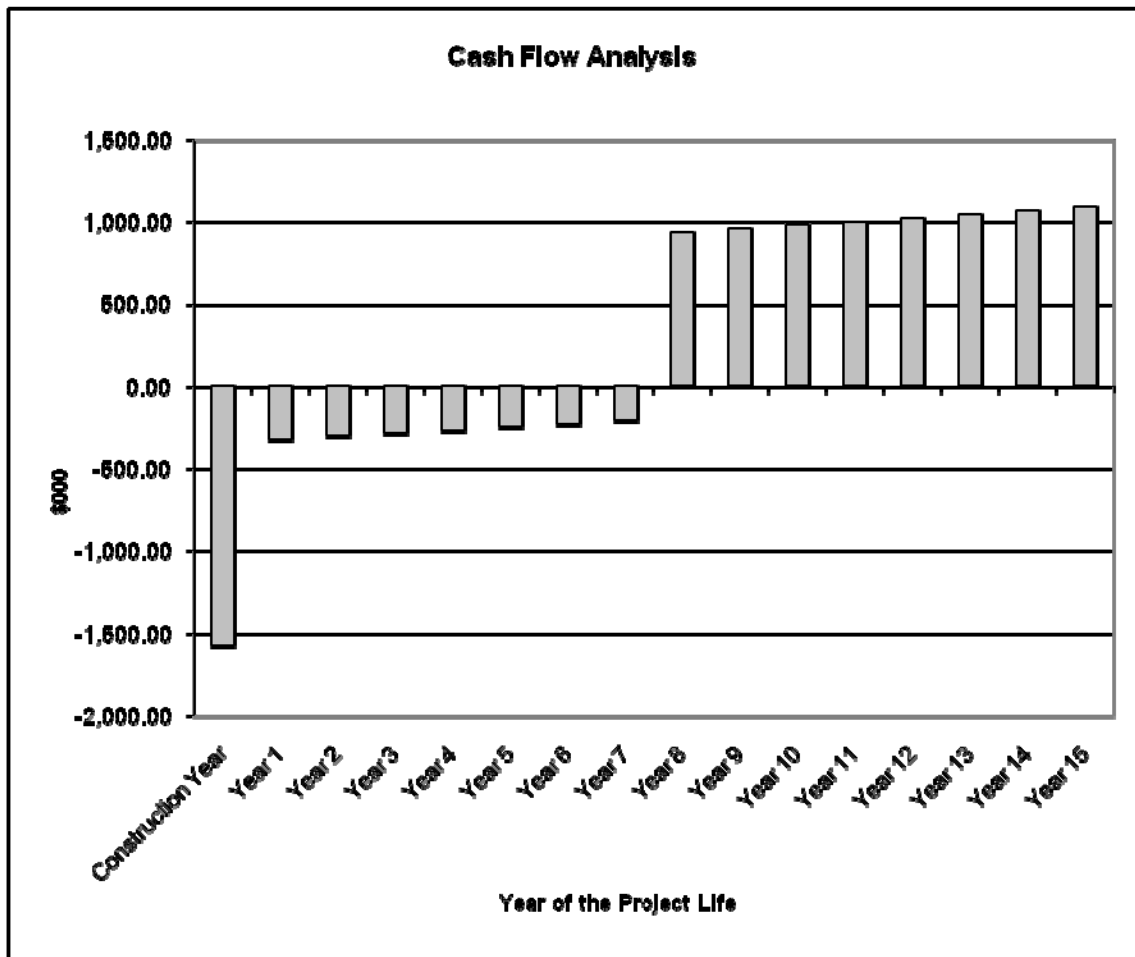
What is the planned project operational lifetime?	15	years
What is the loan term?	7	years
What interest rate is charged for the loan?	6	%
What is the developer's equity share in the project?	20	%
What is the carbon credit unit sale price?	3	\$/tonne CO2E
What percent of CMM is consumed by prime-mover use?	10	%
What is the distance to the natural gas pipeline?	35000	ft
What is the cost of electric power used by the project?	70	\$/MWh
What is the price of the methane sold to the pipeline?	8	\$/mmBtu(HHV)
What is the installed cost of high pressure line from project to natural gas pipeline?	55	\$/ft

Default Parameters:

What is the inflation rate?	2.5	%
What is the real discount rate?	12	%
What are the royalty, severance tax, and negotiation fees?	20	%
What is the contingency factor?	5	%
What is the annual escalation rate for carbon credits?	2	%
How many hours per year will the project operate?	8000	hrs/year

Estimated Outputs:

Available CMM for Other Projects	0	mcf/d
Total capital cost	7,877,000	\$
Total annual cost	2,877,000	\$/year
Equity amount	1,575,000	\$
Loan amount	6,302,000	\$
Carbon credits earned per year	175,983	tonne/year
Internal rate of return (IRR)	9.36	%
Net present value	-516,000	\$
Quantity of exported Methane	390,720	Mcf/year





Coalbed Methane Scenario: Pipeline Gas Run #1

Construction

	Year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	
Savings or Product Revenues		3,157.01	3,235.94	3,316.84	3,399.76	3,484.75	3,571.87	3,661.17	3,752.70	3,846.51	
Carbon Credit Revenues			538.51	549.28	560.26	571.47	582.90	594.56	606.45	618.58	
Operating Costs		2,876.98	2,948.90	3,022.63	3,098.19	3,175.65	3,255.04	3,336.41	3,419.82	3,505.32	
Debt Service		1,128.86	1,128.86	1,128.86	1,128.86	1,128.86	1,128.86	1,128.86	0.00	0.00	
Net Cash Flow		-1,575.43	-320.87	-303.31	-285.37	-267.02	-248.28	-229.12	-209.54	939.32	959.77

527.95

4.0 Technical Basis of the Model

Coal Mine Methane Drainage, Gathering, and Delivery System

Drainage gas includes AMM and gob gas, and is associated with all scenarios except stand-alone VAM. The system for collecting drainage gas as defined in the model consists of two components: the CMM drainage system and the CMM gathering and delivery system:

1. The CMM drainage system includes the gas wells and the associated blowers that draw the gas from the wells. Since new gob wells are drilled every year as the mining progresses, these costs are treated as annual operating costs. Abandoned mine drainage wells are typically drilled once, so these costs are treated as capital costs.

The wellhead blowers will be purchased at the start of either gob or abandoned mine drainage projects. For gob well projects, the blowers will be moved from well to well through time. The blower costs will be handled as an initial project capital cost for both project types.

2. The CMM gathering and delivery system consists of the piping and associated valves and meters necessary to get the gas from the wellhead blowers to the satellite compressor station and the pipeline that connects the compressors to the gas project or use. For gob wells, the piping and associated valves and meters necessary to get the gas from the wellhead blowers to the satellite compressor station must be installed annually as the mining progresses. Therefore, these costs are treated as annual operating costs. For abandoned mine gas wells, the piping and associated valves and meters necessary to get the gas from the wellhead blowers to the satellite compressor station are generally installed at the beginning of the project and are typically treated as capital costs.

For both gob and abandoned mine drainage systems, the satellite compressor station and the pipeline that connects the compressors to the gas project are one-time purchases and will be handled as an initial project capital cost.

The model always includes the cost of the CMM gathering and delivery system in the overall project cost, but allows the user to opt out of including the CMM drainage system cost in the overall project cost. In addition, the user can elect to include only a portion of the drainage system cost in the overall project cost. This option is used to simulate a case where the drainage system is already in place or is owned by an entity other than the developer of the project. This can also simulate a situation where the cost of the drainage system will be borne partially by the CMM project bottom line and partially be the coal sales bottom line, since the installation of a drainage system can increase mine productivity and decrease down time.

Recovery Annual Costs

There are no significant annual operating costs for abandoned mine wells.

Annual operating cost of recovering methane from gob wells is composed of two elements:

1. Annual cost to install gob wells in the drainage system (W)
2. Annual cost to install gathering system piping (G) that connects the wells to the satellite compressors.

It is assumed that CMM is used for powering the blowers and compressors in the gathering and delivery system. This gas use is deducted from the gas delivered to the end use. However, this gas must be included in the carbon credit calculations since it is combusted and eligible for credits.

The annual cost for gob well drainage systems becomes:

$$\text{Annual cost} = G + (W * F)$$

F = the fraction of the drainage system cost that is included in the project cost.

Gob well (W) cost inputs:

- Well spacing, ft/well (1,000 ft/well default)
- Mining rate, ft/yr (12,000 ft/yr default)
- Mine depth, ft (1,000 ft default)
- Unit drilling cost, \$/ft (140 \$/ft default)

Example gob well cost calculation using default values:

$$W = \frac{12,000 \text{ ft} / \text{yr}}{1000 \text{ ft} / \text{well}} \times 1,000 \text{ ft} \times 140 \$ / \text{ft} = 1,680,000 \$ / \text{yr}$$

Selecting the default mining rate of 12,000 ft/yr and the default well spacing of 1,000 ft/well results in a model-assumed well installation rate of 12 wells per year.

Annual gathering system (G) cost inputs:

- Mining rate, ft/yr (as above) (12,000 ft/yr default)
- Unit cost of pipeline installed (40 \$/ft default)

Example gob well gathering system cost calculation using default values:

$$G = 12,000 \text{ ft} \times 40 \$ / \text{ft} = 480,000 \$ / \text{yr}$$

Recovery Capital Costs

The capital cost of recovering methane from gob and abandoned mine drainage systems includes the following three elements:

1. Blower (suction pump) cost (B)
2. Satellite compressor cost (C), and
3. Pipeline cost (P)

For abandoned mine drainage systems, the capital cost also includes:

1. Well costs, and
2. Between-well piping.

The capital cost equation for either drainage system includes:

$$\text{Capital cost} = C + P + (B * F)$$

F = the fraction of the drainage system cost that is included in the project cost.

