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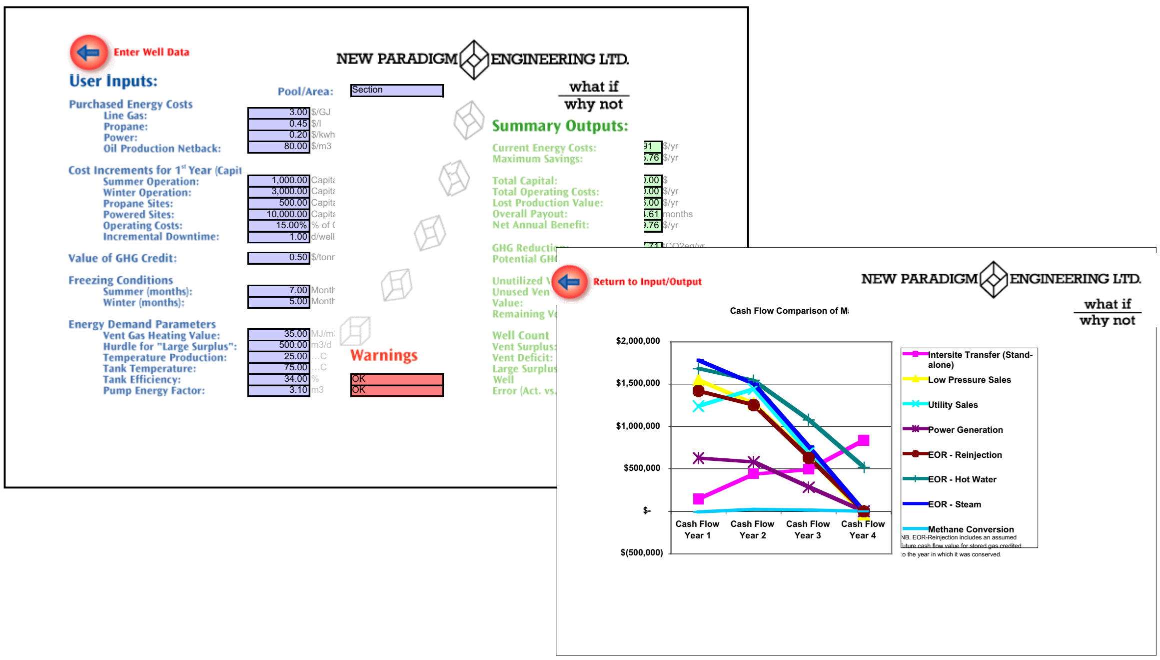
Heavy Oil Vent Gas Toolbox

User Guide: September 2001



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Content by:

Bruce Peachey, P.Eng. – New Paradigm Engineering Ltd

William Radvanyi - Trendsetting Services Inc.

Contact: Bruce Peachey, P.Eng.

Ph: (780) 448-9195

Fax: (780) 462-7297

E-mail: bruce@newparadigm.ab.ca

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1. Purpose and Intended Use of the Tools

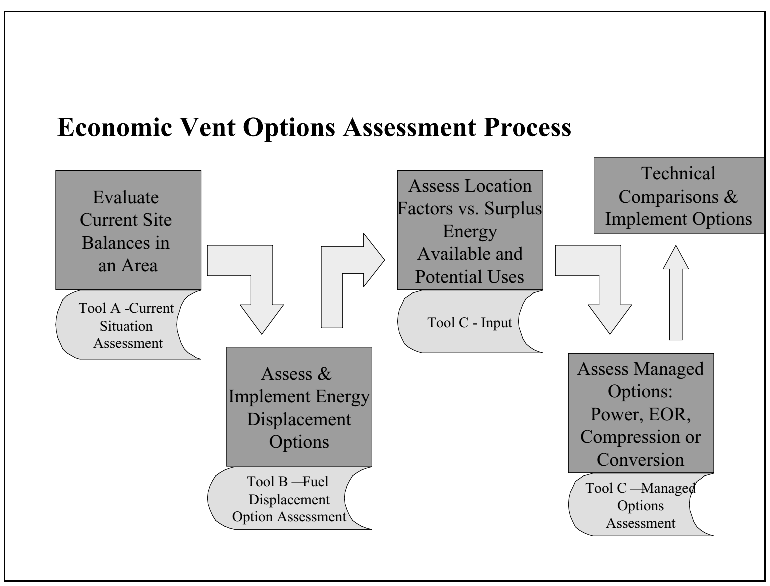
The purpose of the Heavy Oil Vent Gas Options Tools, are to help producers of conventional heavy oil in Western Canada to carry out some basic economic assessments which will help to initiate change by showing the economic incentives to reduce methane emissions and then to assist them in planning for short-term and/or long-term changes in operations to make maximum economic use of the available vent gas.

