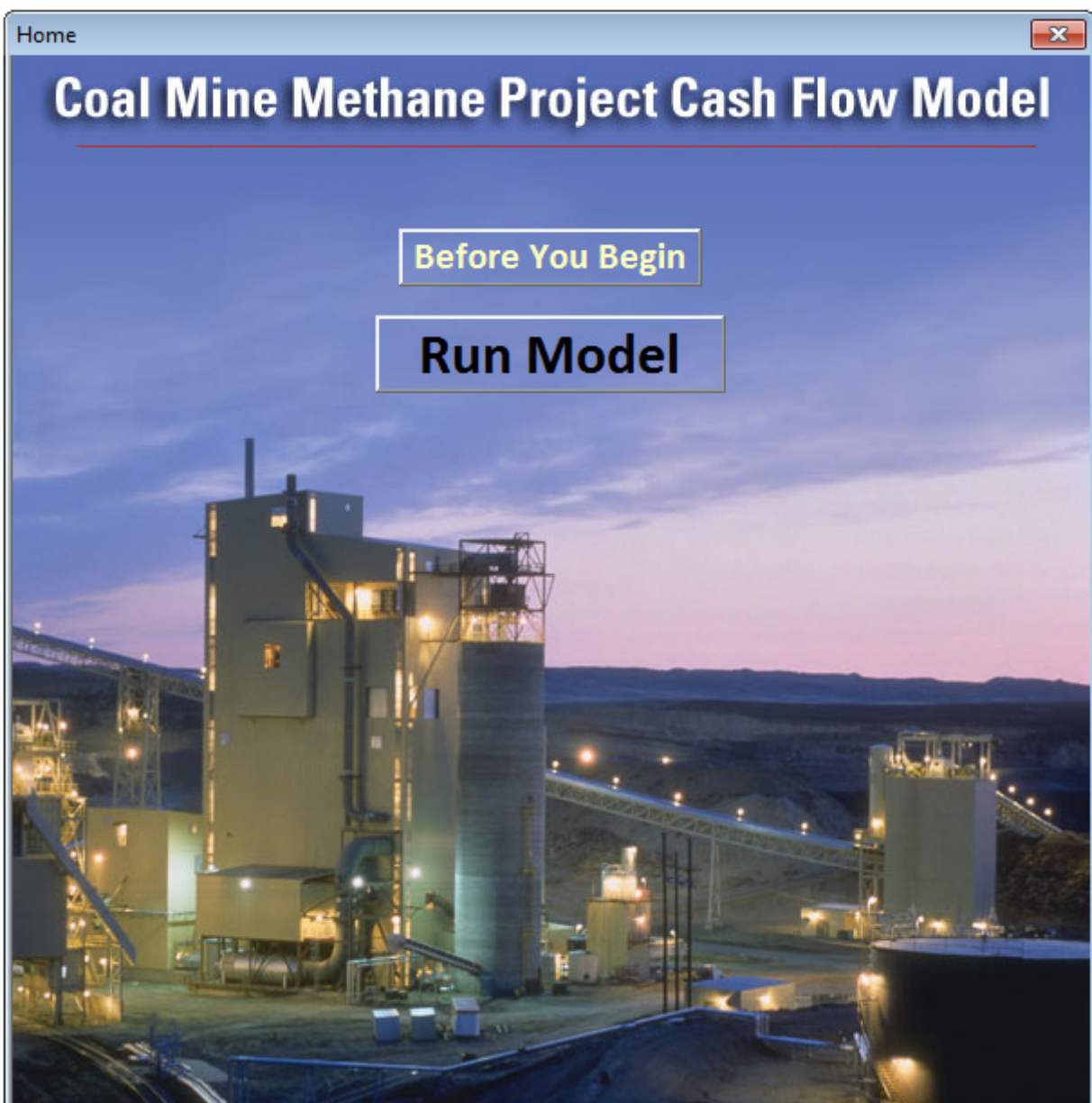




User's Manual for the Coal Mine Methane Project Cash Flow Model

(Version 3)
EPA 430-B-21-001



June 2016



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1 Introduction

Welcome to the Coal Mine Methane Project Cash Flow Model, Version 3.0. 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 (CMM) in one of ten ways from gob wells, abandoned mine drainage wells or mine ventilation air. Version 3.0 of the model upgrades the previous version by:

- Adding the capability to investigate the potential of using CMM in the production of compressed natural gas (CNG) or liquefied natural gas (LNG).
- Adding options for including “soft costs” such as staffing costs, permitting costs.
- Adding the option to include the cost of monetizing carbon credits - validation, verification, and transaction costs.
- Changing the way NPV and Royalty and Severance Taxes calculations are made.
- Users can now define which methane Global Warming Potential (GWP) value they wish to use.¹
- Adding hover notes for many of the input values.
- New design features making the model more user friendly.
- Facilitating the evaluation of CMM projects located outside of the U.S. by offering an international version of the model based on the International System of Units (SI units).

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 Industry Contacts list <https://www.epa.gov/epa-coalbed-methane-outreach-program/network-contacts>.

CMOP is a voluntary outreach program with a mission to promote the profitable recovery and use of coal mine methane, 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.

1.1 Input and Output Data

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 CMM project.

¹ The UN IPCC 5th Assessment Report (2014) uses a Global Warming Potential (GWP) value of 25 - this is used as the default in the model. The user has the option of changing this to a value used in another Report if desired. The model allows the user to define a value between 21 and 50 if they choose.



The user will be required to enter data specific to a coal mine and 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, Internal Rate of Return, and Payback Period for the project.

The model's generated 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)
 - ◆ Payback Period
 - ◆ Cash flow

1.2 Contact:

For questions regarding the model, contact:

Coalbed Methane Outreach Program
U.S. Environmental Protection Agency
www.epa.gov/cmop
CMOPmodel@adv-res.com

2 Getting Started

This User's Manual is organized to follow the model's 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. Reference Section 4 to learn more about the model's assumptions for each project type.

2.1 Opening the Model

Use a PC running a recent Microsoft Windows Operating System and Excel. It is recommended to use Microsoft Windows 7 operating system, along with Excel 2010 or Excel 2013. The model can be run using earlier versions of Excel – follow the screen prompts and warnings - but has not been tested in a Windows 8 environment. 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.
- In Excel 2010, 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.
- In Excel 2013, click the **File** tab. Select **Options**. 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 in the same way 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 2007/2010/2013, 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 Vista, right click on the Desktop and select **Personalize**. Select **Display Settings**. Set the Screen resolution to no less than 1024 x 768.
- In Windows 7, right click on the Desktop and select **Personalize**. Select **Display Settings**. Set the Screen resolution to no less than 1024 x 768.

2.2 Using the Model

The CMM Financial Model is generated “behind the scenes” using an Excel spreadsheet. User interaction with the model takes place using the input data screens. On the “Home” screen, it is recommended to click on the “Before You Begin” button to review Settings, User Tips, and Saving Results instructions. Then “Run Model” takes the user to the “Start” screen. Select a CMM end use scenario along with the source of gas to continue to the following data input screens. (The Coal Drying, Mine Boilers, and Supplemented VAM Oxidizer scenarios also give the user the option of including flares).

The next screen presents four data input tabs. 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. Hover over any of the question boxes to see additional help information appear as a floating info tip.

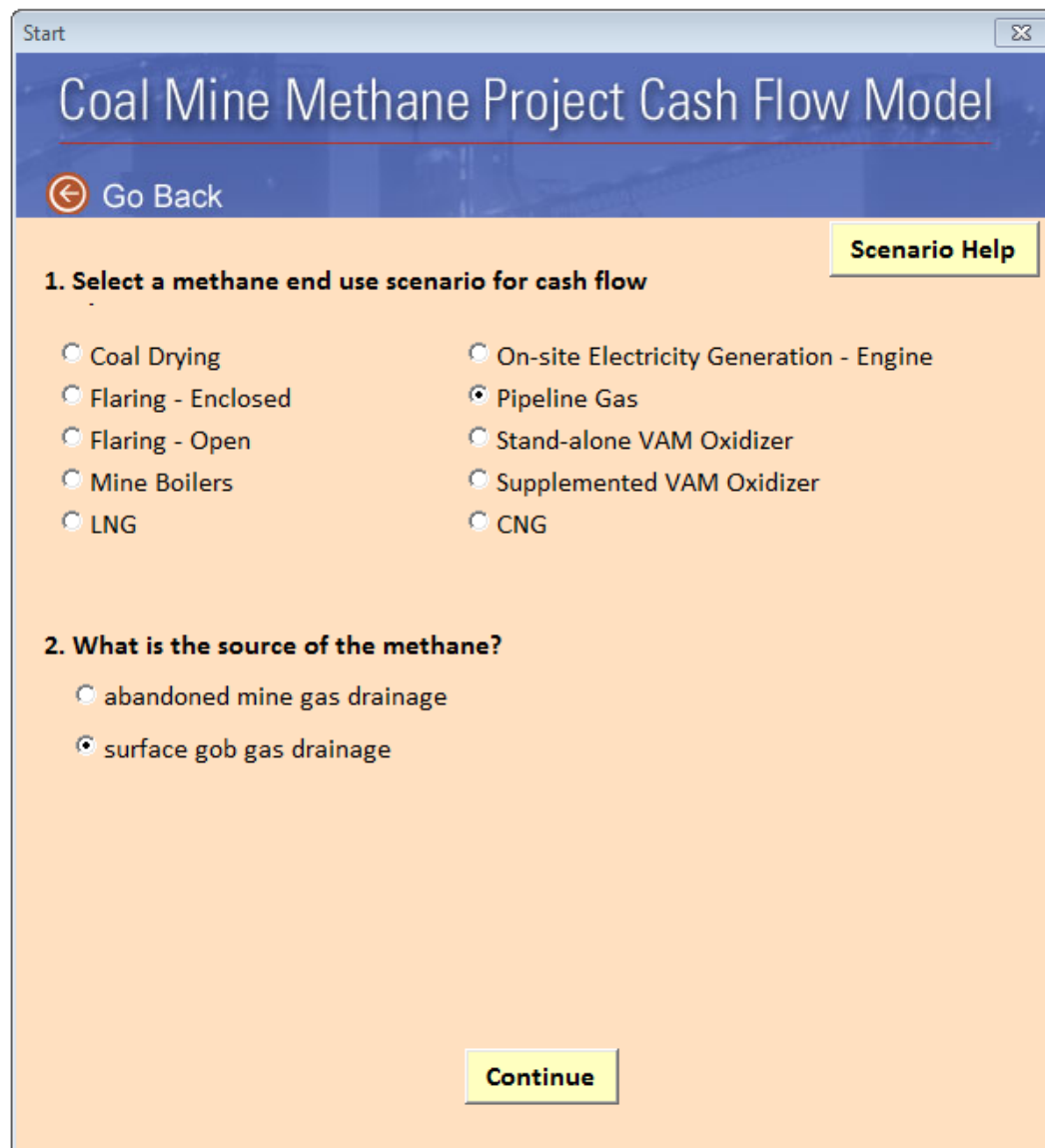
Note that the model generally provides a range of values rather than specific default values. If you enter a value outside of the recommended range, you will receive a warning. However, the model will use your value if you choose not to change it.

3 Quick-Start - Model Run Example

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.

3.1 Start Screen

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



Start

Coal Mine Methane Project Cash Flow Model

Go Back

Scenario Help

1. Select a methane end use scenario for cash flow

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

2. What is the source of the methane?

- abandoned mine gas drainage
- surface gob gas drainage

Continue

Depending on the scenario selected, you will be presented with additional questions about the source of methane for the project.