Blower (B) cost inputs:

- Blower cost, \$/hp (\$1,000/hp default)
- Blower efficiency, hp/mcfd (0.035 hp/mcfd default)
- Gas flow rate, mcfd (no default)

$$B = (\$1,000/\text{hp}) * (0.035 \text{ hp}/\text{mcfd}) * (x \text{ mcfd})$$

Compressor (C) cost inputs:

- Compressor cost, \$/hp (\$1,000/hp default)
- Compressor efficiency, hp/mcfd (0.035 hp/mcfd default)
- Gas flow rate, mcfd (no default)

$$C = (\$1,000/\text{hp}) * (0.035 \text{ hp}/\text{mcfd}) * (x \text{ mcfd})$$

Pipeline (P) cost inputs:

- Pipe cost, \$/ft (\$40/ft default)
- Pipeline length, ft (21,000 ft default)

$$P = (\$40/\text{ft}) * (21,000 \text{ ft}) = \$840,000$$

The capital cost equation for abandoned mine systems also includes:

1. Cost to install drainage wells in the drainage system (W)
2. Cost to install gathering system piping (G) that connects the wells to the satellite compressors.

$$\text{Additional cost} = G + (W * F)$$

F = the fraction of the drainage system cost that is included in the project cost.

Abandoned Mine Drainage well (W) cost inputs:

- Number of wells (20 –as example)
- Mine depth, ft (1,000 ft default)
- Unit drilling cost, \$/ft (140 \$/ft default)

Example well cost calculation using default values:

$$W = 20 \times 1,000 \text{ ft} \times 140 \$ / \text{ft} = \$2,800,000$$

Annual abandoned mine gathering system (G) cost inputs:

- Number of wells (20 –as example)
- Well spacing, ft/well (1,000 ft/well default)
- Unit cost of pipeline installed (40 \$/ft default)

Example gathering system cost calculation using default values:

$$G = 20 \times 1,000 \text{ ft} \times 40 \$ / \text{ft} = \$800,000$$

Coal Drying

This scenario assumes that the mine will retrofit an existing coal dryer at an on-site coal preparation plant to burn methane drained from the mine instead of, or in addition to, burning coal. The scenario assumes that drained gas quality is adequate for the intended end use without requiring any processing (upgrading). Revenues in the form of savings accrue to the mine as a result of offsetting the cost of coal (including its transport cost) that otherwise would have been burned as fuel. Revenues also may result from the sale of carbon emission reductions.

Scenario Assumptions:

- The minimum methane concentration for proper firing is 40%.
- The dryers were originally coal fired (no natural gas option) and will continue using coal for the balance of the heat load not supplied by CMM.
- The theoretical heat required to dry a ton of coal is assumed to range from 0.15 to 0.4 MMBtu/ton, based on coal moisture and pore structure. The default is assumed to be 0.3 MMBtu/ton.
- The thermal efficiency of the dryer is assumed to range from 40% to 65% with a default of 50%.
- The recommended cost of the replaced coal is assumed to range from \$25 to \$50 per ton.
- The recommended avoided handling cost of the replaced coal is assumed to range from \$0.5 to \$1 per ton, with a default of \$0.75 per ton.
- The recommended heating value of coal is assumed to range from 23 MMBtu/ton to 26 MMBtu/ton with a default of 24 MMBtu/ton.
- Utilization capital cost is for conversion of an existing dryer to co-fire CMM with coal, and ranges from \$5,000/(MMBtu/hr) to \$13,000/(MMBtu/hr) with a default of \$7,000/(MMBtu/hr).
- The utilization annual cost of operating the new burner is assumed to be negligible as compared to the cost to maintain the coal feeder that was replaced.
- The hours/yr of operation are standardized with the other scenarios at a range of 7,500-8,300 hours and a default of 8,000 hours. The dryer is expected to have a very high reliability, or availability, but is dependent on the availability of the overall CMM gathering and delivery system.
- 21 tons of CO₂E of carbon credits were earned per ton of methane destroyed, less the weight of the carbon dioxide emitted, and credited for the carbon dioxide avoided by displaced coal use, resulting in a net factor of 23 tons of CO₂E per ton of methane burned.

Coal Drying Spreadsheet

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	\$/HP
3	What is the cost of satellite compressors?	=drainage2	\$/HP
4	What is the distance from the drainage area to the onsite	=drainage3	ft
5	What is the cost of installing header pipe from the drainage	=drainage4	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between drainage wells?	=drainage6	ft
8	What is the mining rate?	=drainage7	ft/yr
9	How many drainage wells are being utilized?	=drainage7alt	wells
10	What is the drainage gas source?	=inputDrainageSource	
11	What is the mine depth?	=drainage8	ft/well
12	What is the drilling cost?	=drainage9	\$/ft
13	What percent of CMM is consumed by prime-mover use?	=user18/100	
14	What do you expect the CMM drained per day to be?	=gas1	mcf/d
15	CMM drained per hour	=B14/24	mcf/h
16	Percent Methane in Drainage Gas	=inputPctMethane/100	
17	Actual gas flow	=IF(B16<>0,B14/B16,0)	mcf/d
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6/100	
20	Average fuel available	=B15*(B19-B13)	mcf/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22	How much coal is dried per hour?	=gas2	t/h
23	How many hours per year will the coal dryer operate?	=default1	h/yr
24	What is the heat required per ton of coal?	=gas4	mmBtu/ton
25	What is the dryer efficiency?	=gas3/100	
26	What is the capital cost to convert the coal dryer?	=user7	\$/mmBtu/h
27	What is the cost per ton of coal replaced by gas?	=user10	\$/ton
28	What is the avoided coal handling cost?	=default31	\$/ton
29	What is the replaced coal's fuel value?	=default32	mmBtu/ton
30	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
31	Drainage and Transport sys unit cap cost	=IF((B14*B19)<>0,(B3*B6)+(B4*B5*B16/(B14*B19)))+(IF(B10="AM",B7*B5*B9*B16/(B14*B19),0)+(B30*IF(inputDrainageSystem="Y",B2*B6)+IF(B10="AM",B11*B12*B9*B16/(B14*B19),0),0)	\$/mcf
32	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW",B14*B19)<>0,B23<>0),((B8*B5)+IF(AND(inputDrainageSystem	\$/mcf
33	CMM fuel value LHV	910	Btu/cf
34	Weight of methane, tonnes	0.01926	tonnes/mcf
35	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
36	GWP ratio: methane to CO2	21	ratio
37	What is the inflation rate?	=default21/100	
38	What is the real discount rate?	=default26/100	
39	What is the developer's equity share in the project?	=user12/100	
40	What is the loan term?	=user15	yr
41	What interest rate is charged for the loan?	=user5/100	
42	Cap Cost Factors		
43	What are the royalty, severance tax, and negotiation fees?	=default11/100	
44	What is the contingency factor?	=default7/100	
45			
46	2 - Feasibility Test		
47	CMM heat value available/hour	=B21	mmBtu/h
48	Coal Dryer heat needed/hour	=IF(B25<>0,B22*B24/B25,0)	mmBtu/h
49	CMM volume needed/hour	=IF(OR(B47<B48,inputScenFlare="OF",inputScenFlare="EF"),B47*1000/B33/(1-B13),B48*1000/B33/(1-	mcf/h
50	CMM available for other uses	=IF(OR(B48>B47,inputScenFlare="OF",inputScenFlare="EF",B19=0),0,B14-(B49*24/B19))	mcf/d
51			
52	3 - Calculate Annual Benefits:		
53	Tons of coal replaced per hour	=IF(B29<>0,IF(B47<B48,B47/B29,B48/B29),0)	ton/h
54	Cost savings per hour - coal	=B53*(B27+B28)	\$/h
55	Cost savings per year - coal	=B54*B23/1000	\$/000/y
56	CMM volume needed/hour	=B49	mcf/h
57	Tonnes CH4 needed/hour	=B56*B34	t/h
58	Carbon credits earned per hour	=B57*(B36+2)	t/h
59	Carbon credits earned per year	=B58*B23	t/y
60	Carbon credit revenue per year	=B59*B35/1000	\$/000/y
61			

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Coal Drying Spreadsheet (continued)

	A	B	C
1	INPUT PARAMETERS	Values	units
62	4 - Calculate New Annual Costs:		
63	CMM needed per hour	=B49	mcf/h
64	Drain & transport O&M cost/h	=IF(B16<>0,(B63*B32)/B16,0)	\$/h
65	Drain & transport O&M cost/yr	=B64*B23/1000	\$000/y
66	Back-up Flare O&M cost/yr	=IF(inputScenFlare="OF",user22,IF(inputScenFlare="EF",user20,0))	
67	Total annual cost	=SUM(B65,B66)	\$000/y
68			
69	5 - Calculate Project Capital Costs		
70	CMM needed per hour	=B49	mcf/h
71	CMM transport system	=IF(B16<>0,B31*B70*24/B16/1000,0)	\$000
72	Dryer conversion	=IF(B47<B48, B47*B26,B48*B26)	\$000
73	Back-up Flare capital cost	=IF(inputScenFlare="OF",B20*24*user21,IF(inputScenFlare="EF",B20*24*user19,0))	
74	Subtotal	=SUM(B71:B73)	\$000
75	Total cap cost with factors	=B74*(1+B43)*(1+B44)	\$000
76			
77	6 - Calculate Loan and Equity		
78	Loan amount	=B75*(1-B39)	\$000
79	Equity amount	=B75*B39	\$000
80			
81	7 - Discounted Cash Flow Analysis	(\$000)	
82	Years >>> 0		1
83	A - Benefits		
84	Coal savings		=IF(C\$82<=\$B\$18,B55,0)
85	Carbon Credit Revenues		=IF(C\$82<=\$B\$18,\$B60,0)
86	Total Benefits		=SUM(C84:C85)
87	B - Costs		
88	CMM transport cost + drain share		=IF(C\$82<=\$B\$18,-B67,0)
89	C - Cash Flow from Operations		=SUM(C86:C88)
90			
91	D - Debt Service		=IF(OR(C\$82>\$B\$40,C\$82>\$B\$18),0,PMT(\$B\$41,\$B\$40,\$B\$78))
92	E - Net Cash Flow	=-B79	=SUM(C89:C91)
93			
94	8 - Financial Measurements: IRR, NPV, Payback		
95	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B92:V92)),0,IRR(\$B92:V92))
96	Net Present Value		=NPV(B38,B92:V92)

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Flaring – Open and Enclosed

The mine can flare the drained methane as long as it contains greater than 30% methane. These scenarios assume that the mine will install one or more open or enclosed flares. The cost of the flare includes monitoring and metering equipment in order to prove methane destruction because the only revenue source will be associated with the sale of certified carbon emission reductions.