The process intended for the tools is shown in the diagram below. The ideal analysis will work from a high level snap shot of the current operation; to a more detailed assessment of how to displace external fuel/energy use, that provides the greatest economic benefit for vent gas use; and finally to consider the relative economics and technical pro's and con's of options for the managing any remaining vent gas, that is left over after the external fuel sources have been displaced.

Current Situation Assessment – Tool A. Highlights the energy balance situation for a group of wells in an area and the potential value of utilizing the vent gas to displace outside fuel or power sources.

Fuel Displacement Option Assessment – Tool B. Helps to economically assess options, which will address the needs of an individual site, which might have one or more wells venting. Often the economics will show most options to be short payout so a technical assessment of options or simply operator preference may decide which option(s) to implement.

Managed Options Assessment – Tool C. Once all the gas possible is used for on-site energy needs the next best use of the gas will be to export the energy in a value added form that provides the most benefit in a given location and situation at a given time. If this fails to provide positive economics the final option is to convert the methane to carbon dioxide to generate potential GHG credits/offsets which might be tradable.



2. General Directions

The following are some general directions that apply to the three main spreadsheet tools:

- **On Opening –** Click Enable Macros to ensure proper display of the user interface sheets.
- **Moving Between User Interface Sheets –** Point and click on the appropriate orange dot.
- **User Input on User Interface Sheets** – Input is allowed into all fields shaded in blue. Green shading shows cells containing calculated values, which are locked. Red cells are for warnings and are also locked.
- **Input/Output Summaries** – These interface sheets are intended to be the main sheets used to compare runs for a given case study. The well or site data would be generally entered once based on the best information available at the time. Values for various costs and commodities would vary between runs and used to highlight the impacts of changes in the key economic variables on what options are selected.
- **Protection of User Interface Sheets** – These sheets allow the user to input data in selected unlocked cells, but are protected from other changes as they incorporate a template, which is not easily modified.
- **View Detail Sheets** - <Ctrl>d
- **Return to User Interface Sheets** - <Ctrl>u
- **User Input on Detail Sheets** – In some tools there are areas in the detailed sheets where the user may change, over-ride or modify default values for some assumed properties, cost estimating parameters or variables which should not change significantly between a given set of runs but may vary between users or operating areas. These cells are shaded in yellow on the detailed sheets.
- **Use of Detailed Sheet Charts** – Some detailed sheets contain charts that might be of use for the user and can be copied or printed as with any Excel chart.
- **Protection on Detail Sheets** – Password is "**ch4**". The end-user can see the content and modify calculations, or add others. Note that changes to some detailed sheets will impact the User Interface Sheets so modification of the detail sheets should be done with caution.
- **Utility Cost Spreadsheet** – This is a spreadsheet issued with the original vent gas options report and was not upgraded as it mainly serves to help users understand their power bills and check power costs that vary with power use versus those that are fixed.
- **Option Summary** – This .pdf document has been widely distributed and can be used to help users better understand the options in the spreadsheets and where some of the cost factors are derived from. It contains one page sheets on each option (including some options not addressed in the spreadsheet as they were felt to be of low utility); flowsheets to help work through when options should be considered; and technical comparison tables which compare options in similar uses.