Note that 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 nearby. 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.

3.2 Gas Collection Tab

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.

Pipeline Gas
X

Gas Collection
Gas Availability
User-Defined Inputs
Default Parameters

Gathering & Delivery System Parameters	Amount / Units	Recommended Values
What is the cost of satellite compressors?	<input type="text" value="1000"/> \$/HP	[1,000]
What is the distance from the drainage area to the onsite project?	<input type="text" value="21000"/> ft	
What is the cost of installing header pipe from the drainage area?	<input type="text" value="40"/> \$/ft	[40]
What are the compressor and blower efficiencies?	<input type="text" value="0.035"/> HP/mcfd	[0.02-0.07]
What is the mining rate?	<input type="text" value="12000"/> ft/yr	[12,000]
What is the spacing between gob drainage wells?	<input type="text" value="1000"/> ft	[1,000]
Do you want to include the drainage well and drainage blower development costs in this cost analysis?		<input type="radio"/> Yes <input checked="" type="radio"/> No
What is the cost of well-head blowers?	<input type="text"/> \$/HP	[1,000]
What is the mine depth?	<input type="text"/> ft	[1,000]
What is the drilling cost?	<input type="text"/> \$/ft	[140]
What is the fraction of this project's drainage system cost that will be included in the analysis?	<input type="text"/> %	[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

3.2.1 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:

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

Recommended values for these input parameters are based on a range of representational values from operations in the United States.

- Distance from the drainage area to the CMM project installation – an average distance to the drainage wells, which will vary greatly according to individual project characteristics.
- Mining rate – typical rates in the U.S. are between 150-300 feet per week (7,000 – 15,000 feet per year) depending on seam thickness and mining conditions.
- Spacing between gob drainage wells – spacing will vary depending on mining rate, gas content and project economics. (See "CMM Recovery - A Primer" p.35 www.epa.gov/cmop/docs/cmm_primer.pdf)

3.2.2 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.

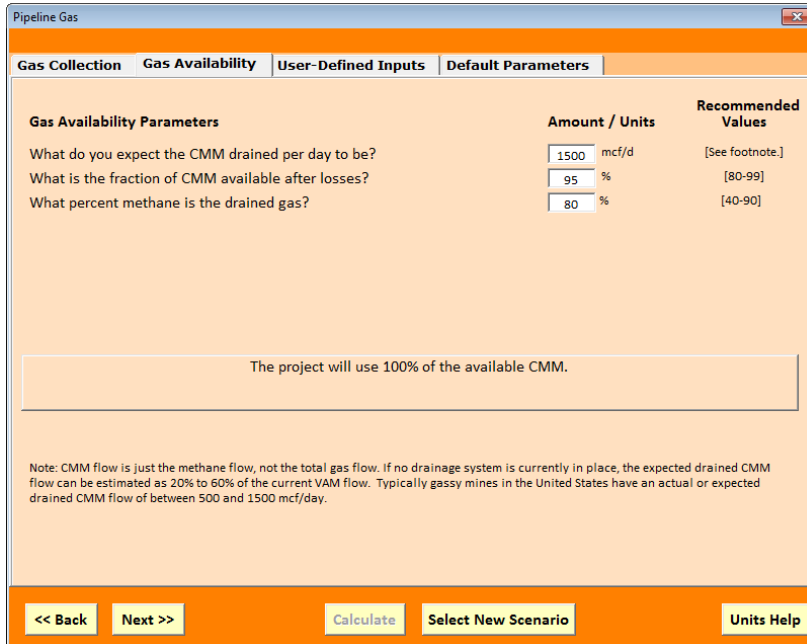
For example, if your coal mine does not have a drainage system in place, you will likely want to include these costs to give a better overall picture of the project. However, if the mine already has a drainage system in place for reasons such as safety, then you could exclude these costs and focus the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

3.3 Gas Availability Tab

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.



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?	80 %	[40-90]

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.

Note that throughout the model, CMM flow (CMM drained per day) refers only to the flow of coal mine methane (i.e., CH₄ only) 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 is currently used. 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.

3.4 User-Defined Inputs Tab

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

User-Defined Input Parameters	Amount / Units	Recommended Values
Scenario Name (up to 40 characters):	Pipeline Gas incl well costs and loan	
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?	2 \$/tonne CO2E	
What is the distance to the natural gas pipeline?	32000 ft	
What is the cost of electric power used by the project?	65 \$/MWh	[\$50-\$90]
What is the price of the methane sold to the pipeline?	5 \$/mmBtu(HHV)	[\$2.00-\$12.00]
What is the installed cost of the high pressure line from the project site to the natural gas pipeline?	55 \$/ft	[40-70]
What is the cost of the catalytic oxidizer?	1250 \$,000	[1,250]

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.

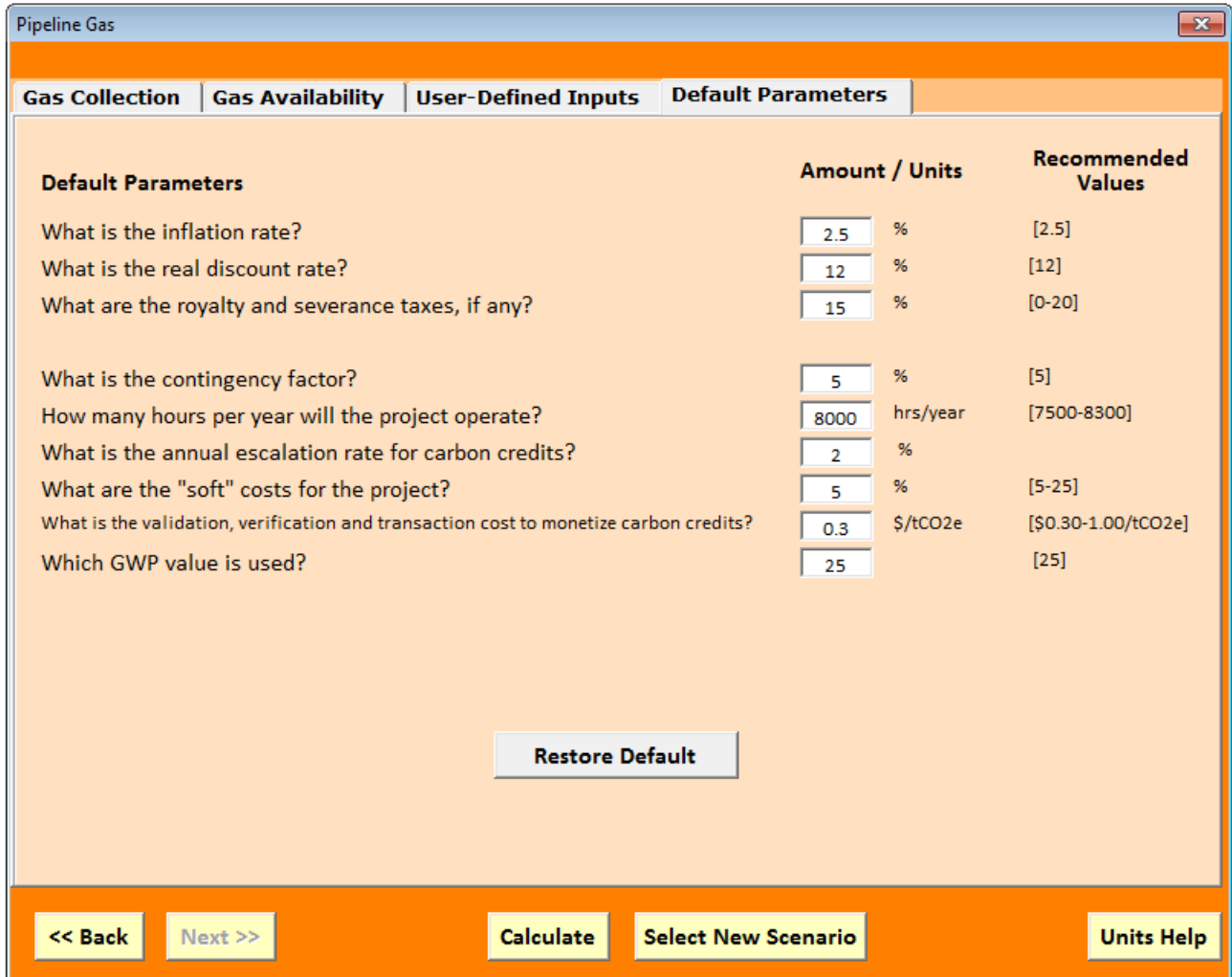
Note that the name of the scenario type does not appear in the output report automatically and you will not be able to identify the end-use type unless you specify it in the **Scenario Name**.

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.

3.5 Default Parameters Tab

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



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 and severance taxes, if any?	<input type="text" value="15"/> %	[0-20]
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"/> %	[5-25]
What are the "soft" costs for the project?	<input type="text" value="5"/> %	[5-25]
What is the validation, verification and transaction cost to monetize carbon credits?	<input type="text" value="0.3"/> \$/tCO ₂ e	[\$0.30-1.00/tCO ₂ e]
Which GWP value is used?	<input type="text" value="25"/>	[25]

Restore Default

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

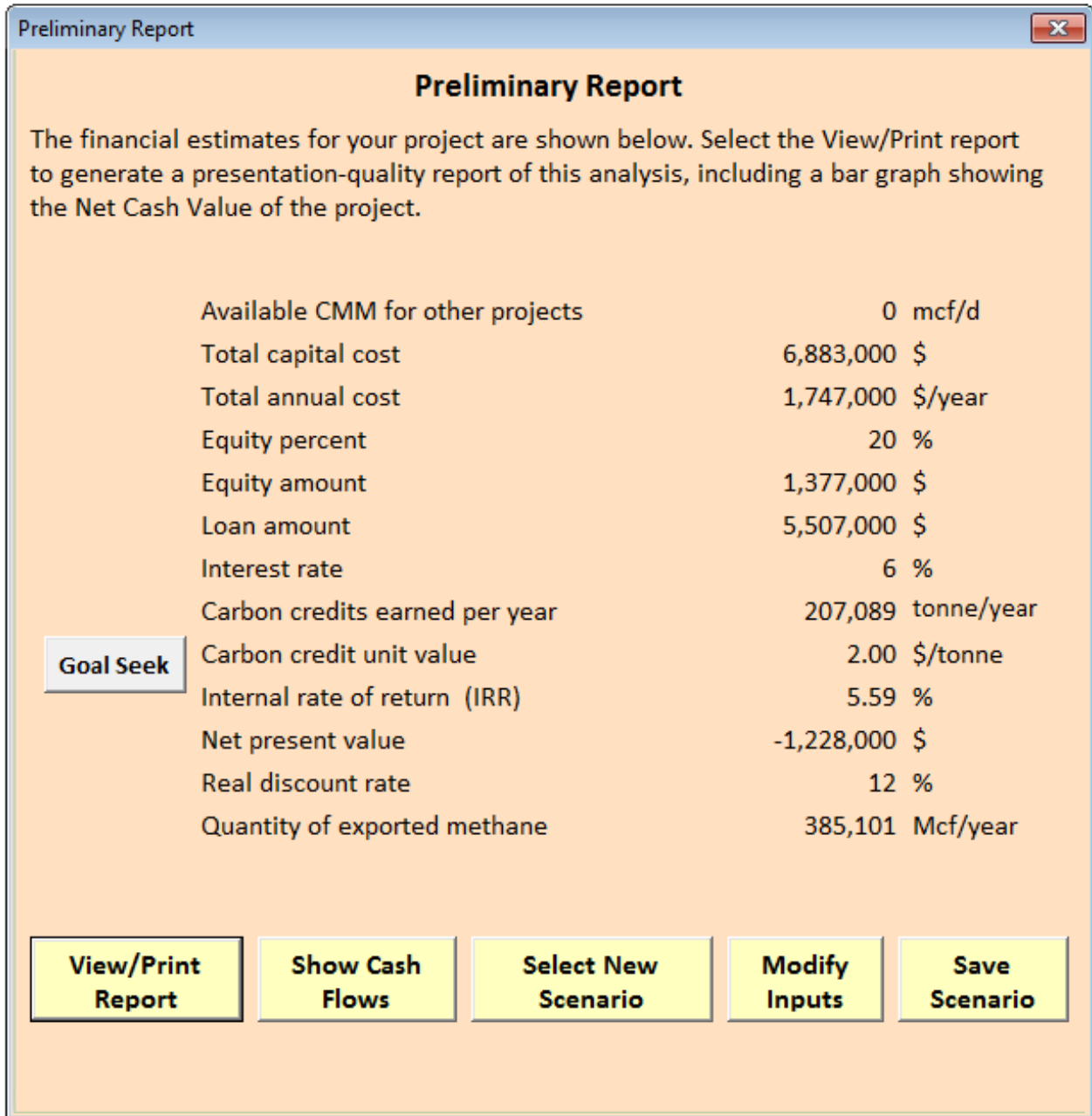
Since many of these parameters may not be familiar to users, EPA has provided a full set of default parameters. However, users can override the default parameters. Selecting **Restore Default Values** restores the EPA-provided values.