An open flare is a combustion device for burning gases, consisting of a burner that is mounted such that the flame is "open" and is not shielded. An enclosed flare is a combustion device for burning gases, consisting of a burner that is mounted such that the flame is shielded or enclosed in a stack.

Scenario Assumptions:

- The minimum methane concentration for safe flaring is 30%.
- The utilization capital cost for an installed flare is a function of the inlet gas rate. The default cost of an enclosed flare is \$280/Mcfpd and ranges from \$115 to \$450/Mcfpd. The default cost for an open flare is \$80/Mcfpd and ranges from \$30/Mcfpd to \$125/Mcfpd. The flare units include the burner, pilots, instrumentation, automatic flare lockout controls, and flame arrestors.
- The annual operating cost of the enclosed flare is assumed to range from \$10,000 to \$20,000 per year with a default value of \$15,000 per year. The annual operating cost of the open flare is assumed to range from \$5,000 to \$15,000 per year with a default value of \$10,000 per year. These operating costs consist primarily of maintenance activities associated with the burner, pilots, instrumentation, automatic flare lockout controls, and flame arrestors.
- The hours/yr of operation are standardized with the other scenarios at a range of 7,500-8,300 hours and a default of 8,000 hours. The flare is expected to have a very high reliability, or availability, but is dependent on the availability of the overall CMM gathering and delivery system.
- 21 tons of CO₂E of carbon credits were earned per ton of methane destroyed, less the weight of the carbon dioxide emitted, 2.75 tons, resulting in a net factor of 18.25 tons of CO₂E per ton of methane burned.

CMM ENCLOSED FLARE PROJECT

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	\$/HP
3	What is the cost of satellite compressors?	=drainage2	\$/HP
4	What is the distance from the drainage area to the onsite project?	=drainage3	ft
5	What is the cost of installing header pipe from the drainage area?	=drainage4	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between drainage wells?	=drainage6	ft
8	What is the mining rate?	=drainage7	ft/yr
9	How many drainage wells are being utilized?	=drainage7alt	wells
10	What is the drainage gas source?	=inputDrainageSource	
11	What is the mine depth?	=drainage8	ft/well
12	What is the drilling cost?	=drainage9	\$/ft
13	What percent of CMM is consumed by prime-mover use?	=user18/100	
14	What do you expect the CMM drained per day to be?	=gas1	mcfd
15	CMM drained per hour	=B14/24	mcfd/h
16	Percent Methane in Drainage Gas	=inputPctMethane/100	
17	Actual gas flow	=IF(B16<>0,B14/B16,0)	mcfd
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6/100	
20	Average fuel available	=B15*(B19-B13)	mcfd/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22			
23	How many hours per year will the flare operate?	=default2	hours/yr
24			
25	What is the capital cost of the enclosed flare?	=user19	\$/000/mcfd
26	What is the O&M cost of the enclosed flare?	=user20	\$/000/yr
27			
28			
29			
30	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
31	Drainage and Transport sys unit cap cost	=IF((B14*B19)<>0,(B3*B6)+(B4*B5*B16/(B14*B19)))+(IF(B10="AM",B7*B5*B9*B16/(B14*B19,0))+(B30*IF(inputDrainageSystem="Y", (B2*B6)+IF(B10="AM",B11*B12*B9*B16/(B14*B19,0),0)),0)	\$/mcfd
32			
33	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW", (B14*B19)<>0,B23<>0), ((B8*B5)+IF(AND(inputDrainageSystem="Y", B7<>0), B8*B11*B12*B30/B7,0))*B16*24/(B14*B19)/B23,0)	\$/mcf
34	CMM fuel value LHV	910	Btu/cf
35	Weight of methane, tonnes	0.01926	tonnes/mcf
36	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
37	GWP ratio: methane to CO2	21	ratio
38	What is the inflation rate?	=default21/100	
39	What is the real discount rate?	=default26/100	
40	What is the developer's equity share in the project?	=user12/100	
41	What is the loan term?	=user15	yr
42	What interest rate is charged for the loan?	=user5/100	
43	Cap Cost Factors		
44	What are the royalty, severance tax, and negotiation fees?	=default11/100	
45	What is the contingency factor?	=default7/100	

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"

2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.

3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

CMM ENCLOSED FLARE PROJECT (CONT.)

	A	B	C
1	INPUT PARAMETERS	Values	units
46	2 - Feasibility Test		
47	CMM heat value available/hour	=B21	mmBtu/h
48			
49	CMM volume needed/hour	=B47*1000/B33/(1-B13)	mcf/h
50	CMM available for other uses	0	mcf/d
51			
52	3 - Calculate Annual Benefits:		
53			
54			
55			
56	CMM volume needed/hour	=B49	mcf/h
57	Tonnes CH4 needed/hour	=B56*B34	t/h
58	Carbon credits earned per hour	=B57*(B36-2.75)	t/h
59	Carbon credits earned per year	=B58*B23	t/y
60	Carbon credit revenue per year	=B59*B35/1000	\$000/y
61			
62	4 - Calculate New Annual Costs:		
63	Flare O&M cost	=B26	\$000/y
64	Drain & transport O&M cost/h	=IF(B16<>0,(B49*B32)/B16,0)	\$/h
65	Drain & transport O&M cost/y	=B64*B23/1000	\$000/y
66	--		
67	Total annual cost	=B65+B63	\$000/y
68			
69	5 - Calculate Project Capital Costs		
70	CMM needed per hour	=B49	mcf/h
71	CMM transport system	=IF(B16<>0,B31*B70*24/B16/1000,0)	\$000
72	Installed Cost Flare	=B20*B25*24	\$000
73	--		
74	Subtotal	=SUM(B71:B72)	\$000
75	Total cap cost with factors	=B74*(1+B43)*(1+B44)	\$000
76			
77	6 - Calculate Loan and Equity		
78	Loan amount	=B75*(1-B39)	\$000
79	Equity amount	=B75*B39	\$000
80			
81	7 - Discounted Cash Flow Analysis	(\$000)	
82		Years >>> 0	1
83	A - Benefits		
84			=IF(C\$82<=\$B\$18,B55,0)
85	Carbon Credit Revenues		=IF(C\$82<=\$B\$18,\$B60,0)
86	Total Benefits		=SUM(C84:C85)
87	B - Costs		
88	Annual Drainage and Flare O&M Cost		=IF(C\$82<=\$B\$18,-B67,0)
89	C - Cash Flow from Operations		
90			=SUM(C86:C88)
91	D - Debt Service		
92	E - Net Cash Flow	=-B79	=IF(OR(C\$82>\$B\$40,C\$82>\$B\$18),0,PMT(\$B\$41,\$B\$40,\$B\$78))
93			=SUM(C89:C91)
94	8 - Financial Measurements: IRR, NPV, Payback		
95	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B92:V92)),0,IRR(\$B92:V92))
96	Net Present Value		=NPV(B38,B92:V92)

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

CMM OPEN FLARE PROJECT

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	\$/HP
3	What is the cost of satellite compressors?	=drainage2	\$/HP
4	What is the distance from the drainage area to the onsite project?	=drainage3	ft
5	What is the cost of installing header pipe from the drainage area?	=drainage4	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between drainage wells?	=drainage6	ft
8	What is the mining rate?	=drainage7	ft/yr
9	How many drainage wells are being utilized?	=drainage7alt	wells
10	What is the drainage gas source?	=inputDrainageSource	
11	What is the mine depth?	=drainage8	ft/well
12	What is the drilling cost?	=drainage9	\$/ft
13	What percent of CMM is consumed by prime-mover use?	=user18/100	
14	What do you expect the CMM drained per day to be?	=gas1	mcfd
15	CMM drained per hour	=B14/24	mcfd/h
16	Percent Methane in Drainage Gas	=inputPctMethane/100	
17	Actual gas flow	=IF(B16<>0,B14/B16,0)	mcfd
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6/100	
20	Average fuel available	=B15*(B19-B13)	mcfd/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22			
23	How many hours per year will the flare operate?	=default2	hours/yr
24			
25	What is the capital cost of the open flare?	=user21	\$000/mcfd
26	What is the O&M cost of the open flare?	=user22	\$000/yr
27			
28			
29			
30	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
31	Drainage and Transport sys unit cap cost	=IF((B14*B19)<>0,(B3*B6)+(B4*B5*B16/(B14*B19))+((B10="AM",B7*B5*B9*B16/(B14*B19,0))+ (B30*IF(inputDrainageSystem="Y", (B2*B6)+IF(B10="AM",B11*B12*B9*B16/(B14*B19,0),0),0)	\$/mcfd
32			
33	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW", (B14*B19)<>0,B23<>0),((B8*B5)+IF(AND(inputDrainageSystem="Y", B7<>0),B8*B11*B12*B30/B7,0))*B16*24/(B14*B19)/B23,0)	\$/mcf
34	CMM fuel value LHV	910	Btu/cf
35	Weight of methane, tonnes	0.01926	tonnes/mcf
36	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
37	GWP ratio: methane to CO2	21	ratio
38	What is the inflation rate?	=default21/100	
39	What is the real discount rate?	=default26/100	
40	What is the developer's equity share in the project?	=user12/100	
41	What is the loan term?	=user15	yr
42	What interest rate is charged for the loan?	=user5/100	
43	Cap Cost Factors		
44	What are the royalty, severance tax, and negotiation fees?	=default11/100	
45	What is the contingency factor?	=default7/100	

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

CMM OPEN FLARE PROJECT (CONT.)