3. Current Situation Assessment – Tool A

3.1. **General Description**- This tool provides a snap shop of the energy balance situation for a group of wells in an area, and the potential value of utilizing the vent gas to displace outside fuel or power sources. The key output is a high level economic assessment of the potential impact of utilizing vent gas in an area, and the incentives that drive the implementation of vent gas utilization options. If fuel use information is available it can be used to calculate tank efficiencies and engine fuel use.

3.2. **Input Well Data** – Key aspects of User Interface sheet for well data:

3.2.1. **Area/Pool –** The data table has rows for up to 20 wells. Separate copies of the tool can be made for areas of that general size, such as a Section, group of similar Sections or a group of outlying wells. It is preferable to group wells in an area or pool with similar characteristics to assist in calculating the energy balance.

3.2.2. **Well ID –** Free format text or numbers, the ID will carry through to other sheets. Whatever is easiest to allow identification of the wells in the grouping.

3.2.3. **Oil, Water, Annulus Vent Volumes –** Must be filled in for each well being considered. It is preferred to use measured numbers that come from the same production period so that they will provide consistent results. These are the primary inputs required to carry out a site energy balance.

3.2.4. **Line Gas, Propane Use, Power Use –** Where information is available on use of outside energy it can be input. Best results will come from having fuel/energy measured from the same, or similar, time frames as the production volumes. The program will use measured numbers to check calculated energy demand numbers. If no measured fuel/energy is available for a well input a '1' in the appropriate cell to show which fuel is used as make-up on the site. If a measured fuel number is input it will be used in the energy balance calculations, if no measurement is input the spreadsheet will calculate a demand. Power use is assumed to be only for pump drives. If only gas or only propane are selected then it is assumed that fuel is used for engines and tank heaters.

3.2.5. **Tank Vent –** Optional Input that does not impact the overall balance as volumes are usually small compared to the annulus vent. High tank vent rates would indicate wells that are subject to foaming which may be of use in Tool B.

3.2.6. **Surplus/Deficit –** The calculated energy balance for each well showing how much vent gas is left over after meeting all that well's energy demands, or the amount of outside fuel that would still be required if all the vent gas was used.

3.3. **User Input/Output** – This User Interface Sheet is the primary run summary sheet for testing the impacts of key economic factors on the overall economics of utilizing vent gas in the area. Key features of this sheet are:

3.3.1. **Purchased Energy Costs –** Input the key commodity values being experienced in the operation. These can later be varied to determine impacts of the changes.

3.3.2. **Cost Increments for 1st Year (Capital)** – These are intended as ballpark estimates of what might be spent or budgeted to fix up wells for vent gas use. The spreadsheets will combine the estimates as appropriate based on the well data to develop a total capital cost to convert all wells to vent gas use. Operating costs are assumed to be a fixed percentage of whatever capital is spent and a cell is provided to input any potential well downtime that might be caused by the use of vent gas and this loss will be included in the economic assessment.

3.3.3. **Value of GHG Credit –** This value should be based on corporate guidelines but could be worth between nothing and \$3-4/tCO2e in current markets. The calculation of GHG Credit value is kept separate from the main economics.

3.3.4. **Energy Demand Parameters –** Are used to calculate energy demand on the site, and highlight wells with large surpluses for potential managed options later on.

3.3.4.1. **Tank efficiency** is the overall heating efficiency, and if some wells were provided with data on measured fuel use this variable can be used to adjust the calculation for wells where no fuel measurement was available.

3.3.4.2. **Pump energy factor** is similar to a tank efficiency and is defined as the amount of natural gas consumed in an engine to lift 1 m3 of produced fluid to surface. The *Warning cells* beside these input warn: a) if there are *not enough wells with measured fuel* use to be representative; or b) if the comparison of *actual measured to calculated demand do not agree* with each other. The outputs to the right of the warnings show the number of wells, which had input data out of the total and the error between actual and calculated demand numbers for those wells.