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**.

3.6 Preliminary Report Screen

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**. There is also an option to **Goal Seek** a carbon credit unit value to achieve a user's desired Internal Rate of Return.



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	6,883,000 \$
Total annual cost	1,747,000 \$/year
Equity percent	20 %
Equity amount	1,377,000 \$
Loan amount	5,507,000 \$
Interest rate	6 %
Carbon credits earned per year	207,089 tonne/year
Goal Seek Carbon credit unit value	2.00 \$/tonne
Internal rate of return (IRR)	5.59 %
Net present value	-1,228,000 \$
Real discount rate	12 %
Quantity of exported methane	385,101 Mcf/year

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. In this example “pipeline scenario” costs include 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. The cost of the blower system may also be included if the user chooses to incorporate the 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 the user chooses 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 the 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 15 and 16 show an example report for the pipeline scenario presented in this manual.

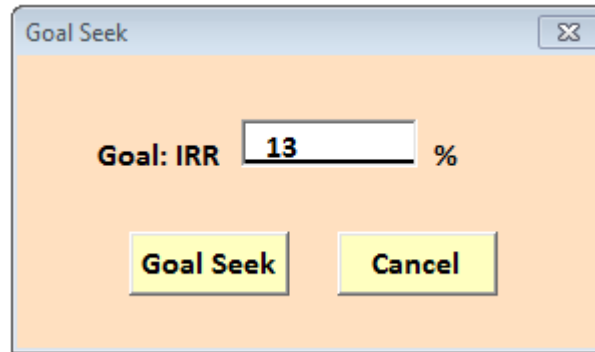
Select **Show Cash Flows** to view the **Cash Flow Report**, which presents the net cash flow over the lifetime of the project—up to 20 years. The Cash Flow Report includes year 0, which is the year to construct the project. Page 17 shows an example cash flow report.

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.

3.7 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.

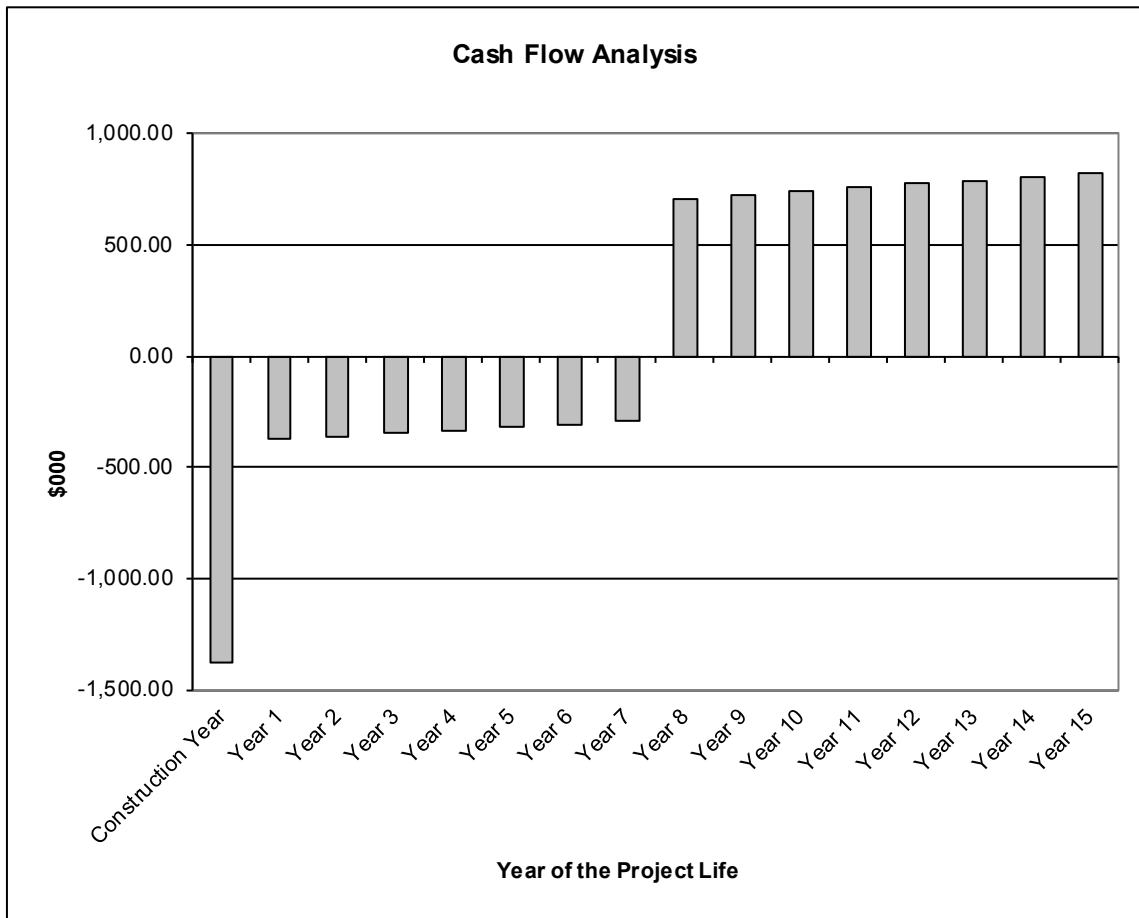


For example, the Pipeline Gas project that is presented in this manual has an initial net present value of \$-1,228,000 and initial IRR of 5.59%, as shown in the Preliminary Report on page 16. However, by inputting 13.0% IRR into Goal Seek, the model determines that a carbon credit price of 2.91 is required to achieve the financial goal, improving the financial viability of the scenario to a net present value of \$194,000.

Carbon credit price is used for the goal seek function because this parameter is the most flexible and the one for which a project developer could negotiate or obtain a better value to improve the financial viability of the project.

Estimated Outputs:

Available CMM for Other Projects	0 mcf/d
Total capital cost	6,883,000 \$
Total annual cost	1,747,000 \$/year
Equity amount	1,377,000 \$
Loan amount	5,507,000 \$
Carbon credits earned per year	207,089 tonne/year
Internal rate of return (IRR)	5.59 %
Net present value	-1,228,000 \$
Quantity of exported Methane	385,101 Mcf/year



Coalbed Methane Scenario: Pipeline Gas incl well costs and loan

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 gob drainage wells?	1000 ft

Drainage Well & Blower Development Costs

What is the cost of well-head blowers?	Not Applicable
What is the mine depth?	\$/HP
What is the drilling cost?	ft
What is the fraction of this project's drainage system cost that will be included in the analysis?	\$/ft
	%

Gas Availability


What is the source of the coal mine methane?	surface gob gas drainage
Percent Methane in Drainage Gas	80 %
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?	2.00 \$/tonne CO2E
What percent of CMM is consumed by prime-mover use?	10 %
What is the distance to the natural gas pipeline?	32000 ft
What is the cost of electric power used by the project?	65 \$/MWh
What is the price of the methane sold to the pipeline?	5 \$/mmBtu(HHV)
What is the installed cost of high pressure line from project to natural gas pipeline?	55 \$/ft
Which GWP value is used?	25

Default Parameters:

What is the inflation rate?	2.5 %
What is the real discount rate?	12 %
What are the royalty and severance taxes, if any?	15 %
What is the contingency factor?	5 %
What is the annual escalation rate for carbon credits?	2 %
What are the "soft" costs for the project?	5 %
What is the validation, verification and transaction cost to monetize carbon credits?	0.3 \$/tCO2e
Which GWP value is used?	25
How many hours per year will the project operate?	8000 hrs/year

	Coalbed Methane Scenario: Pipeline Gas incl well costs and loan							
	Construction Year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Savings or Product Revenues		1,944.76	1,993.38	2,043.21	2,094.29	2,146.65	2,200.32	2,255.33
Carbon Credit Revenues		414.18	422.46	430.91	439.53	448.32	457.29	466.43
Operating Costs		-1,747.49	-1,791.18	-1,835.96	-1,881.86	-1,928.90	-1,977.13	-2,026.55
Debt Service		-986.43	-986.43	-986.43	-986.43	-986.43	-986.43	-986.43
Net Cash Flow	-1,376.66	-374.99	-361.77	-348.27	-334.47	-320.36	-305.95	-291.23

	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
	Savings or Product Revenues	2,311.71	2,369.50	2,428.74	2,489.46	2,551.69	2,615.49	2,680.87
Carbon Credit Revenues	475.76	485.28	494.98	504.88	514.98	525.28	535.78	546.50
Operating Costs	-2,077.22	-2,129.15	-2,182.38	-2,236.94	-2,292.86	-2,350.18	-2,408.94	-2,469.16
Debt Service	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Cash Flow	710.25	725.63	741.34	757.40	773.81	790.58	807.72	825.23

4 Technical Basis of the Model

4.1 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, this system must be installed annually as 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 by the coal sales bottom line, since the installation of a drainage system can increase mine productivity and decrease down time.

4.2 Recovery Annual Costs

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

The 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), and
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:

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

4.3 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:

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

4.4 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.

4.4.1 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 per year (hrs/yr) of operation are standardized with the other scenarios at a range of 4,500-8,300 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.
- Depending on the GWP used, 21/25 tons of CO₂E of carbon credits are 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 23/27 tons of CO₂E per ton of methane burned.