	A	B	C
1	INPUT PARAMETERS	Values	units
46	2 - Feasibility Test		
47	CMM heat value available/hour	=B21	mmBtu/h
48			
49	CMM volume needed/hour	=B47*1000/B33/(1-B13)	mcf/h
50	CMM available for other uses	0	mcf/d
51			
52	3 - Calculate Annual Benefits:		
53			
54			
55			
56	CMM volume needed/hour	=B49	mcf/h
57	Tonnes CH4 needed/hour	=B56*B34	t/h
58	Carbon credits earned per hour	=B57*(B36-2.75)	t/h
59	Carbon credits earned per year	=B58*B23	t/y
60	Carbon credit revenue per year	=B59*B35/1000	\$000/y
61			
62	4 - Calculate New Annual Costs:		
63	Flare O&M cost	=B26	\$000/y
64	Drain & transport O&M cost/h	=IF(B16<>0,(B49*B32)/B16,0)	\$/h
65	Drain & transport O&M cost/y	=B64*B23/1000	\$000/y
66	--		
67	Total annual cost	=B65+B63	\$000/y
68			
69	5 - Calculate Project Capital Costs		
70	CMM needed per hour	=B49	mcf/h
71	CMM transport system	=IF(B16<>0,B31*B70*24/B16/1000,0)	\$000
72	Installed Cost Flare	=B20*B25*24	\$000
73	--		
74	Subtotal	=SUM(B71:B72)	\$000
75	Total cap cost with factors	=B74*(1+B43)*(1+B44)	\$000
76			
77	6 - Calculate Loan and Equity		
78	Loan amount	=B75*(1-B39)	\$000
79	Equity amount	=B75*B39	\$000
80			
81	7 - Discounted Cash Flow Analysis	(\$000)	
82			
83	A - Benefits	Years >>> 0	1
84			
85	Carbon Credit Revenues		=IF(C\$82<=\$B\$18,B55,0)
86	Total Benefits		=IF(C\$82<=\$B\$18,\$B60,0)
87	B - Costs		=SUM(C84:C85)
88	Annual Drainage and Flare O&M Cost		=IF(C\$82<=\$B\$18,-B67,0)
89	C - Cash Flow from Operations		=SUM(C86:C88)
90			
91	D - Debt Service		=IF(OR(C\$82>\$B\$40,C\$82>\$B\$18),0, PMT(\$B\$41, \$B\$40, \$B\$78))
92	E - Net Cash Flow	=-B79	=SUM(C89:C91)
93			
94	8 - Financial Measurements: IRR, NPV, Payback		
95	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B92:V92)),0,IRR(\$B92:V92))
96	Net Present Value		=NPV(B38,B92:V92)

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Mine Boilers

The mine can use drained methane as a fuel for on-site boilers that provide space and/or water heating for mine facilities (e.g., washrooms, offices). This scenario assumes that the mine will retrofit an existing on-site boiler to burn methane drained from the mine instead of, or in addition to burning coal. The scenario assumes that drained gas quality is adequate for the intended end use without requiring any processing (upgrading). Revenues in the form of savings accrue to the mine as a result of offsetting the cost of coal (including its transport cost) that otherwise would have been burned as fuel. Revenues also may result from the sale of carbon emission reductions.

Scenario Assumptions:

- The minimum methane concentration for proper firing is 40%.
- Assume the boilers were originally coal fired (no natural gas option) and will continue using coal for the balance of the heat load not supplied by CMM.
- The recommended cost of the replaced coal is assumed to range from \$25 to \$50 per ton.
- The recommended avoided handling cost of the replaced coal is assumed to range from \$0.5 to \$1 per ton, with a default of \$0.75 per ton.
- The recommended heating value of coal is assumed to range from 23 MMBtu/ton to 26 MMBtu/ton with a default of 24 MMBtu/ton.
- The utilization capital cost is for conversion of a boiler to co-fire with CMM and coal ranges from \$5,625/(MMBtu/hr) to \$12,500/(MMBtu/hr) with a default of \$7,500/(MMBtu/hr).
- The utilization annual cost of operating the new burner is assumed to be negligible as compared to the cost to maintain the coal feeder that was replaced.
- The hours/yr of operation are standardized with the other scenarios at a range of 7,500-8,300 hours and a default of 8,000 hours. The boiler is expected to have a very high reliability, or availability, but is dependent on the availability of the overall CMM gathering and delivery system.
- 21 tons of CO₂E of carbon credits were earned per ton of methane destroyed, less the weight of the carbon dioxide emitted, and credited for the carbon dioxide avoided by displaced coal use, resulting in a net factor of 23 tons of CO₂E per ton of methane burned.

CMM BOILER PROJECT

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	\$/HP
3	What is the cost of satellite compressors?	=drainage2	\$/HP
4	What is the distance from the drainage area to the onsite project?	=drainage3	ft
5	What is the cost of installing header pipe from the drainage area?	=drainage4	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between drainage wells?	=drainage6	ft
8	What is the mining rate?	=drainage7	ft/yr
9	How many drainage wells are being utilized?	=drainage7alt	wells
10	What is the drainage gas source?	=inputDrainageSource	
11	What is the mine depth?	=drainage8	ft/well
12	What is the drilling cost?	=drainage9	\$/ft
13	What percent of CMM is consumed by prime-mover use?	=user18/100	
14	What do you expect the CMM drained per day to be?	=gas1	mcfd
15	CMM drained per hour	=B14/24	mcfd/h
16	Percent Methane in Drainage Gas	=inputPctMethane/100	
17	Actual gas flow	=IF(B16<>0,B14/B16,0)	mcfd
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6/100	
20	Average fuel available	=B15*(B19-B13)	mcfd/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22	What is the boiler capacity?	=gas5	mmBtu/h
23	How many hours per year will the mine boiler operate?	=default3	hours/yr
24	What is the average boiler load?	=gas7	mmBtu/h
25	What is the capital cost to convert coal boiler to gas?	=user11	\$000/(mmBtu/h)
26			
27	What is the cost per ton of coal replaced by gas?	=user10	\$/ton
28	What is the avoided coal handling cost?	=default31	\$/ton
29	What is the replaced coal's fuel value?	=default32	mmBtu/ton
30	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
31	Drainage and Transport sys unit cap cost	=IF((B14*B19)<>0,(B3*B6)+(B4*B5*B16/(B14*B19))+IF(B10="AM",B7*B5*B9*B16/(B14*B19,0))+B30*IF(InputDrainageSystem="Y",B2*B6)+IF(B10="AM",B11*B12*B9*B16/(B14*B19,0)),0)	\$/mcfd
32	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW",B14*B19)<>0,B23<>0),(B8*B5)+IF(AND(inputDrainageSystem="Y",B7<>0),B8*B11*B12*B30/B7,0)*B16*24/(B14*B19)/B23,0)	\$/mcf
33	CMM fuel value LHV	910	Btu/cf
34	Weight of methane, tonnes	0.01926	tonnes/mcf
35	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
36	GWP ratio: methane to CO2	21	ratio
37	What is the inflation rate?	=default21/100	
38	What is the real discount rate?	=default26/100	
39	What is the developer's equity share in the project?	=user12/100	
40	What is the loan term?	=user15	yr
41	What interest rate is charged for the loan?	=user5/100	
42	Cap Cost Factors		
43	What are the royalty, severance tax, and negotiation fees?	=default11/100	
44	What is the contingency factor?	=default7/100	
45			

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

CMM BOILER PROJECT (CONT.)