3.3.5. **Summary Outputs**: - These outputs show the calculated current costs for energy as well as the maximum potential savings, capital, operating, value of any lost production, payout, net annual benefit, GHG reductions, potential GHG credit value, how much vent gas remains, the value of remaining vent gas if it could be sold, remaining GHG emissions and well count information. The outputs shown as an example are based on 15 actual wells from a case study and two fictitious wells.

3.4. **Use of Detailed Sheets –** While the main variables, inputs and outputs are shown on the User Interface Sheets, there are more detailed calculation sheets in the background that can be accessed (<Ctrl>d) to determine how the calculations were done and to show other information. Some key tools to note are:

3.4.1. **Sheets A1 and A2 –** Mirror the User Interface sheets.

3.4.2. **Sheet A3 Well Data Extension –** Shows the basic calculations to extend the data through unit conversions and basic calculations required for the output.

3.4.3. **Sheet A4 Detail by Well –** This sheet is used to calculate and total costs, emission and other information which then is summarized for the user interface output.

3.4.4. **Sheet A4a Well Balance Plot –** This sheet shows a chart that compares the individual well energy demand as natural gas vs. the amount of gas in the annulus vent stream. This graphically shows the energy balance situation for the area.

3.4.5. **Sheet A5 Energy Use –** This sheet is provided to help the user analyze the relationship between fuel use vs. fluid volumes for a group of wells in a similar area. The data on each well is carried in from the main well data and other sheets but measured data for the fuel split between tank heaters and engines can also be input if it is available. Plots are generated with a linear formula to use in predicting fuel use for other wells. The initial input information on tank engine fuel split is real data for the case study wells and the outputs seem to give reasonable results for other operations in similar operations with similar equipment. Generally the engines will use 1/3 to 1/4 of the gas used for production heating.

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4. Fuel Displacement Option Assessment – Tool B

4.1. **General Description** – This tool helps to economically assess fuel displacement options, which will address _the needs of an individual site_, with one or more wells venting. Fuel displacement is the most economic use of vent gas and therefore should be the first set of options considered and implemented. Often the economics will show most options to be short payout, so a technical assessment of the options, or simply operator preference, may decide which option(s) to implement.

4.2. **Input Site Data** – The key input data are for each of the wells on the site with data shown for four years to allow for up to 5 wells on a single site are as follows:

4.2.1. **Oil, WOR and GOR Profiles** – The input table is set up to show four years for each well on the site so the user can take into account future production forecasts and assess their impact. As it is usually easier to forecast oil, WOR and GOR trends these are the inputs. It is suggested that if producers have a standard well production profile for an area this might be used for forecasting even though there generally is a wide range of production behaviour in any given pool. Space is provided for up to five wells, if there are more a second spreadsheet could be used for the remainder, or just the 5 largest venters/producers may be used as they tend to be the wells that will drive the fuel displacement economics.

4.2.2. **Calculated Water and Annulus Gas Volumes** – Volumes calculated from the oil production and water/gas to oil ratio inputs.

4.2.3. **Allowable Casing Pressure** – This input is used to determine if compression is required to use the vent gas and to calculate gas volumes, which might require compression.

4.2.4. **Surplus/Deficit Calculation** – This is similar to the calculation in Tool A and shows the supply/surplus trends for each well as wells can move from an energy surplus to an energy deficit as volumes change over the years.

4.2.5. **Well Counts** – The well counts assist with some calculations for options and specify the number of wells on the site (maybe different from the number of wells input, i.e. could specify 7 wells even if only 5 wells worth of data is input). The *total wells on site* number of wells drives the cost estimates for some of the winterization and other options even though the extra wells may not greatly affected the vent volumes. The number of *trapped wells* shows the number of wells that vent high volumes on an infrequent basis (see one page option sheet 12.3.3). The number of *foamy wells* shows the number of wells where it is found that low annulus pressures are required to promote production (see option sheet 12.3.2).