4.4.2 Coal Drying Spreadsheet

	A	B	C
1	INPUT PARAMETERS	<i>Values</i>	<i>units</i>
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?	40	\$/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between gob 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	0
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?	=gas1zz	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?	=gas6zz/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?	=gas2zz	t/h
23	How many hours per year will the coal dryer operate?	=default1	h/y
24	What is the heat required per ton of coal?	=gas4zz	mmBtu/ton
25	What is the dryer efficiency?	=gas3zz/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="Y", B7 <>0), B8*B11*B12*B30/B7, 0))*B16*24/(B14*B19)/B23, 0)	\$/mcf
33	CMM fuel value LHV		Btu/cf
34	Weight of methane, tonnes		tonnes/mcf
35	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
36	GWP ratio: methane to CO2	=default20	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 is the contingency factor?	=default7/100	
44	What are the "soft" costs for the project?	=default14/100	
45	Annual Cost Factors		
46	What are the royalty and severance taxes, if any?	=default11/100	
47	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
48			
49	2 - Feasibility Test		
50	CMM heat value available/hour	=B21	mmBtu/h
51	Coal Dryer heat needed/hour	=IF(B25<>0,B22*B24/B25,0)	mmBtu/h

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)

1	INPUT PARAMETERS	Values	units
52	CMM volume needed/hour	=IF(OR(B50<B51,inputScenFlare="OF",inputScenFlare="EF"),B50*1000/B33/(1-B13),B51*1000/B33/(1-B13))	mcf/h
53	CMM available for other uses	=IF(OR(B51>B50,inputScenFlare="OF",inputScenFlare="EF",B19=0),0,B14-(B52*24/B19))	mcf/d
54			
55	3 - Calculate Annual Benefits:		
56	Tons of coal replaced per hour	=IF(B29<>0,IF(B50<B51,B50/B29,B51/B29),0)	ton/h
57	Cost savings per hour - coal	=B56*(B27+B28)	\$/h
58	Cost savings per year - coal	=B57*B23/1000	\$/000/y
59	CMM volume needed/hour	=B52	mcf/h
60	Tonnes CH4 needed/hour	=B59*B34	t/h
61	Carbon credits earned per hour	=B60*(B36+2)	t/h
62	Carbon credits earned per year	=B61*B23	t/y
63	Carbon credit revenue per year	=B62*B35/1000	\$/000/y
64			
65	4 - Calculate New Annual Costs:		
66	CMM needed per hour	=B52	mcf/h
67	Drain & transport O&M cost/h	=IF(B16<>0,(B66*B32)/B16,0)	\$/h
68	Drain & transport O&M cost/yr	=B67*B23/1000	\$/000/y
69	Back-up Flare O&M cost/yr	=IF(inputScenFlare="OF",user22,IF(inputScenFlare="EF",user20,0))	
70	Royalty and Severance Taxes	=coalCmmDrained*365*B46*3/1000	
71	Carbon credit monetization cost/yr	=B47*coalCERsEarnedPerYear/1000	
72	Total annual cost	=SUM(B68,B69,B71,B70)	\$/000/y
73			
74	5 - Calculate Project Capital Costs		
75	CMM needed per hour	=B52	mcf/h
76	CMM transport system	=IF(B16<>0,B31*B75*24/B16/1000,0)	\$/000
77	Dryer conversion	=IF(B50<B51,B50*B26,B51*B26)	\$/000
78	Back-up Flare capital cost	=IF(inputScenFlare="OF",B20*24*user21,IF(inputScenFlare="EF",B20*24*user19,0))	
79	Subtotal	=SUM(B76:B78)	\$/000
80	Total cap cost with factors	=(B79*(1+B44))*(1+B43)	\$/000
81			
82	6 - Calculate Loan and Equity		
83	Loan amount	=B80*(1-B39)	\$/000
84	Equity amount	=B80*B39	\$/000
85			
86	7 - Discounted Cash Flow Analysis		
87		Years >>>	1
88	A - Benefits		
89	Coal savings		=IF(C587<=\$B518,B58,0)
90	Carbon Credit Revenues		=IF(C587<=\$B518,\$B63,0)
91	Total Benefits		=SUM(C89:C90)
92	B - Costs		
93	CMM transport cost + drain share		=IF(C587<=\$B518,-B72,0)
94	C - Cash Flow from Operations		
95			=SUM(C91:C93)
96	D - Debt Service		
97	E - Net Cash Flow	=B84	=IF(OR(C587>\$B540,C587>\$B518),0,PMT(\$B541,\$B540,-SUM(C94:C96))
98			
99	8 - Financial Measurements: IRR, NPV, Payback		
100	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B97:X97)),0,IRR(\$B97:X97))
101	Net Present Value		=NPV(B38,C97:X97)+coalMinusEquityAmount
102		=SUMPRODUCT(B97:X97,B103:X103)	
103	Discount Factor	=1/(1+coalRealDiscountRate)^B87	=1/(1+coalRealDiscountRate)^

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.

4.5 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.

4.5.1 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 4,500-8,300 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.
- Depending on the GWP chosen, 21/25 tons of CO₂E of carbon credits are earned per ton of methane destroyed, less the weight of the carbon dioxide emitted, 2.75 tons, resulting in a net factor of 18.25/21.25 tons of CO₂E per ton of methane burned.

4.5.2 Enclosed Flare 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 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 gob 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?	=gas1zz	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?	=gas6zz/100	
20	Average fuel available	=B15*(B19-B13)	mcf/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	\$/mcf
26	What is the O&M cost of the enclosed flare?	=user20	\$/yr
27			
28	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
29	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
30	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
31	CMM fuel value LHV	910	Btu/cf
32	Weight of methane, tonnes	0.01926	tonnes/mcf
33	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
34	GWFP ratio: methane to CO2	=default20	ratio
35	What is the inflation rate?	=default21/100	
36	What is the real discount rate?	=default26/100	
37	What is the developer's equity share in the project?	=user12/100	
38	What is the loan term?	=user15	yr
39	What interest rate is charged for the loan?	=user5/100	
40	Cap Cost Factors		
41	What is the contingency factor?	=default7/100	
42	What are the "soft" costs for the project?	=default14/100	
43	Annual Cost Factors		
44	What are the royalty and severance taxes, if any?	=default11/100	
45	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
46			
47	2 - Feasibility Test		
48	CMM heat value available/hour	=B21	mmBtu/h
49			
50	CMM volume needed/hour	=B50*1000/B33/(1-B13)	mcf/h
51	CMM available for other uses	0	mcf/d

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.

Enclosed Flare Spreadsheet (continued)

	A	B	C
1	INPUT PARAMETERS	Values	units
53	3 - Calculate Annual Benefits:		
54			
55			
56			
57	CMM volume needed/hour	=B52	mcf/h
58	Tonnes CH4 needed/hour	=B59*B34	t/h
59	Carbon credits earned per hour	=B60*(B36-2.75)	t/h
60	Carbon credits earned per year	=B61*B23	t/y
61	Carbon credit revenue per year	=B62*B35/1000	\$000/y
62			
63	4 - Calculate New Annual Costs:		
64	Flare O&M cost	=B26	\$000/y
65	Drain & transport O&M cost/h	=IF(B16<>0,(B52*B32)/B16,0)	\$/h
66	Drain & transport O&M cost/yr	=B67*B23/1000	\$000/y
67	Carbon credit monetization cost/yr	=B47*cflareCERsEarnedPerYear/1000	\$000/y
68	Royalty and Severance Taxes	=B14*365*B46*3/1000	\$000/y
69	Total annual cost	=B68+B66+B69+B70	\$000/y
70			
71	5 - Calculate Project Capital Costs		
72	CMM needed per hour	=B52	mcf/h
73	CMM transport system	=IF(B16<>0,B31*B74*24/B16/1000,0)	\$000
74	Installed Cost Flare	=B20*B25*24	\$000
75	--		
76	Subtotal	=SUM(B75:B76)	\$000
77	Total cap cost with factors	=(B78*(1+B44))*(1+B43)	\$000
78			
79	6 - Calculate Loan and Equity		
80	Loan amount	=B79*(1-B39)	\$000
81	Equity amount	=B79*B39	\$000
82			
83	7 - Discounted Cash Flow Analysis	(\$000)	
84	Years >>>	0	1
85	A - Benefits		
86			=IF(C\$86<=\$B\$18,B\$8,0)
87	Carbon Credit Revenues		=IF(C\$86<=\$B\$18,\$B63,0)
88	Total Benefits		=SUM(C88:C89)
89	B - Costs		
90	Annual Drainage and Flare O&M Cost		=IF(C\$86<=\$B\$18,-B71,0)
91	C - Cash Flow from Operations		=SUM(C90:C92)
92			
93	D - Debt Service		=IF(OR(C\$86>\$B\$40,C\$86>\$B\$18),0,PMT(\$B\$41,\$B\$40,\$B\$82))
94	E - Net Cash Flow	=B83	=SUM(C93:C95)
95			
96	8 - Financial Measurements: IRR, NPV, Payback		
97	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B96:X96)),0,IRR(\$B96:X96))
98	Net Present Value		=NPV(B38,C96:X96)+cflareMinusEquityAmount

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.

4.5.3 Open Flare Spreadsheet

	A	B	C
1	INPUT PARAMETERS	<i>Values</i>	<i>units</i>
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 gob 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?	=gas1zz	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?	=gas6zz/100	
20	Average fuel available	=B15*(B19-B13)	mcf/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	\$/mcf
26	What is the O&M cost of the open flare?	=user22	\$/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)	\$/mcf
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	=default20	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 is the contingency factor?	=default7/100	
44	What are the "soft" costs for the project?	=default14/100	
45	Annual Cost Factors		
46	What are the royalty and severance taxes, if any?	=default11/100	
47	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
48			
49	2 - Feasibility Test		
50	CMM heat value available/hour	=B21	mmBtu/h
51			
52	CMM volume needed/hour	=B50*1000/B33/(1-B13)	mcf/h
53	CMM available for other uses	0	mcf

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.

Open Flare Spreadsheet (continued)

	A	B	C
1	INPUT PARAMETERS	<i>Values</i>	<i>units</i>
55	3 - Calculate Annual Benefits:		
56			
57			
58			
59	CMM volume needed/hour	=B52	mcf/h
60	Tonnes CH4 needed/hour	=B59*B34	t/h
61	Carbon credits earned per hour	=B60*(B36-2.75)	t/h
62	Carbon credits earned per year	=B61*B23	t/y
63	Carbon credit revenue per year	=B62*B35/1000	\$000/y
64			
65	4 - Calculate New Annual Costs:		
66	Flare O&M cost	=B26	\$000/y
67	Drain & transport O&M cost/h	=IF(B16<=0,(B52*B32)/B16,0)	\$/h
68	Drain & transport O&M cost/y	=B67*B23/1000	\$000/y
69	Royalty and severance taxes cost/yr	=B14*365*3*B46/1000	
70	Carbon credit monetization cost/yr	=B47*oflareCERsEarnedPerYear/1000	\$000/y
71	--		
72	Total annual cost	=B68+B66+B70+B69	\$000/y
73			
74	5 - Calculate Project Capital Costs		
75	CMM needed per hour	=B52	mcf/h
76	CMM transport system	=IF(B16<=0,B31*B75*24/B16/1000,0)	\$000
77	Installed Cost Flare	=B20*B25*24	\$000
78	--		
79	Subtotal	=SUM(B76:B77)	\$000
80	Total cap cost with factors	=B79*(1+B44)*(1+B43)	\$000
81			
82	6 - Calculate Loan and Equity		
83	Loan amount	=B80*(1-B39)	\$000
84	Equity amount	=B80*B39	\$000
85			
86	7 - Discounted Cash Flow Analysis		
87		(\$000)	
88		Years >>>	0
89	A - Benefits		
90	Carbon Credit Revenues		=IF(C587<=\$B518,B58,0)
91	Total Benefits		=IF(C587<=\$B518,\$B63,0)
92	B - Costs		
93	Annual Drainage and Flare O&M Cost		=SUM(C89:C90)
94	C - Cash Flow from Operations		=IF(C587<=\$B518,-B72,0)
95			=SUM(C91:C93)
96	D - Debt Service		=IF(OR(C587>\$B540,C587>\$B518),0,
97	E - Net Cash Flow	=B84	PMT(\$B541, \$B540, \$B583))
98			=SUM(C94:C96)
99	8 - Financial Measurements: IRR, NPV, Payback		
100	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B97:X97)),0,IRR(\$B97:X97))
101	Net Present Value		=NPV(B38,C97:X97)+oflareMinusEquityAmount

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.