	A	B	C
1	INPUT PARAMETERS	Values	units
46	2 - Feasibility Test		
	CMM heat value available/hour		mmBtu/h
47		=B21	
	Average Mine Boiler Heat Load		mmBtu/h
48		=B24	
	CMM volume needed/hour	=IF(OR(B47<B48,inputScenFlare="OF",inputScenFlare="E F"),B47*1000/B33/(1-B13),B48*1000/B33/(1-B13))	mcf/h
49	CMM available for other uses	=IF(OR(B48>B47, inputScenFlare="OF",inputScenFlare="EF",B19=0),0, B14- (B49*24/B19))	mcf/d
50			
51			
52	3 - Calculate Annual Benefits:		
	Tons of coal replaced per hour		ton/h
53		=IF(B29<>0,IF(B47<B48,B47/B29,B48/B29),0)	
54	Cost savings per hour - coal	=B53*(B27+B28)	\$/h
55	Cost savings per year - coal	=B54*B23/1000	\$000/y
56	CMM volume needed/hour	=B49	mcf/h
57	Tonnes CH4 needed/hour	=B56*B34	t/h
	Carbon credits earned per hour		t/h
58		=B57*(B36+2)	
	Carbon credits earned per year		t/y
59		=B58*B23	
	Carbon credit revenue per year		\$000/y
60		=B59*B35/1000	
61			
62	4 - Calculate New Annual Costs:		
	CMM needed per hour	=B49	mcf/h
63	Drain & transport O&M cost/h		\$/h
64		=IF(B16<>0,(B63*B32)/B16,0)	
	Drain & transport O&M cost/yr		\$000/y
65		=B64*B23/1000	
	Back-up Flare O&M cost/yr	=IF(inputScenFlare="OF",user22,IF(inputScenFlare="EF",u ser20,0))	
66			
67	Total annual cost	=SUM(B65,B66)	\$000/y
68			
69	5 - Calculate Project Capital Costs		
	CMM needed per hour	=B49	mcf/h
70	CMM transport system	=IF(B16<>0,B31*B70*24/B16/1000,0)	\$000
	Cost to Convert Convert Boiler to Burn CMM		\$000
71		=IF(B47<B48, B47*B25, B22*B25)	
	Back-up Flare capital cost	=IF(inputScenFlare="OF",B20*24*user21,IF(inputScenFlare ="EF",B20*24*user19,0))	
72			
73	Subtotal	=SUM(B71:B73)	\$000
74	Total cap cost with factors	=B74*(1+B43)*(1+B44)	\$000
75			
76			
77	6 - Calculate Loan and Equity		
	Loan amount	=B75*(1-B39)	\$000
78			
79	Equity amount	=B75*B39	\$000
80			
81	7 - Discounted Cash Flow Analysis	(\$000)	
82			
		Years >>> 0	1
83	A - Benefits		
	Coal savings		=IF(C\$82<=\$B\$18,B55,0)
84			
85	Carbon Credit Revenues		=IF(C\$82<=\$B\$18,\$B60,0)
	Total Benefits		=SUM(C84:C85)
86			
87	B - Costs		
	CMM transport cost + drain share		=IF(C\$82<=\$B\$18,-B67,0)
88			
89	C - Cash Flow from Operations		=SUM(C86:C88)
90			
	D - Debt Service		=IF(OR(C\$82>\$B\$40,C\$82>\$B\$18),0, PMT(\$B\$41, \$B\$40, \$B\$78))
91			
92	E - Net Cash Flow	=-B79	=SUM(C89:C91)
93			
	8 - Financial Measurements: IRR, NPV, Payback		
94			
95	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B92:V92)),0,IRR(\$B92:V92))
96	Net Present Value		=NPV(B38,B92:V92)

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

On-site Electricity Generation – Engine

Drained methane can be used to fire internal combustion (IC) engines that drive generators to make electricity for sale to the local power grid. Even a mine that generates power to cover its own power needs only must usually connect to the power grid for the purposes of supply reliability. In this scenario the feasibility test involves considering the drained methane concentration. Some readily available IC engines are able to run on fuel that is as low as 25% methane if the fuel's oxygen level is high and its carbon dioxide content is low. For most situations a 25 or 35% cut off is reasonable. The scenario includes costs for gas processing to remove solids and water as well as the cost of equipment for connecting to the power grid. Revenues in the form of power sales accrue to the project as well as revenues that may also result from the sale of carbon emission reductions.

Scenario Assumptions:

- The minimum methane concentration of this scenario is 25%.
- The recommended electrical power efficiency is between 30% and 44% with a default value of 35%.
- The utilization capital cost for gas pretreatment, power generation and electrical interconnection equipment ranges from \$1,100/kW to \$1,500/kW with a default of \$1,300/kW.
- The utilization annual cost is recommended to range between \$0.015/kW-hr and \$0.03/kW-hr with a default of \$0.02/kW-hr.
- The price for selling the electricity from the project ranges from 0.04-0.1 \$/kWh with a default value of 0.07 \$/kWh.
- The hours/yr of operation are standardized with the other scenarios at a range of 7,500-8,300 hours and a default of 8,000 hours. The engines are expected to have a very high reliability, or availability, but are dependent on the availability of the overall CMM gathering and delivery system.
- 21 tons of CO₂E of carbon credits were earned per ton of methane destroyed, less the weight of the carbon dioxide emitted, 2.75 tons, resulting in a net factor of 18.25 tons of CO₂E per ton of methane burned.

CMM ON-SITE ELECTRICITY PROJECT

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	\$/HP
3	What is the cost of satellite compressors?	=drainage2	\$/HP
4	What is the distance from the drainage area to the onsite project?	=drainage3	ft
5	What is the cost of installing header pipe from the drainage area?	=drainage4	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between drainage wells?	=drainage6	ft
8	What is the mining rate?	=drainage7	ft/yr
9	How many drainage wells are being utilized?	=drainage7alt	wells
10	What is the drainage gas source?	=inputDrainageSource	
11	What is the mine depth?	=drainage8	ft/well
12	What is the drilling cost?	=drainage9	\$/ft
13	What percent of CMM is consumed by prime-mover use?	=user18/100	
14	What do you expect the CMM drained per day to be?	=gas1	mcfd
15	CMM drained per hour	=B14/24	mcfd/h
16	Percent Methane in Drainage Gas	=inputPctMethane/100	
17	Actual gas flow	=IF(B16<>0,B14/B16,0)	mcfd/d
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6/100	
20	Average fuel available	=B15*(B19-B13)	mcfd/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22	What is the overall efficiency of the engine-generator set?	=user6/100	Based on LHV
23	How many hours per year will the engine operate?	=default4	hours/yr
24	Capital cost of treatment, engine-gen set, & electrical eqp?		\$000/kW
25	What is the O&M cost of the reciprocating engine?	=user3	\$/kWh
26	For what price can CMM-based electricity be sold?	=user4	\$/kWh
27		=user1	
28			
29	What is the fraction of this project's drainage system cost that will be included in the analysis?		
30	Drainage and Transport sys unit cap cost	=drainage10/100 =IF((B14*B19)<>0,(B3*B6)+(B4*B5*B16/(B14*B19))+IF(B10="AM",B7*B5*B9*B16/(B14*B19),0))+ (B30*IF(inputDrainageSystem="Y",B2*B6)+IF(B10="AM",B11*B12*B9*B16/(B14*B19),0),0),0)	\$/mcfd
31	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW",B14*B19)<>0,B23<>0),(B8*B5)+IF(AND(inputDrainageSystem="Y",B7<>0),B8*B11*B12*B30/B7,0))*B16^24/(B14*B19)/B23,0)	\$/mcf
32	CMM fuel value LHV	910	Btu/cf
33	Weight of methane, tonnes	0.01926	tonnes/mcf
34	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
35	GWP ratio: methane to CO2	21	ratio
36	What is the inflation rate?	=default21/100	
37	What is the real discount rate?	=default26/100	
38	What is the developer's equity share in the project?	=user12/100	
39	What is the loan term?	=user15	yr
40	What interest rate is charged for the loan?	=user5/100	
41	Cap Cost Factors		
42	What are the royalty, severance tax, and negotiation fees?	=default11/100	
43	What is the contingency factor?	=default7/100	
44			
45			

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

CMM ON-SITE ELECTRICITY PROJECT (CONT.)

	A	B	C
1	INPUT PARAMETERS	Values	units
46	2 - Feasibility Test		
47	CMM heat value available/hour	=B21	mmBtu/h
48			
49	CMM volume needed/hour	=B47*1000/B33/(1-B13)	mcf/h
50	CMM available for other uses	0	mcf/d
51			
52	3 - Calculate Annual Benefits:		
53	Engine Capacity	=B47*B22/3.412	MW
54	Annual Electricity Production	=B53*B23	MVWh
	Annual Revenue from Sale of Electricity		\$000
55		=B27*B54	
56	CMM volume needed/hour	=B49	mcf/h
57	Tonnes CH4 needed/hour	=B56*B34	t/h
58	Carbon credits earned per hour	=B57*(B36-2.75)	t/h
59	Carbon credits earned per year	=B58*B23	t/y
60	Carbon credit revenue per year	=B59*B35/1000	\$000/y
61			
62	4 - Calculate New Annual Costs:		
63	Engine O&M cost	=B54*B26	\$000/y
64	Drain & transport O&M cost/h	=IF(B16<>0,(B49*B32)/B16,0)	\$/h
65	Drain & transport O&M cost/y	=B64*B23/1000	\$000/y
66	--		
67	Total annual cost	=B65+B63	\$000/y
68			
69	5 - Calculate Project Capital Costs		
70	CMM needed per hour	=B49	mcf/h
71	CMM transport system	=IF(B16<>0,B31*B70*24/B16/1000,0)	\$000
	Installed Cost of Engine-Generator Sets		\$000
72		=B53*B25*1000	
73	--		
74	Subtotal	=SUM(B71:B72)	\$000
75	Total cap cost with factors	=B74*(1+B43)*(1+B44)	\$000
76			
77	6 - Calculate Loan and Equity		
78	Loan amount	=B75*(1-B39)	\$000
79	Equity amount	=B75*B39	\$000
80			
81	7 - Discounted Cash Flow Analysis	(\$000)	
82		Years >>> 0	1
83	A - Benefits		
84	Electricity Revenues		=IF(C\$82<=\$B\$18,B55,0)
85	Carbon Credit Revenues		=IF(C\$82<=\$B\$18,\$B60,0)
86	Total Benefits		=SUM(C84:C85)
87	B - Costs		
88	Annual Drainage and Engine O&M Cost		=IF(C\$82<=\$B\$18,-B67,0)
89	C - Cash Flow from Operations		=SUM(C86:C88)
90			
91	D - Debt Service		=IF(OR(C\$82>\$B\$40,C\$82>\$B\$18),0,PMT(\$B\$41,\$B\$40,\$B\$78))
92	E - Net Cash Flow	=-B79	=SUM(C89:C91)
93			
94	8 - Financial Measurements: IRR, NPV, Payback		
95	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B92:V92)),0,IRR(\$B92:V92))
96	Net Present Value		=NPV(B36,B92:V92)

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Pipeline Gas

This scenario assumes the installation of a pressure swing adsorption type system to remove nitrogen and carbon dioxide down to a 4% inert level. The utilization cost is a function of both the inlet gas flow rate and methane concentration, and includes the cost of dehydration and compression necessary to process the gas and then to boost the sales gas to 900 psig (**Figure 1**). The project also assumes the installation of a catalytic oxygen removal system and a pipeline from the project to the natural gas transmission system. Revenues in the form of gas sales to a common carrier pipeline accrue to the project. Figure 2 illustrates the expected methane recovery as a function of inlet methane concentration. Revenues also may result from the sale of carbon emission reductions.