4.3. **User Input/Output** – As with Tool A this User Interface Sheet is the primary sheet for inputting variables and providing the output results. With this tool the user should note on each run which options from the Cost Option sheet were selected for the run as these determine capital and operating costs.

4.3.1. **Economic Parameters –** These are basic commodity values that drive the benefits of utilizing vent gas on the lease. Some variables, such as methanol and CaCl costs are only used for specific options.

4.3.2. **Site Conditions –** These inputs define the site and assume that all wells on a given site or pad will have similar equipment and layouts. Inputs are used to calculate economics and highlight if there are options that are not suitable for the site. The key inputs are:

4.3.2.1. **Tank Gas Line A/G? –** Input "**Y**" if the lines are above grade or "**N**" if they are below grade. This impacts which winterization options might be used.

4.3.2.2. **Make-up Fuel Source –** Input choices are "**NG**" for Natural Gas or "**P**" for Propane. This is a major cost variable for the economics due to the premium on propane compared to natural gas.

4.3.2.3. **Freezing Conditions –** Input the number of months the wells will be expected to experience temperatures below freezing. If no winterization option is selected on the Cost Option sheet then the benefits will only be calculated based on the non-winter months, so the benefits will be reduced.

4.3.2.4. **Pump Type –** Input choices are "**PCP**" or "**Beam**" and mainly affects compressor choices.

4.3.2.5. **Pump Drive Type –** Input choices are "**Eng**" for a standard gas engine drive; "**Elec**" for a direct electric drive; and "**Elec/Hyd**" for an electric drive with a hydraulic system delivering power to the pump rods. The pump drive has a major impact on the cost to convert the drives to vent gas to displace purchase fuel or line power.

4.3.3. **Energy Demand Parameters –** These are the same as those described in Tool A and generally should be whatever best fits the site operation with the Tool A values for the tank efficiency and pump energy factor being the recommended ones to use if no better information is available.

4.3.4. **Summary Outputs –** Calculates current energy costs, potential cost savings through maximum use of vent gas, capital, operating, payout and annual benefit values. Note that the maximum savings are based on the options selected and will be lower if provision is not made for winterization on the site or if compression is not used for wells with low annulus pressures. Other values calculated are related to GHG emissions, potential credits, the volume of vent gas that are surplus to the site's energy needs.

4.4. Cost Options – This sheet allows the user to select which options should be implemented at a given site and provides the basis for estimating capital and operating costs for those options. *In all cases options are selected by typing in a "**1**" (number one).* This does not indicate how many units are installed as the spreadsheet will assume all wells that require the option will be done. The spreadsheet then shows the capital cost associated with that option for the wells that require it and estimates operating and maintenance costs based on the capital item selected.

4.4.1. **Implementation/Cost Estimating Factors** – The first two factors input select how the options will be implemented and which cost estimates to use. The options are described below:

4.4.1.1. **Project Type**: Input choices are: "**Single**" for where only a single site is being modified in an area and is generally the most expensive method of implementing a vent option. "**New**" is for if options will be installed on a new site when it is constructed and planned from the start, so is the lowest cost implementation method. "**Multi**" is in between the two extremes and is for cases where a large number of existing sites are to be converted by a single crew as a program.

4.4.1.2. **Cost Estimate Using**: Input choices are: "**Default**" which uses cost estimating factors provided by New Paradigm Engineering Ltd based on assumed equipment configurations, typical layouts, rough cost data from vendors and experience. "**User**" will use cost factors from detailed sheets that are set up to be modified by the user based on costs they estimate themselves, or to reflect actual costs encountered for similar conversions. Initially the User inputs are the same as the Default settings so it is recommended that users just modify items where they have more detail or better estimates.