4.6 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.

4.6.1 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 4,500-8,300 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.
- Depending on the GWP value used 21/25 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 23/27 tons of CO₂e per ton of methane burned.

4.6.2 Mine Boiler 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 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 gob 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?	=gas1zz	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?	=gas6zz/100	
20	Average fuel available	=B15*(B19-B13)	mcf/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22	What is the boiler capacity?	=gas5zz	mmBtu/h
23	How many hours per year will the mine boiler operate?	=default3	hours/yr
24	What is the average boiler load?	=gas7zz	mmBtu/h
25	What is the capital cost to convert coal boiler to gas?	=user11	\$/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)	\$/mcf
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	=default20	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 is the contingency factor?	=default7/100	
44	What are the "soft" costs for the project?	=default14/100	
45	Annual Cost Factors		
46	What are the royalty and severance taxes, if any?	=default11/100	
47	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e

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 Boiler (continued)

	A	B	C
1	INPUT PARAMETERS	Values	units
49	2 - Feasibility Test		
50	CMM heat value available/hour	=B21	mmBtu/h
51	Average Mine Boiler Heat Load	=B24	mmBtu/h
52	CMM volume needed/hour	=IF(OR(B50<B51,inputScenFlare="OF",inputScenFlare="EF"),B50*1000/B33/(1-B13),B51*1000/B33/(1-B13))	mcf/h
53	CMM available for other uses	=IF(OR(B51>B50,inputScenFlare="OF",inputScenFlare="EF",B19=0),0,B14-(B52*24/B19))	mcf/d
55	3 - Calculate Annual Benefits:		
56	Tons of coal replaced per hour	=IF(B29<>0,IF(B50<B51,B50/B29,B51/B29),0)	ton/h
57	Cost savings per hour - coal	=B56*(B27+B28)	\$/h
58	Cost savings per year - coal	=B57*B23/1000	\$/000/y
59	CMM volume needed/hour	=B52	mcf/h
60	Tonnes CH4 needed/hour	=B59*B34	t/h
61	Carbon credits earned per hour	=B60*(B36+2)	t/h
62	Carbon credits earned per year	=B61*B23	t/y
63	Carbon credit revenue per year	=B62*B35/1000	\$/000/y
65	4 - Calculate New Annual Costs:		
66	CMM needed per hour	=B52	mcf/h
67	Drain & transport O&M cost/h	=IF(B16<>0,(B66*B32)/B16,0)	\$/h
68	Drain & transport O&M cost/yr	=B67*B23/1000	\$/000/y
69	Back-up Flare O&M cost/yr	=IF(inputScenFlare="OF",user22,IF(inputScenFlare="EF",user20,0))	
70	Royalty and severance taxes cost/yr	=boilerCmmDrained*365*B46*3/1000	
71	Carbon credit monetization cost/yr	=B47*boilerCERsEarnedPerYear/1000	
72	Total annual cost	=SUM(B68:B71)	\$/000/y
74	5 - Calculate Project Capital Costs		
75	CMM needed per hour	=B52	mcf/h
76	CMM transport system	=IF(B16<>0,B31*B75*24/B16/1000,0)	\$/000
77	Cost to Convert Convert Boiler to Burn CMM	=IF(B50<B51,B50*B25,B22*B25)	\$/000
78	Back-up Flare capital cost	=IF(inputScenFlare="OF",B20*24*user21,IF(inputScenFlare="EF",B20*24*user19,0))	
79	Subtotal	=SUM(B76:B78)	\$/000
80	Total cap cost with factors	=(B79*(1+B44))*(1+B43)	\$/000
82	6 - Calculate Loan and Equity		
83	Loan amount	=B80*(1-B39)	\$/000
84	Equity amount	=B80*B39	\$/000
86	7 - Discounted Cash Flow Analysis		
87		(\$000)	
87	Years >>>	0	1
88	A - Benefits		
89	Coal savings		=IF(C\$87<=\$B\$18,B58,0)
90	Carbon Credit Revenues		=IF(C\$87<=\$B\$18,\$B63,0)
91	Total Benefits		=SUM(C89:C90)
92	B - Costs		
93	CMM transport cost + drain share		=IF(C\$87<=\$B\$18,-B72,0)
94	C - Cash Flow from Operations		=SUM(C91:C93)
96	D - Debt Service		=IF(OR(C\$87>\$B\$40,C\$87>\$B\$18),0,PMT(\$B\$41,\$B\$40,\$B\$83))
97	E - Net Cash Flow	=B84	=SUM(C94:C96)
99	8 - Financial Measurements: IRR, NPV, Payback		
100	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B97:X97)),0,IRR(\$B97:X97))
101	Net Present Value		=NPV(B38,C97:X97)+boilerMinusEquityAmount

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.

4.7 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 only to cover its own power needs 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.

4.7.1 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 \$400/kW to \$1,500/kW with a default of \$1,150/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 4,500-8,300 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.
- Depending on the GWP value used, 21/25 tons of CO₂E of carbon credits are earned per ton of methane destroyed, less the weight of the carbon dioxide emitted, 2.75 tons, resulting in a net factor of 18.25/22.25 tons of CO₂E per ton of methane burned.

4.7.2 On-site Electricity Generation Spreadsheet

	A	B	C
1	INPUT PARAMETERS	Values	units
2	What is the cost of well-head blowers?	=drainage1	S/HP
3	What is the cost of satellite compressors?	=drainage2	S/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	S/ft
6	What are the compressor and blower efficiencies?	=drainage5	HP/mcfd
7	What is the spacing between gob 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	S/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?	=gas1zz	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?	=gas6zz/100	
20	Average fuel available	=B15*(B19-B13)	mcf/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			
25	Capital cost of treatment, engine-gen set, & electrical eqp?	=user3	\$000/kW
26	What is the O&M cost of the reciprocating engine?	=user4	S/kWh
27	For what price can CMM-based electricity be sold?	=user1	S/kWh
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))	S/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)	S/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	S/tonne CO2E
36	GWP ratio: methane to CO2	=default20	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 is the contingency factor?	=default7/100	
44	What are the "soft" costs for the project?	=default14/100	
45	Annual Cost Factors		
46	What are the royalty and severance taxes, if any?	=default11/100	
47	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	S/tCO2e

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 Spreadsheet (continued)

	A	B	C
1	INPUT PARAMETERS	Values	units
49	2 - Feasibility Test		
50	CMM heat value available/hour	=B21	mmBtu/h
51			
52	CMM volume needed/hour	=B50*1000/B33/(1-B13)	mcf/h
53	CMM available for other uses	0	mcf/d
54			
55	3 - Calculate Annual Benefits:		
56	Engine Capacity	=B50*B22/3.412	MW
57	Annual Electricity Production	=B56*B23	MWh
58	Annual Revenue from Sale of Electricity	=B27*B57	\$000
59	CMM volume needed/hour	=B52	mcf/h
60	Tonnes CH4 needed/hour	=B59*B34	t/h
61	Carbon credits earned per hour	=B60*(B36-2.75)	t/h
62	Carbon credits earned per year	=B61*B23	t/y
63	Carbon credit revenue per year	=B62*B35/1000	\$000/y
64			
65	4 - Calculate New Annual Costs:		
66	Engine O&M cost	=B57*B26	\$000/y
67	Drain & transport O&M cost/h	=IF(B16<=0,(B52*B32)/B16,0)	\$/h
68	Drain & transport O&M cost/y	=B67*B23/1000	\$000/y
69	Carbon credit monetization cost/yr	=B47*engineCERsEarnedPerYear/1000	\$000/y
70	Royalty and severance taxes	=B46*B14*365*3/1000	\$000/y
71	Total annual cost	=B68+B66+B69+B70	\$000/y
72			
73	5 - Calculate Project Capital Costs		
74	CMM needed per hour	=B52	mcf/h
75	CMM transport system	=IF(B16<=0,B31*B74*24/B16/1000,0)	\$000
76	Installed Cost of Engine-Generator Sets	=B56*B25*1000	\$000
77	–		
78	Subtotal	=SUM(B75:B76)	\$000
79	Total cap cost with factors	=B78*(1+B44))*(1+B43)	\$000
80			
81	6 - Calculate Loan and Equity		
82	Loan amount	=B79*(1-B39)	\$000
83	Equity amount	=B79*B39	\$000
84			
85	7 - Discounted Cash Flow Analysis	(\$000)	
86	Years >>>	0	1
87	A - Benefits		
88	Electricity Revenues		=IF(C586<=\$B518,B58,0)
89	Carbon Credit Revenues		=IF(C586<=\$B518,\$B63,0)
90	Total Benefits		=SUM(C88:C89)
91	B - Costs		
92	Annual Drainage and Engine O&M Cost		=IF(C586<=\$B518,-B71,0)
93	C - Cash Flow from Operations		=SUM(C90:C92)
94			
95	D - Debt Service		=IF(OR(C586>\$B540,C586>\$B518),0,PMT(\$B541,\$B540,\$B582))
96	E - Net Cash Flow	=B83	=SUM(C93:C95)
97			
98	8 - Financial Measurements: IRR, NPV, Payback		
99	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B96:X96)),0,IRR(\$B96:X96))
	Net Present Value		=NPV(B39,C96:X96)+engineMinusEquityAmount
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.

4.8 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 an oxygen removal system and a pipeline from the project to the natural gas transmission system. The capital costs of the oxygen removal system and the pipeline are input by the user.

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.

4.8.1 Scenario Assumptions:

- The contaminated tail gas is not utilized.
- The minimum methane concentration for the project type is assumed to be 40%.
- The capital cost of the oxygen removal system has a default value of \$1.25 million, but this can be changed by the user.
- 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 4,500-8,300 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.
- Depending on the GWP value chosen, 21/25 tons of CO₂E of carbon credits are 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.