Scenario Assumptions:

- The contaminated tail gas is not utilized.
- The minimum methane concentration for the project type is assumed to be 40%.
- The pipeline cost is assumed to be \$55/ft.
- The capital cost of the catalytic oxidation system is assumed to be \$1.25 million.
- The utilization annual cost includes a fixed O&M of \$300,000/yr and a variable O&M of \$0.75/mcf.
- The hours/yr of operation are standardized with the other scenarios at a range of 7,500-8,300 hours and a default of 8,000 hours. The plant is expected to have a very high reliability, or availability, but is dependent on the availability of the overall CMM gathering and delivery system.
- 21 tons of CO₂E of carbon credits were earned per ton of methane recovered, less the weight of the carbon dioxide associated with the production of grid electricity used by the project, 0.59 tons CO₂/MWh.

Cost of gas upgrade facility

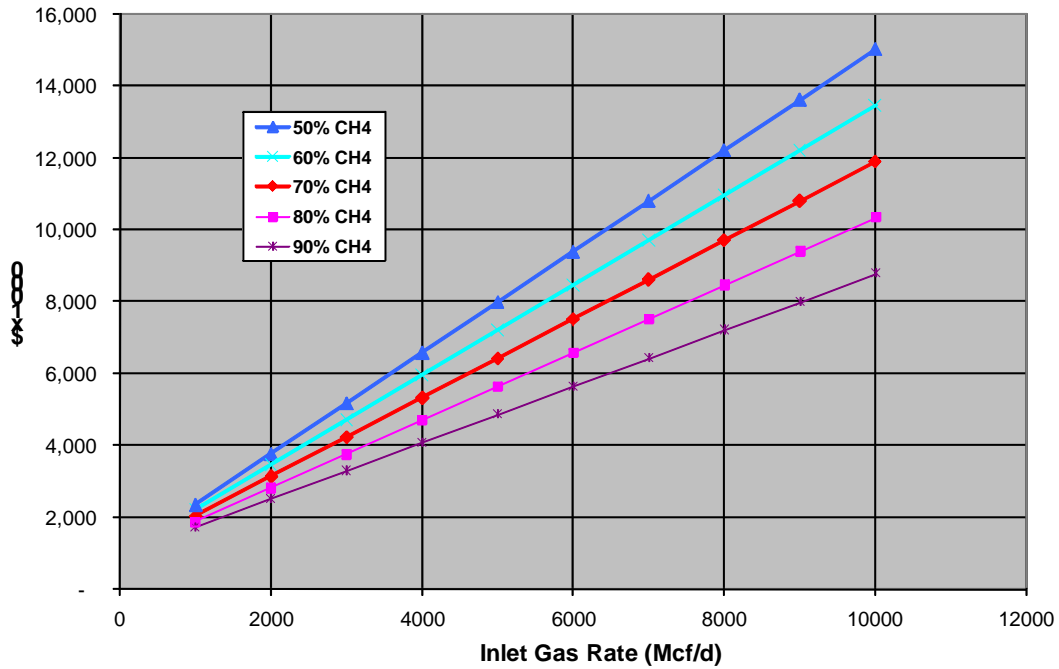


Figure 1: Example calculations at different rates and compositions

Methane Recovery Efficiency

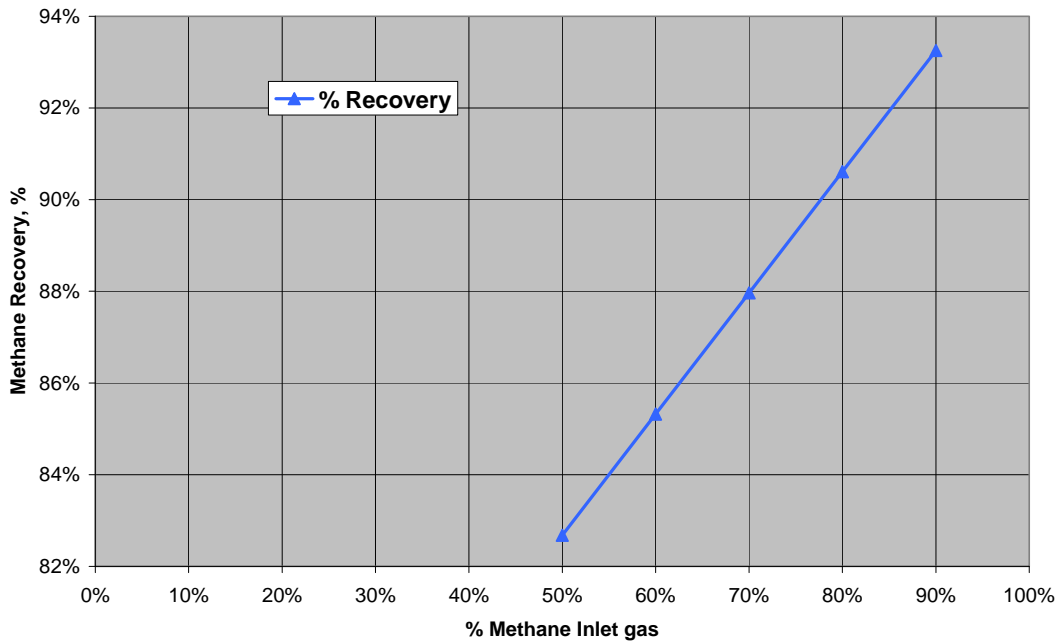


Figure 2: Percent of inlet methane recovered for sale at various inlet compositions

CMM PIPELINE PROJECT

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	\$/HP
3	What is the cost of satellite compressors?	=drainage2	\$/HP
4	What is the distance from the drainage area to the onsite project?	=drainage3	ft
5	What is the cost of installing header pipe from the drainage area?	=drainage4	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between drainage wells?	=drainage6	ft
8	What is the mining rate?	=drainage7	ft/yr
9	How many drainage wells are being utilized?	=drainage7alt	wells
10	What is the drainage gas source?	=inputDrainageSource	
11	What is the mine depth?	=drainage8	ft/well
12	What is the drilling cost?	=drainage9	\$/ft
13	What percent of CMM is consumed by prime-mover use?	=user18/100	
14	What do you expect the CMM drained per day to be?	=gas1	mcfd
15	CMM drained per hour	=B14/24	mcfd/h
16	Percent Methane in Drainage Gas	=inputPctMethane/100	
17	Actual gas flow	=IF(B16<>0,B14/B16,0)	mcfd
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6/100	
20	Average fuel available	=B15*(B19-B13)	mcfd/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22	What is the distance to the natural gas pipeline?	=user13	ft
23	How many hours per year will the project operate?	=default5	hours/yr
24	What is the installed cost of high pressure line from project to natural gas pipeline?	=user14	\$/ft
25	What is the cost of electric power used by the project?	=user2	\$/MW
26	What is the price of the methane sold to the pipeline?	=user9	\$/mmBtu(HHV)
27			
28			
29			
30	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
31	Drainage and Transport sys unit cap cost	=IF((B14*B19)<>0,(B3*B6)+(B4*B5*B16/(B14*B19)))+(IF(B10="AM",B7*B5*B9*B16/(B14*B19),0))+ (B30*IF(inputDrainageSystem="Y", (B2*B6)+IF(B10="AM", B11*B12*B9*B16/(B14*B19),0),0)	
31	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW", (B14*B19)<>0,B23 <>0), ((B8*B5)+IF(AND(inputDrainageSystem="Y", B7<>0), B8*B11*B12*B30/B7,0))*B16*24/(B14*B19)/B23,0)	\$/mcf
32			
33	CMM fuel value LHV	910	Btu/cf
34	Weight of methane, tonnes	0.01926	tonnes/mcf
35	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
36	GWVP ratio: methane to CO2	21	ratio
37	What is the inflation rate?	=default21/100	
38	What is the real discount rate?	=default26/100	
39	What is the developer's equity share in the project?	=user12/100	
40	What is the loan term?	=user15	yr
41	What interest rate is charged for the loan?	=user5/100	
42	Cap Cost Factors		
43	What are the royalty, severance tax, and negotiation fees?	=default11/100	
44	What is the contingency factor?	=default7/100	
45	CMM fuel value HHV	1010	Btu/cf
46	2 - Feasibility Test		
47	CMM combusted in gathering sys. prime movers	=B13*B15	mcfd/h
48	CMM entering project	=B20	mcfd/h
49	CMM volume sold to pipeline	=B48*(0.959-0.2644*(1-B16))	mcfd/h
50	CMM available for other uses	0	mcfd
51			
52	3 - Calculate Annual Benefits:		
53			
54	CMM volume sold to pipeline	=B49	mcfd/h
55	Revenue from gas sales	=B54*B23*B45*B26/1000/1000	\$/000/yr
56	CMM available for carbon credits	=B49+B47	mcfd/h
57	Tonnes CH4 available for carbon credits	=B56*B34	t/h
58	Carbon credits earned per hour	=B57*B36-(IF(B16=0,0,(B48*0.43*24*0.7457*default9/B16	t/h
59	Carbon credits earned per year	=B58*B23	t/yr
60	Carbon credit revenue per year	=B59*B35/1000	\$/000/yr
61			

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 2 'InputScnFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

CMM PIPELINE PROJECT (CONT.)

	A	B	C
1	INPUT PARAMETERS	Values	units
62	4 - Calculate New Annual Costs:		
	Project O&M cost	=IF(B16<>0,(300)+(0.75*B23*B48/B16/1000)+(B48*B23*B25*0.43*24*0.7457/B16/1000/1000),0)	\$000/yr
63			
64	Drain & transport O&M cost/h	=IF(B16<>0,(B48*B32)/B16,0)	\$/h
65	Drain & transport O&M cost/y	=B64*B23/1000	\$000/y
66	--		
67	Total annual cost	=B65+B63	\$000/y
68			
69	5 - Calculate Project Capital Costs		
70	CMM needed per hour	=B48	mcf/h
71	CMM transport system	=IF(B16<>0,B31*B70*24/B16/1000,0)	\$000
	Installed Cost of Processing Plant	=IF(B16<>0,(1250)+(B22*B24/1000)+(936)+(B48*24*(1.5765*(1-B16)+0.6196)/B16),0)	\$000
72			
73	--		
74	Subtotal	=SUM(B71:B72)	\$000
75	Total cap cost with factors	=B74*(1+B43)*(1+B44)	\$000
76			
77	6 - Calculate Loan and Equity		
78	Loan amount	=B75*(1-B39)	\$000
79	Equity amount	=B75*B39	\$000
80			
81	7 - Discounted Cash Flow Analysis		
82		Years >>> 0	(\$000)
83	A - Benefits		1
84	Gas Sales Revenues		=IF(C\$82<=\$B\$18,B55,0)
85	Carbon Credit Revenues		=IF(C\$82<=\$B\$18,\$B60,0)
86	Total Benefits		=SUM(C84:C85)
87	B - Costs		
88	Annual Drainage and Project O&M Cost		=IF(C\$82<=\$B\$18,-B67,0)
89	C - Cash Flow from Operations		=SUM(C86:C88)
90			
	D - Debt Service		=IF(OR(C\$82>\$B\$40,C\$82>\$B\$18),0,PMT(\$B\$41,\$B\$40,\$B\$78))
91			
92	E - Net Cash Flow	=B79	=SUM(C89:C91)
93			
94	8 - Financial Measurements: IRR, NPV, Payback		
95	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B92:V92)),0,IRR(\$B92:V92))
96	Net Present Value		=NPV(B38,B92:V92)

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 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Stand-alone VAM

The ventilation air exhausted from coal mines can contain significant amounts of methane, called ventilation air methane (VAM). Thermal oxidizers can be used to combust the methane to CO₂, which greatly reduces its global warming potential (GWP). The Stand-alone VAM Oxidizer scenario is based on routing VAM with a concentration between 0.25% and 1.25% to a thermal oxidizer. Project capital costs include duct-work for collecting the VAM at the mine surface, and the design and installation of the oxidizer unit and its peripherals. The annual operation and maintenance costs include the labor and utilities required to operate and maintain the oxidation unit and peripherals, as well as the cost to move the unit periodically as the mine vent shaft is relocated. The cost analysis also includes the economic benefits accrued from the sale of carbon credits for methane destruction.

Scenario Assumptions:

- The VAM oxidizer is located adjacent to the evasee or VAM exit, and will be relocated when the evasee is relocated to new coal faces.
- The VAM oxidizer is only used to oxidize VAM for carbon credits and not for waste heat recovery.
- Stand-alone oxidizers require methane concentrations between 0.25 and 1.25% for optimal operation.
- The assumed destruction efficiency of the oxidizer for the purpose of carbon credits is 95%.
- Capital costs include: minimal duct runs, duct blowers and the oxidizer. Total installed capital cost ranges between \$20 and \$25 per cfm of ventilation air.
- Annual costs include: O&M, electricity for duct blowers, and periodic oxidatizer relocation. Annual O&M is assumed to range from \$1.00 to \$1.60 per cfm. Oxidizer relocation charges are assumed to range from \$3.00 to \$5.00 per cfm of capacity for each event. The electrical load on the duct blowers associated with the oxidizer is assumed to range from \$0.05 to \$0.10 kWh per mcf of air directed to the oxidizer.
- The frequency of oxidizer relocation is assumed to range from 3 to 10 years.
- 21 tons of CO₂E of carbon credits were earned per ton of methane recovered, less the weight of the carbon dioxide emitted, 2.75 tons, and less the weight of the carbon dioxide associated with the production of grid electricity used by the project, 0.59 tons CO₂/MWh.

Stand-alone VAM

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the planned project operational lifetime?	=user16	years
3			
4			
5			
6	What percent methane is in the ventilation air?	=gas9/100	
7	What do you expect the recoverable ventilation air flow to be?	=gas10	mcf/m
8	How many hours per year will the VAM system operate?	=default33	hours/yr
9	What is the installed capital cost of VAM oxidizer system?		\$/cfm
10	What is the annual O&M cost of the VAM oxidizer system?	=user23	\$/cfm-yr
11	What is the frequency VAM system will be relocated?	=user24	years
12	What is the VAM oxidation system relocation cost?	=user25	\$/cfm
13	What is the electrical load of the oxidizer blowers?	=user26	kWh/mcf
14		=user27	
15			
16			
17	CMM fuel value LHV	910	Btu/cf
18	Weight of methane, tonnes	0.01926	tonnes/mcf
19	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
20	GWP ratio: methane to CO2	21	ratio
21	What is the inflation rate?	=default21/100	
22	What is the real discount rate?	=default26/100	
23	What is the developer's equity share in the project?	=user12/100	
24	What is the loan term?	=user15	yr
25	What interest rate is charged for the loan?	=user5/100	
26	Cap Cost Factors		
27	What are the royalty, severance tax, and negotiation fees?	=default11/100	
28	What is the contingency factor?	=default7/100	
29	What is the cost of electric power used by the project?	=user2	\$/MWh
30	2 - Feasibility Test		
31	CMM Available (always 0 for Standalone VAM)	0	
32			
33			
34			
35			
36	3 - Calculate Annual Benefits:		
37	Carbon credits earned per year	=+B7*60*B8*B6*B18*(B20-2.75)*0.95- (B7*B8*B13*60*default9/1000)	tonnes CO2e/y
38	Carbon credit revenue per year	=B37*B19/1000	\$000/y
39			
40			
41			
42			
43			
44			
45			
46	4 - Calculate New Annual Costs:		
47	O&M cost	=+B7*B10*1000/1000	\$000/y
48	Electricity cost	=B7*60*B8*B13*B29/1000/1000	\$000/y
49	Relocation cost	=B12*B7*1000/B11/1000	\$000/y
50	Total annual cost	=SUM(B47:B49)	\$000/y
51			
52			

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Stand-alone VAM (continued)

	A	B	C
1	INPUT PARAMETERS	<u>Values</u>	<u>units</u>
	5 - Calculate Project Capital Costs		
53			
54	Installed Capital Cost	=B7*B9*1000/1000	\$000
55	Subtotal	=B54	\$000
56	Total cap cost with factors	=B55*(1+B27)*(1+B28)	\$000
57			
58			
59			
60			
	6 - Calculate Loan and Equity		
61			
62	Loan amount	=B56*(1-B23)	\$000
63	Equity amount	=B56*B23	\$000
64			
	7 - Discounted Cash Flow Analysis		
65		(\$000)	
66			
67	A - Benefits	Years >>> 0	1
68			
69	Carbon Credit Revenues		=IF(C\$66<=\$B\$2,\$B38,0)
70	Total Benefits		=SUM(C68:C69)
71	B - Costs		
72	Annual Costs		=IF(C\$66<=\$B\$2,-B50,0)
	C - Cash Flow from Operations		
73			=SUM(C70:C72)
74			
	D - Debt Service		
75			=IF(OR(C\$66>\$B\$24,C\$66>\$B\$2),0, PMT(\$B\$25,\$B\$24,\$B\$62))
76	E - Net Cash Flow	=-B63	=SUM(C73:C75)
77			
	8 - Financial Measurements: IRR, NPV, Payback		
78			
	Internal Rate of Return - IRR		
79			=IF(ISERR(IRR(\$B76:V76)),0,IRR(\$B76:V76))
80	Net Present Value		=NPV(B22,B76:V76)

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Supplemented VAM

The ventilation air exhausted from coal mines can contain significant amounts of methane, called ventilation air methane (VAM). Thermal oxidizers can be used to combust the methane to CO₂, which greatly reduces its global warming potential (GWP). The Supplemented VAM Oxidizer scenario is based on routing VAM with a concentration less than 0.25% to a thermal oxidizer that is also supplied with supplemental fuel. The supplemental fuel is assumed to be either gob drainage gas or abandoned mine methane. Project capital costs include duct-work for collecting the VAM at the mine surface, the design and installation of the oxidizer unit and its peripherals and the wells and piping required to provide the supplemental fuel. The annual operation and maintenance costs include the labor and utilities required to operate and maintain the oxidation unit, peripherals and the supplemental fuel system, as well as the cost to move the oxidation unit periodically as the mine vent shaft is relocated. The cost analysis also includes the economic benefits accrued from the sale of carbon credits for methane destruction.