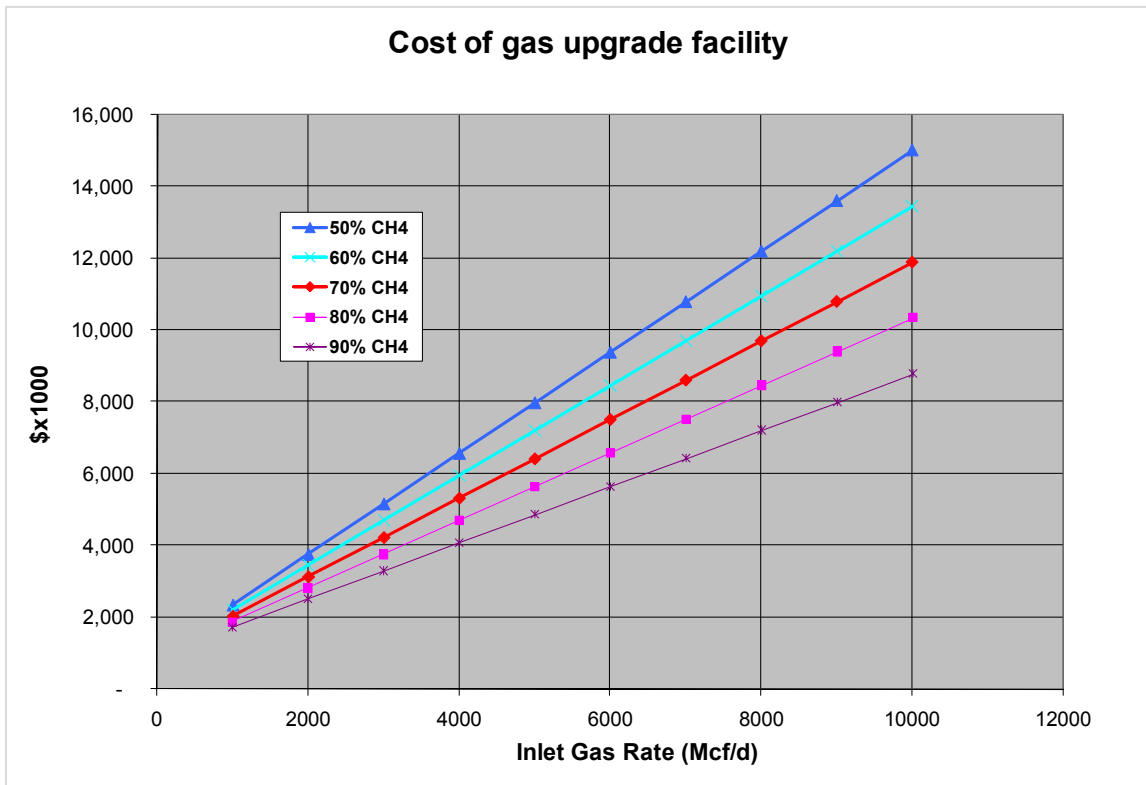


Figure 1: Example calculations at different rates and compositions

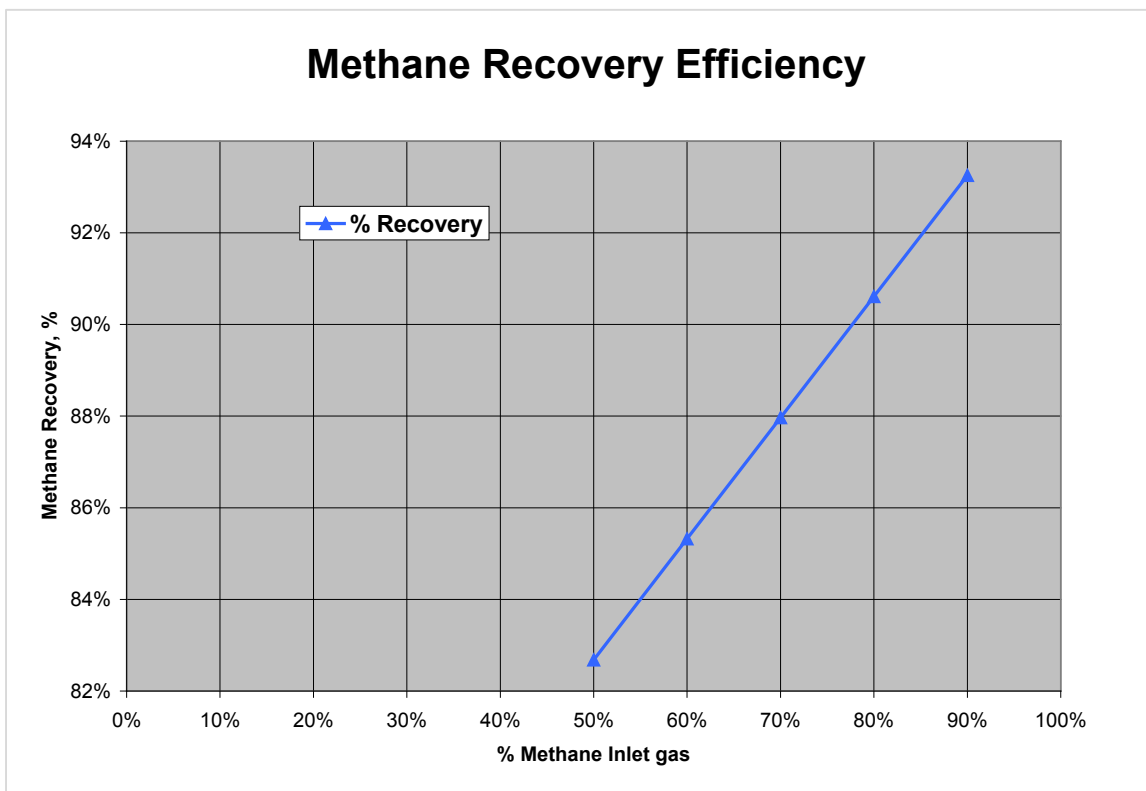


Figure 2: Percent of inlet methane recovered for sale at various inlet compositions

4.8.2 Pipeline Gas Spreadsheet

	A	B	C
1	INPUT PARAMETERS	<i>Values</i>	<i>units</i>
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 gob 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?	=gas1zz	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?	=gas6zz/100	
20	Average fuel available	=B15*(B19-B13)	mcf/h
21	Fuel value	=B20*B30/1000	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	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
28	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))+ (B27*IF(inputDrainageSystem="Y", (B2*B6)+IF(B10="AM", B11*B12*B9*B16/(B14*B19),0),0),0)	\$/mcf
29	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*B27/B7,0))*B16*24/(B14*B19)/B23,0)	\$/mcf
30	CMM fuel value LHV	910	Btu/cf
31	Weight of methane, tonnes	0.01926	tonnes/mcf
32	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
33	GWP ratio: methane to CO2	=default20	ratio
34	What is the inflation rate?	=default21/100	
35	What is the real discount rate?	=default26/100	
36	What is the developer's equity share in the project?	=user12/100	
37	What is the loan term?	=user15	yr
38	What interest rate is charged for the loan?	=user5/100	
39	Cap Cost Factors		
40	What is the contingency factor?	=default7/100	
41	What are the "soft" costs for the project?	=default14/100	
42	Annual Cost Factors		
43	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
44	What are the royalty and severance taxes, if any?	=default11/100	
45			
46	CMM fuel value HHV	1010	Btu/cf

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 Spreadsheet (continued)

1	INPUT PARAMETERS	Values	units
47	2 - Feasibility Test		
48	CMM combusted in gathering sys. prime movers	=B13*B15	mcf/h
49	CMM entering project	=B20	mcf/h
50	CMM volume sold to pipeline	=B49*(0.959-0.2644*(1-B16))	mcf/h
51	CMM available for other uses	0	mcf/d
52			
53	3 - Calculate Annual Benefits:		
54			
55	CMM volume sold to pipeline	=B50	mcf/h
56	Revenue from gas sales	=B55*B23*B46*B26/1000/1000	\$000/yr
57	CMM available for carbon credits	=B50+B48	mcf/h
58	Tonnes CH4 available for carbon credits	=B57*B31	t/h
	Carbon credits earned per hour	=B58*B33- (IF(B16=0,0,(B49*0.43*24*0.7457*default9/B16/1000)))	t/h
59	Carbon credits earned per year	=B59*B23	t/y
61	Carbon credit revenue per year	=B60*B32/1000	\$000/y
62			
63	4 - Calculate New Annual Costs:		
	Project O&M cost	=IF(B16<=0,(300)+(0.75*B23*B49/B16/1000)+(B49*B23*B25*0.43*24*0.7457/B16/1000/1000),0)	\$000/yr
64	Drain & transport O&M cost/h	=IF(B16<=0,(B49*B29)/B16,0)	\$/h
66	Drain & transport O&M cost/y	=B65*B23/1000	\$000/y
67	Carbon credit monetization cost/yr	=B43*pipelineCERsEarnedPerYear/1000	\$000/y
68	Royalty and severance taxes	=B56*B44	\$000/y
69	Total annual cost	=B66+B64+B67+B68	\$000/y
70			
71	5 - Calculate Project Capital Costs		
72	CMM needed per hour	=B49	mcf/h
73	CMM transport system	=IF(B16<=0,B28*B72*24/B16/1000,0)	\$000
	Installed Cost of Processing Plant	=IF(B16<=0,(1250)+(B22*B24/1000)+(936)+(B49*24*(1.5765*(1-B16)+0.6196)/B16),0)	\$000
74			
75	--		
76	Subtotal	=SUM(B73:B74)	\$000
77	Total cap cost with factors	=(B76*(1+B41))*(1+B40)	\$000
78			
79	6 - Calculate Loan and Equity		
80	Loan amount	=B77*(1-B36)	\$000
81	Equity amount	=B77*B36	\$000
82			
83	7 - Discounted Cash Flow Analysis	(\$000)	
84	Years >>>	0	1
85	A - Benefits		
86	Gas Sales Revenues	=IF(C\$84<=\$B\$18,B56,0)	
87	Carbon Credit Revenues	=IF(C\$84<=\$B\$18,\$B61,0)	
88	Total Benefits	=SUM(C86:C87)	
89	B - Costs		
90	Annual Drainage and Project O&M Cost	=IF(C\$84<=\$B\$18,-B69,0)	
91	C - Cash Flow from Operations	=SUM(C88:C90)	
92			
93	D - Debt Service	=IF(OR(C\$84>\$B\$37,C\$84>\$B\$18),0,PMT(\$B\$38,\$B\$37,\$B\$80))	
94	E - Net Cash Flow	=B81	=SUM(C91:C93)
95			
96	8 - Financial Measurements: IRR, NPV, Payback		
97	Internal Rate of Return - IRR	=IF(ISERR(IRR(\$B94:X94)),0,IRR(\$B94:X94))	
98	Net Present Value	=NPV(B35,C94:X94)+pipelineMinusEquityAmount	

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.

4.9 Compressed Natural Gas

This scenario models drained coal mine methane being processed to pipeline quality and then compressed to 3,600 psi to produce CNG. It is assumed that the CNG will be produced and distributed from a facility on site.

Similar to the pipeline scenario, 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 project also assumes the installation of an oxygen removal system as part of the gas processing.

Produced pipeline quality gas is then further compressed and distributed from (or stored at) an on-site facility. See “Costs Associated with Compressed Natural Gas Vehicle Fueling Infrastructure”, U.S. Department of Energy, Alternative Fuels Data Center, September 2014, for estimates of the capital costs associated with distribution systems of varying production sizes. (http://www.afdc.energy.gov/uploads/publication/cng_infrastructure_costs.pdf)

Revenues are calculated in the form of CNG sales accruing to the project. Revenues also may result from the sale of carbon emission reductions.

4.9.1 Scenario Assumptions:

- The contaminated tail gas is not utilized.
- The minimum methane concentration for the project type is assumed to be 40%.
- The annual utilization cost of the pressure swing adsorption (PSA) system 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 gas to an initial 900 psig (**Figure 1**).
- The default capital cost of the oxygen removal system is \$1.25 million, but can be adjusted on the “User Input” tab.
- The utilization annual cost of the combined PSA and CatOx system includes a fixed O&M of \$300,000/yr and a variable O&M of \$0.75/mcf.
- The capital cost of the CNG compression and distribution system is input by the user based on a \$/GGE/day basis. The default value is \$1,000/GGE/day.
- The operating cost of the CNG compression and distribution is input by the user based on a \$/GGE/day basis. The default value is \$0.35.
- The hours/yr of operation are standardized with the other scenarios at a range of 4,500-8,300 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.
- Depending on the GWP value used, 21/25 tons of CO₂E of carbon credits are 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.