Scenario Assumptions:

- The VAM oxidizer is located adjacent to the evasee or VAM exit, and will be relocated when the evasee is relocated to new coal faces.
- The VAM oxidizer is only used to oxidize VAM for carbon credits and not for waste heat recovery.
- Supplemented oxidizers require oxidizer inlet methane concentrations between 0.25 and 1.25% for optimal operation.
- Supplemental fuel will be provided by gob drainage gas or abandoned mine drainage gas, and mixed with VAM immediately prior to entering the VAM oxidizer.
- The assumed destruction efficiency of the oxidizer for the purpose of carbon credits is 95%.
- Capital costs include: minimal duct runs, duct blowers, the oxidizer and the equipment used to recover the drainage gas. Total installed capital cost for the duct runs, duct blowers and the oxidizer ranges between \$20 and \$25 per cfm of ventilation air. See the previous discussion- **Coal Mine Methane Drainage, Gathering, and Delivery System**- for the cost of the drainage gas equipment costs.
- Annual costs include: O&M, electricity for duct blowers, the periodic oxidizer relocation and the costs associated with the equipment used to recover the drainage gas. Annual O&M for the oxidizer and blowers is assumed to range from \$1.00 to \$1.60 per cfm. Oxidizer relocation charges are assumed to range from \$3.00 to \$5.00 per cfm of capacity for each event. The electrical load on the duct blowers associated with the oxidizer is assumed to range from \$0.05 to \$0.10 kWh per mcf of air directed to the oxidizer. See the previous discussion- **Coal Mine Methane Drainage, Gathering, and Delivery System**- for the operating cost of the drainage gas equipment costs.
- The frequency of oxidizer relocation is assumed to range from 3 to 10 years.
- 21 tons of CO₂E of carbon credits were earned per ton of methane recovered, less the weight of the carbon dioxide emitted, 2.75 tons, and less the weight of the carbon dioxide associated with the production of grid electricity used by the project, 0.59 tons CO₂/MWh.

Supplemented VAM

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	\$/HP
3	What is the cost of satellite compressors?	=drainage2	\$/HP
4	What is the distance from the drainage area to the onsite project?	=drainage3	ft
5	What is the cost of installing header pipe from the drainage area?	=drainage4	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between drainage wells?	=drainage6	ft
8	What is the mining rate?	=drainage7	ft/yr
9	How many drainage wells are being utilized?	=drainage7alt	wells
10	What is the drainage gas source?	=inputDrainageSource	
11	What is the mine depth?	=drainage8	ft/well
12	What is the drilling cost?	=drainage9	\$/ft
13	What percent of CMM is consumed by prime-mover use?	=user18/100	
14	What do you expect the supplemental CMM drained per day to be?	=gas1alt	mcfd
15	CMM drained per hour	=B14/24	mcfd/h
16	Percent Methane in Drainage Gas	=gas8alt/100	
17	Actual gas flow	=IF(B16<>0,B14/B16,0)	mcfd
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6alt/100	
20	Average fuel available	=B15*(B19-B13)	mcfd/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22	What percent methane is in the ventilation air?	=gas11/100	
23	What do you expect the recoverable ventilation air flow to be?	=gas12	mcfd/m
24	How many hours per year will the VAM system operate?	=default33	hours/yr
25	What is the installed capital cost of VAM oxidizer system?	=user23	\$/scfm
26	What is the annual O&M cost of the VAM oxidizer system?	=user24	\$/scfm-yr
27	What is the frequency VAM system will be relocated?	=user25	years
28	What is the VAM oxidation system relocation cost?	=user26	\$/cfm
29	What is the electrical load of the oxidizer blowers?	=user27	kWh/mcf
30	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
31	Drainage and Transport sys unit cap cost	=IF((B14*B19)<>0,(B3*B6)+(B4*B5*B16/(B14*B19)))+(IF(B10="AM",B7*B5*B9*B16/(B14*B19,0))+ (B30*IF(inputDrainageSystem="Y",B2*B6)+IF(B10="AM",B11*B12*B9*B16/(B14*B19,0),0)),0)	\$/mcf
32	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW",B14*B19)<>0,B24<>0),(B8*B5)+IF(AND(inputDrainageSystem="Y",B7<>0),B8*B11*B12*B30/B7,0))*B16*24/(B14*B19)/B24,0)	\$/mcf
33	CMM fuel value LHV	910	Btu/cf
34	Weight of methane, tonnes	0.01926	tonnes/mcf
35	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
36	GWP ratio: methane to CO2	21	ratio
37	What is the inflation rate?	=default21/100	
38	What is the real discount rate?	=default26/100	
39	What is the developer's equity share in the project?	=user12/100	
40	What is the loan term?	=user15	yr
41	What interest rate is charged for the loan?	=user5/100	
42	Cap Cost Factors		
43	What are the royalty, severance tax, and negotiation fees?	=default11/100	
44	What is the contingency factor?	=default7/100	
45	What is the cost of electric power used by the project?	=user2	\$/MWh

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.

Supplemented VAM (continued)

	A	B	C
1	INPUT PARAMETERS	Values	units
46	2 - Feasibility Test		
47	heat available	=B21	mmBtu/h
48	heat needed	=B23*B16*(gas13/100-B22)*B33/(16.6667*B16-(gas13*16.6666/100))	mmBtu/h
49	Supplemental methane volume consumed/hour	=IF(OR(B47<B48,inputScenFlare="OF",inputScenFlare="EF"),B47*1000/B33/(1-B13),B48*1000/B33/(1-B13))	mcf/h
50	CMM available for other uses	=IF(OR(B48>B47,inputScenFlare="OF",inputScenFlare="EF",B19=0),0,B14-(B49*24/B19))	mcf/d
51			
52	3 - Calculate Annual Benefits:		
53	Carbon credits earned from VAM destruction per year	=+B23*B24*B22*B34*(B36-2.75)*0.95*60	tonnes/y
54	Carbon credits from supplemental gas destruction per year		tonnes/y
55	Carbon credit revenue per year	=B49*B34*(B36-2.75)*B24 =(B53+B54-((B23+(B17*B19/24/60))*B24*B29*60*default/9/1000))*B35/1000	\$000/y
56	Total credits earned per year	=supVAMcers1+supVAMcers2	
57			
58			
59			
60			
61			
62	4 - Calculate New Annual Costs:		
63	Drain & transport O&M cost/yr	=IF(B16<>0,(B49*B32)/B16,0))*B24/1000	\$000/y
64	Back-up Flare O&M cost/yr	=IF(inputScenFlare="OF",user2,IF(inputScenFlare="EF",user2,0,0))	\$000/y
65	VAM Oxidizer O&M	=+(B23+(B17*B19/24/60))*B26*1000/1000	\$000/y
66	VAM Oxidizer Electricity cost	=B23+(B17*B19/24/60))*B24*B29*B45*60/1000/1000	\$000/y
67	Oxidizer Relocation cost	=B28*(B23+(B17*B19/24/60))*1000/B27/1000	\$000/y
68	Total annual cost	=SUM(B63:B67)	\$000/y
69	5 - Calculate Project Capital Costs		
70	CMM needed per hour		mcf/h
71	CMM transport system	=B49	
72	Installed Oxidizer Capital Cost	=IF(B16<>0,B31*B70*24/B16/1000,0)	\$000
73	Back-up Flare capital cost	=B23+(B17*B19/24/60))*B25*1000/1000 =IF(inputScenFlare="OF",B20*24*user2,IF(inputScenFlare="E F",B20*24*user19,0))	\$000
74	Subtotal	=SUM(B71:B73)	\$000
75	Total cap cost with factors	=B74*(1+B43)*(1+B44)	\$000
76			
77	6 - Calculate Loan and Equity		
78	Loan amount	=B75*(1-B39)	\$000
79	Equity amount	=B75*B39	\$000
80			
81	7 - Discounted Cash Flow Analysis	(\$000)	
82			
83	A - Benefits	Years >>> 0	1
84	Carbon Credit Revenues		=IF(C\$82<=\$B\$18,\$B55,0)
85	Total Benefits		=SUM(C84:C85)
86	B - Costs		
87	Oxidizer and supplemental CMM Annual Costs		=IF(C\$82<=\$B\$18,-B68,0)
88			
89	C - Cash Flow from Operations		=SUM(C86:C88)
90			
91	D - Debt Service		=IF(OR(C\$82>\$B\$40,C\$82>\$B\$18),0,PMT(\$B\$41,\$B\$40,\$B\$78))
92	E - Net Cash Flow	=-B79	=SUM(C89:C91)
93			
94	8 - Financial Measurements: IRR, NPV, Payback		
95	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B92:V92)),0,IRR(\$B92:V92))

1 'InputDrainageSystem' refers to the user's Y/N response to "Do you want to include the drainage well and drainage blower development costs in this cost analysis?"
 2 'InputScenFlare' refers to the user's response to "Select a flare type if flares are to be included in the project." EF means enclosed flare; OF means open flare.
 3 Variables such as "drainage", "gas", "default", and "user" are values selected or entered in the user input screens.