4.9.2 CNG Spreadsheet

	A	B	C
1	INPUT PARAMETERS		<i>units</i>
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 gob 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?	=gas1zz	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?	=gas6zz/100	
20	Average fuel available	=B15*(B19-B13)	mcf/h
21	Fuel value	=B20*B31/1000	mmBtu/h
22	What is the size of the CNG distribution system?	=User30	GGE/day
23	How many hours per year will the project operate?	=default5	hours/yr
24	What is the installed capital cost of the CNG system?	=User31	\$/GGE/day
25	What is the cost of electric power used by the project?	=user2	\$/MW
26	What is the price of sold CNG?	=user28	\$/GGE
27	What is the cost of the catalytic oxidizer?	=user37	\$/,000
28	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
29	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))+((B28*IF(inputDrainageSystem="Y",B2*B6)+IF(B10="AM",B11*B12*B9*B16/(B14*B19),0)),0)	\$/mcf
30	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*B28/B7,0))*B16*24/(B14*B19)/B23,0)	\$/mcf
31	CMM fuel value LHV	910	Btu/cf
32	Weight of methane, tonnes	0.01926	tonnes/mcf
33	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
34	GWP ratio: methane to CO2	=default20	ratio
35	What is the inflation rate?	=default21/100	
36	What is the real discount rate?	=default26/100	
37	What is the developer's equity share in the project?	=user12/100	
38	What is the loan term?	=user15	yr
39	What interest rate is charged for the loan?	=user5/100	
40	Cap Cost Factors		
41	What is the contingency factor?	=default7/100	
42	What are the "soft" costs for the project?	=default14/100	
43	Annual Cost Factors		
44	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
45	What is the O&M cost of the CNG system?	=user38	\$/GGE/day
46	What are the royalty and severance taxes, if any?	=default11/100	
48	CMM fuel value HHV		Btu/cf

CNG Spreadsheet (continued)

	A	B	C
1	INPUT PARAMETERS		<i>units</i>
50			
51			
52	2 - Feasibility Test		
53	CMM combusted in gathering sys. prime movers	=B13*B15	mcf/h
54	CMM needed for project	=(B22*0.126/24)/(0.959-0.2644*(1-B16))	mcf/h
55	CMM volume after processing	=B51*(0.959-0.2644*(1-B16))	mcf/h
56	CMM available for other uses	=IF(OR(B51>B20,inputScenFlare="OF",inputScenFlare="E F",B19=0),0,(B20-B51)*24)	mcf/d
58	3 - Calculate Annual Benefits:		
59	CNG volume sold	=B52	mcf/h
60	Revenue from gas sales	=(B22/24)*B23*B26/1000	\$000/yr
61	CMM available for carbon credits	=B52+B50	mcf/h
62	Tonnes CH4 available for carbon credits	=B59*B32	t/h
63	Carbon credits earned per hour	=B60*B34 (IF(B16=0,0,(B51*0.43*24*0.7457*default9/B16/1000)))	t/h
64	Carbon credits earned per year	=B61*B23	t/y
65	Carbon credit revenue per year	=B62*B33/1000	\$000/y
66			
67	4 - Calculate New Annual Costs:		
68	CNG distribution system O&M cost	=(B22*B45/24)*B23/1000	\$000/yr
69	Processing system O&M cost	=IF(B16<>0,(300)+(0.75*B23*B51/B16/1000)+(B51*B23*B25*0.43*24*0.7457/B16/1000/1000),0)	\$000/yr
70	Drain & transport O&M cost/h	=IF(B16<>0,(B51*B30)/B16,0)	\$/h
71	Drain & transport O&M cost/y	=B68*B23/1000	\$000/y
72	Carbon credit monetization cost/yr	=B44*cngCERsEarnedPerYear/1000	\$000/y
73	Royalty and severance taxes	=B58*B46	\$000/y
74	Total annual cost	=SUM(B66:B71)-B68	\$000/y
75			
76	5 - Calculate Project Capital Costs		
77	CMM needed per hour	=B51	mcf/h
78	CMM transport system	=IF(B16<>0,B29*B75*24/B16/1000,0)	\$,000
79	Installed Cost of Processing Plant	=IF(B16<>0,(B27)+(936)+(B51*24*(1.5765*(1-B16)+0.6196)/B16),0)	\$,000
80	Installed Cost of CNG Distribution System	=B22*B24/1000	\$,000
81	Subtotal	=SUM(B76:B78)	\$,000
82	Total cap cost with factors	=(B79*(1+B42))*(1+B41)	\$,000
84	6 - Calculate Loan and Equity		
85	Loan amount	=B80*(1-B37)	\$000
86	Equity amount	=B80*B37	\$000
87			
88	7 - Discounted Cash Flow Analysis		
89		Years >>>	1
90	A - Benefits		
91	Gas Sales Revenues	=IF(D\$87<=\$B\$18,\$B58,0)	-
92	Carbon Credit Revenues	=IF(D\$87<=\$B\$18,\$B63,0)	-
93	Total Benefits	=SUM(D89:D90)	-
94	B - Costs		
95	Annual Drainage and Project O&M Cost	=IF(D\$87<=\$B\$18,-B72,0)	-
96	C - Cash Flow from Operations	=SUM(D91:D93)	-
97			
98	D - Debt Service	=IF(OR(D\$87>\$B\$38,D\$87>\$B\$18),0,PMT(\$B\$39,\$B\$38,\$B\$83))	-
99	E - Net Cash Flow	=B84	-
100			
101	8 - Financial Measurements: IRR, NPV, Payback		
102	Internal Rate of Return - IRR	=IF(ISERR(IRR(\$B97:W97)),0,IRR(\$B97:W97))	0.0%
103	Net Present Value	=NPV(B36,D97:W97)+cngMinusEquityAmount	-
104			

4.10 Liquefied Natural Gas

This scenario models the drained coal mine methane being processed to pipeline quality and then liquefied to produce LNG. It is assumed that the LNG will be produced and distributed from a facility on site.

As with the pipeline scenario, economics are calculated assuming the installation of a pressure swing adsorption (PSA) type system to remove nitrogen and carbon dioxide down to a 4% inert level. The scenario also assumes the installation of an oxygen removal system as part of the gas processing. Revenues in the form of LNG sales accrue to the project. Revenues also may result from the sale of carbon emission reductions.

4.10.1 Scenario Assumptions:

- The contaminated tail gas is not utilized.
- The minimum methane concentration for the project type is assumed to be 40%.
- The annual utilization cost of the pressure swing adsorption system 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 gas to an initial 900 psig (**Figure 1**).
- The default capital cost of the oxygen removal system is \$1.25 million, but can be adjusted on the “User Input” tab.
- The utilization annual cost of the system includes a fixed O&M of \$300,000/yr and a variable O&M of \$0.75/mcf.
- The capital cost of the LNG liquefaction and distribution system is input by the user and is based on a \$/mcf (CMM drainage rate) price.
- The operating cost of the LNG liquefaction and distribution system is input by the user based on a \$/mcf (CMM drainage rate) price.
- The hours/yr of operation are standardized with the other scenarios at a range of 4,500-8,300 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.
- Depending on the GWP value used, 21/25 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.

4.10.2 LNG Spreadsheet

	A	B	C
1	INPUT PARAMETERS		<i>units</i>
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 gob 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?	=gas1zz	mcf/d
15	CMM drained per hour	=D14/24	mcf/h
16	Percent Methane in Drainage Gas	=inputPctMethane/100	
17	Actual gas flow	=IF(D16<>0,D14/D16,0)	mcf/d
18	What is the planned project operational lifetime?	=user16	years
19	What is the fraction of CMM available after losses?	=gas6zz/100	
20	Average fuel available	=D15*(D19-D13)	mcf/h
21	Fuel value	=D20*D31/1000	mmBtu/h
22			
23	How many hours per year will the project operate?	=default5	hours/yr
24	What is the installed capital cost of the LNG system?	=User32	\$/,000
25	What is the cost of electric power used by the project?	=user2	\$/MW
26	What is the price of sold LNG?	=user29	\$/MMBtu
27	What is the cost of the catalytic oxidizer?	=user37	\$/,000
28	What is the fraction of this project's drainage system cost that will be included in the analysis?	=drainage10/100	
29	Drainage and Transport sys unit cap cost	=IF((D14*D19)<>0,(D3*D6)+(D4*D5*D16/(D14*D19)))+(IF(D10="AM",D7*D5*D9*D16/(D14*D19),0))+ (D28*IF(inputDrainageSystem="Y",D2*D6)+IF(D10="AM",D11*D12*D9*D16/(D14*D19),0),0)	\$/mcfd
30	Drainage and Transport O&M cost	=IF(AND(inputDrainageSource="GW",D14*D19)<>0,D23<>0),((D8*D5)+IF(AND(inputDrainageSystem="Y",D7<>0),D8*D11*D12*D28/D7,0))*D16*24/(D14*D19)/D23,0)	\$/mcf
31	CMM fuel value LHV		Btu/cf
32	Weight of methane, tonnes		tonnes/mcf
33	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
34	GWP ratio: methane to CO2	=default20	ratio
35	What is the inflation rate?	=default21/100	
36	What is the real discount rate?	=default26/100	
37	What is the developer's equity share in the project?	=user12/100	
38	What is the loan term?	=user15	yr
39	What interest rate is charged for the loan?	=user5/100	
40	Cap Cost Factors		
41	What is the contingency factor?	=default7/100	
42	What are the "soft" costs for the project?	=default14/100	
43	Annual Cost Factors		
44	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
45	What is the O&M cost of the LNG system?	=User33	\$/mcf
46	What are the royalty and severance taxes, if any?	=default11/100	
47			
48	CMM fuel value HHV		Btu/cf

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.

LNG Spreadsheet (Continued)

	A	B	C
1	INPUT PARAMETERS		<i>units</i>
49	2 - Feasibility Test		
50	CMM combusted in gathering sys. prime movers	=D13*D15	mcf/h
51	CMM entering processing system	=heatAvailable	mcf/h
52	CMM volume after processing (before liquefaction)	=D20*(0.959-0.2644*(1-D16))	mcf/h
53	CMM available for other uses		mcf/d
54			
55	3 - Calculate Annual Benefits:		
56			
57	LNG volume produced	=D52*D31*1000*0.9/1000000	MMBtu/h
58	Revenue from LNG sales	=D57*D23*D26/1000	\$000/yr
59	CMM available for carbon credits	=D52+D50	mcf/h
60	Tonnes CH4 available for carbon credits	=D59*D32	t/h
61	Carbon credits earned per hour	=D60*D34- (IF(D16=0,0,(D51*0.43*24*0.7457*default9/D16/1000)))	t/h
62	Carbon credits earned per year	=D61*D23	t/y
63	Carbon credit revenue per year	=D62*D33/1000	\$000/y
64			
65	4 - Calculate New Annual Costs:		
66	LNG liquefaction system O&M cost	=(D20*D45)*D23/1000	\$000/yr
67	Processing system O&M cost	=IF(D16<>0,(300)+(0.75*D23*D51/D16/1000)+(D51*D23*D25*0.43*24*0.7457/D16/1000/1000),0)	\$000/yr
68	Drain & transport O&M cost/h	=IF(D16<>0,(D51*D30)/D16,0)	\$/h
69	Drain & transport O&M cost/yr	=D68*D23/1000	\$000/y
70	Carbon credit monetization cost/yr	=D44*IngCERsEarnedPerYear/1000	\$000/y
71	Royalty and severance taxes	=D58*D46	\$000/y
72	Total annual cost	=SUM(D66:D71)-D68	\$000/y
73			
74	5 - Calculate Project Capital Costs		
75	CMM needed per hour	=D51	mcf/h
76	CMM transport system	=IF(D16<>0,D29*D75*24/D16/1000,0)	\$,000
77	Installed Cost of Processing Plant	=IF(D16<>0,(D27)+(936)+(D51*24*(1.5765*(1-D16)+0.6196)/D16),0)	\$,000
78	Installed Cost of LNG Liquefaction System	=D24	\$,000
79	Subtotal	=SUM(D76:D78)	\$,000
80	Total cap cost with factors	=(D79*(1+D42))*(1+D41)	\$,000
81			
82	6 - Calculate Loan and Equity		
83	Loan amount	=D80*(1-D37)	\$000
84	Equity amount	=D80*D37	\$000
85			
86	7 - Discounted Cash Flow Analysis		
87		Years >>>	1
88	A - Benefits		
89	Gas Sales Revenues	=IF(C\$87<=\$D\$18,D58,0)	-
90	Carbon Credit Revenues	=IF(C\$87<=\$D\$18,\$D63,0)	-
91	Total Benefits	=SUM(C89:C90)	-
92	B - Costs		
93	Annual Drainage and Project O&M Cost	=IF(C\$87<=\$D\$18,-D72,0)	-
94	C - Cash Flow from Operations	=SUM(C91:C93)	-
95			
96	D - Debt Service	=IF(OR(C\$87>\$D\$38,C\$87>\$D\$18),0,PMT(\$D\$39,\$D\$38,\$D\$83))	-
97	E - Net Cash Flow	=D84	-
98			
99	8 - Financial Measurements: IRR, NPV, Payback		
100	Internal Rate of Return - IRR	=IF(ISERR(IRR(\$B97:W97)),0,IRR(\$B97:W97))	0.0%
101	Net Present Value	=NPV(D36,C97:W97)+IngMinusEquityAmount	-

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.

4.11 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.

4.11.1 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 oxidizer 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.

4.11.2 Stand-alone VAM Spreadsheet

	A	B	C
1	INPUT PARAMETERS	Values	units
2			
3	What is the planned project operational lifetime?	=user16	years
4			
5	What percent methane is in the ventilation air?	=gas9zz/100	
6	What do you expect the recoverable ventilation air flow to be?	=gas10zz	mcf/m
7	How many hours per year will the VAM system operate?	=default33	hours/yr
8	What is the installed capital cost of VAM oxidizer system?	=user23	\$/cfm
9	What is the annual O&M cost of the VAM oxidizer system?	=user24	\$/cfm-yr
10	What is the frequency VAM system will be relocated?	=user25	years
11	What is the VAM oxidation system relocation cost?	=user26	\$/cfm
12	What is the electrical load of the oxidizer blowers?	=user27	kWh/mcf
13			
14			
15			
16	CMM fuel value LHV	910	Btu/cf
17	Weight of methane, tonnes	0.01926	tonnes/mcf
18	What is the carbon credit unit sale price?	=user8	\$/tonne CO2E
19	GWP ratio: methane to CO2	=default20	ratio
20	What is the inflation rate?	=default21/100	
21	What is the real discount rate?	=default26/100	
22	What is the developer's equity share in the project?	=user12/100	
23	What is the loan term?	=user15	yr
24	What interest rate is charged for the loan?	=user5/100	
25	Cap Cost Factors		
26	What is the contingency factor?	=default7/100	
27	What is the cost of electric power used by the project?	=user2	\$/MWh
28	What are the "soft" costs for the project?	=default14/100	
29	Annual Cost Factors		
30	What are the royalty and severance taxes, if any?	=default11/100	
31	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
32			
33	2 - Feasibility Test		
34			
35	CMM Available (always 0 for Standalone VAM)	0	
36			
37	3 - Calculate Annual Benefits:		
38	Carbon credits earned per year	=B23*60*B24*B22*B34*(B36-2.75)*0.95-(B23*B24*B29*60*default9/1000)	tonnes CO2e/y
39	Carbon credit revenue per year	=B54*B35/1000	\$/000/y
40			
41	4 - Calculate New Annual Costs:		
42	O&M cost	=B23*B26*1000/1000	\$/000/y
43	Electricity cost	=B23*60*B24*B29*B44/1000/1000	\$/000/y
44	Relocation cost	=B28*B23*1000/B27/1000	\$/000/y
45	Royalty and severance taxes	=B23*60*B24*B22*3*B47/1000	
46	Carbon credit monetization cost/yr	=B48*savamCERsEarnedPerYear/1000	\$/000/y
47	Total annual cost	=SUM(B58:B62)	\$/000/y

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	<i>Values</i>	<i>units</i>
49			
50	5 - Calculate Project Capital Costs		
51	Installed Capital Cost	=B23*B25*1000/1000	\$000
52	Subtotal	=B67	\$000
53	Total cap cost with factors	=(B68*(1+B43))*(1+B45)	\$000
54			
55			
56			
57			
58	6 - Calculate Loan and Equity		
59	Loan amount	=B69*(1-B39)	\$000
60	Equity amount	=B69*B39	\$000
61			
62	7 - Discounted Cash Flow Analysis		
63		Years >>> 0	1
64	A - Benefits		
65			
66	Carbon Credit Revenues		=IF(C579<=\$B518,\$B55,0)
67	Total Benefits		=SUM(C81:C82)
68	B - Costs		
69	Annual Costs		=IF(C579<=\$B518,-B63,0)
70	C - Cash Flow from Operations		=SUM(C83:C85)
71			
72	D - Debt Service		=IF(OR(C579>\$B540,C579>\$B518),0, PMT(\$B541,\$B540,\$B575))
73	E - Net Cash Flow	=B76	=SUM(C86:C88)
74			
75	8 - Financial Measurements: IRR, NPV, Payback		
76	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B89:X89)),0,IRR(\$B89:X89))
77	Net Present Value		=NPV(B38,C89:X89)+savamMinusEquityAmount

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.

4.12 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. Note that the model is very sensitive to changes in the “target methane percentage” value and the “recoverable ventilation air flow” value. For the typical VAM flows recommended in the model, large volumes of high quality supplemental gas will be required to obtain larger target methane values.

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.

4.12.1 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.
 - 21/25 tons of CO₂E of carbon credits are 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.

4.12.2 Supplemented VAM Spreadsheet

	A	B	C
1	INPUT PARAMETERS	<i>Values</i>	<i>units</i>
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 gob 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	mcf/d
15	CMM drained per hour	=B14/24	mcf/h
16	Percent Methane in Drainage Gas	=gas8alt/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?	=gas6alt/100	
20	Average fuel available	=B15*(B19-B13)	mcf/h
21	Fuel value	=B20*B33/1000	mmBtu/h
22	What percent methane is in the ventilation air?	=gas11zz/100	
23	What do you expect the recoverable ventilation air flow to be?	=gas12zz	mcf/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)	\$/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	=default20	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 is the contingency factor?	=default7/100	
44	What is the cost of electric power used by the project?	=user2	\$/MWh
45	What are the "soft" costs for the project?	=default14/100	
46	Annual Cost Factors		
47	What are the royalty and severance taxes, if any?	=default11/100	
48	What is the validation, verification and transaction cost to monetize carbon credits?	=default15	\$/tCO2e
49	2 - Feasibility Test		
50	heat available	=B21	mmBtu/h
51	heat needed	=B23*B16*(gas13zz/100-B22)*B33/(16.6667*B16-(gas13zz*16.6666/100))	mmBtu/h

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)

1	INPUT PARAMETERS	Values	units
52	Supplemental methane volume consumed/hour	=IF(OR(B50<B51,inputScenFlare="OF",inputScenFlare="EF"),B50*1000/B33/(1-B13),B51*1000/B33/(1-B13))	mcf/h
53	CMM available for other uses	=IF(OR(B51>B50,inputScenFlare="OF",inputScenFlare="EF",B19=0),0,B14-(B52*24/B19))	mcf/d
55	3 - Calculate Annual Benefits:		
56	Carbon credits earned from VAM destruction per year	=B23*B24*B22*B34*(B36-2.75)*0.95*60	tonnes/y
57	Carbon credits from supplemental gas destruction per year	=B52*B34*(B36-2.75)*B24	tonnes/y
58	Carbon credit revenue per year	=(B56+B57-((B23+(B17*B19/24/60))*B24*B29*60*default9/1000))*B35/1000	\$000/y
59	Total credits earned per year	=supVAMcers1+supVAMcers2	tonnes/y
61	4 - Calculate New Annual Costs:		
62	Drain & transport O&M cost/yr	=(IF(B16<>0,(B52*B32)/B16,0))*B24/1000	\$000/y
63	Back-up Flare O&M cost/yr	=IF(inputScenFlare="OF",user22,IF(inputScenFlare="EF",user20,0))	\$000/y
64	VAM Oxidizer O&M	=(B23+(B17*B19/24/60))*B26*1000/1000	\$000/y
65	VAM Oxidizer Electricity cost	=(B23+(B17*B19/24/60))*B24*B29*B44*60/1000/1000	\$000/y
66	Oxidizer Relocation cost	=B28*(B23+(B17*B19/24/60))*1000/B27/1000	\$000/y
67	Royalty and severance taxes cost/yr	=(supvamCmmDrained*365*B47*3)+(B23*B22*60*B24*B47*3)/1000	\$000/y
68	Carbon credit monetization cost/yr	=B48*supvamCERsEarnedPerYear/1000	\$000/y
69	Total annual cost	=SUM(B63:B69)	\$000/y
70	5 - Calculate Project Capital Costs		
71	CMM needed per hour	=B52	mcf/h
72	CMM transport system	=IF(B16<>0,B31*B72*24/B16/1000,0)	\$000
73	Installed Oxidizer Capital Cost	=(B23+(B17*B19/24/60))*B25*1000/1000	\$000
74	Back-up Flare capital cost	=IF(inputScenFlare="OF",B20*24*user21,IF(inputScenFlare="EF",B20*24*user19,0))	\$000
75	Subtotal	=SUM(B73:B75)	\$000
76	Total cap cost with factors	=(B76*(1+B45))*(1+B43)	\$000
78	6 - Calculate Loan and Equity		
79	Loan amount	=B77*(1-B39)	\$000
80	Equity amount	=B77*B39	\$000
82	7 - Discounted Cash Flow Analysis		
83		(\$000)	
84		Years >>> 0	1
85	A - Benefits		
86	Carbon Credit Revenues		=IF(C\$84<=\$B\$18,\$B\$8,0)
87	Total Benefits		=SUM(C86:C87)
88	B - Costs		
89	Oxidizer and supplemental CMM Annual Costs		=IF(C\$84<=\$B\$18,-B70,0)
90	C - Cash Flow from Operations		=SUM(C88:C90)
92	D - Debt Service		
93	E - Net Cash Flow	=-B81	=IF(OR(C\$84>\$B\$40,C\$84>\$B\$18),0,PMT(\$B\$41,\$B\$40,-SUM(C91:C93))
95	8 - Financial Measurements: IRR, NPV, Payback		
96	Internal Rate of Return - IRR		=IF(ISERR(IRR(\$B94:X94)),0,IRR(\$B94:X94))
97	Net Present Value		=NPV(B38,C94:X94)+supvamMinusEquityAmount

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.