4.4.2. **Permanent Vent Gas Stabilization Options** – These options are considered basic options to stabilize vent gas flows from problem wells and to prepare a lease for use of vent gas.

4.4.2.1. **Installing, Insulating and Dewatering** lines carrying vent gas are considered to be required and a warning will show up under this column if these are not selected. If they are selected but are already installed then a "**1**" can be placed in the installed column so no capital will be shown for these items.

4.4.2.2. **Foamy Flow** and **Trapped Gas** Options were described earlier and in the one page option sheets and should be used to address problem wells.

4.4.2.3. **Convert Drive to Vent Gas** is selected to use vent gas in the artificial lift system drive indicated on the User Input/Summary sheet. Generally it is more expensive to convert an electric drive to vent gas as these options use a gas-fired engine connected in parallel with the electric motor. If there are multiple wells on a lease the power demand load is calculated and a single gas engine driven generator will be included in the estimate to power the whole lease.

4.4.3. **On-Site Production Heating Options –** These selections are mainly intended for selecting a production heating system for new wells although in some cases circumstances may lead to a change in heating equipment. Heaters of various types are assumed to come in standard increments and the overall heat load determines how many even increments are required. The Enhanced Fire-Tube Heater Control Option only applies to fire-tube heaters and is to cover the costs of any changes to level the fuel demand of the tank heaters, which might be done through control changes, or by changing to a smaller burner so it can be adjusted to a continuous rate of fire.

4.4.4. **Winterization Options –** Generally one of these options must be selected to allow for year round use of vent gas. More than one can be selected but no additional benefit will be generated. Normally it is assumed that winterization systems are not already installed, however, if they are the costs can be zeroed out by an entry in a yellow cell on the detailed sheet "B2" that matches this user interface sheet.

4.4.5. **Gas Compression Options –** Where there are wells operating with a well annulus pressure below 250 kPa the gas from that well will not be useable for production heating with some types of heaters unless a compressor is installed. If a compressor is selected it will be sized based on the largest volume of gas, requiring compression, during any of the four years of projected operation. The estimate is base on one compressor unit per site.

4.5. Use of Detailed Sheets – Detailed sheets in this tool mainly allow for the user to input their own cost estimating factors for capital and operating. There are also some sheets that provide additional information to help users understand the options and calculate variables such as water condensation, methanol and Calcium Chloride useage.

4.5.1. **Sheets B1 and B2 –** Basically mirror the user interface sheets.

4.5.2. **Sheet B3 Generic Capital** - contains two capital cost matrices for cost estimates based on the selection of project type. One matrix contains the default values, the one below it is for user input values if the user wants to change the estimate basis. Most costs are per well or for standard size increments for heaters and compressors. The spreadsheet then calculates the cost for the site based on the number of wells or number of increments required to meet the demand.

4.5.3. **Sheet B4 Generic Operating** - is similar to the capital cost estimating sheet but calculates operator and maintenance costs based on hours and hourly rates to operate and maintain each option. Again the top matrix is default values, the lower matrix is for user input values. Often producers don't address operating and maintenance costs, but the time and extra effort required from field personnel will also affect how well the vent gas systems are operating and ultimately whether the economic benefits are achieved.

4.5.4. **Sheet B4a Variable Operating** - contains some rough charts and calculations to estimate water condensation, methanol requirements and CaCl required for dryers. The plots provided might be useful for operators to have to control chemical use.

4.5.5. **Sheet B5 Well Data Extension –** contains the various values calculated from the input well data and is in very rough form. Users can change the formulas if they want by removing the protection on the sheet and making adjustments.

5. Managed Options Assessment – Tool C

5.1. **General Description** – This tool helps to assess the strategic options for use of any large volumes of surplus vent gas once the maximum possible amount is used for on-site energy needs. After fuel displacement the next best use of the gas will be to *export the energy in a value added form* (i.e. sales gas, power or increased oil production) that provides the most benefit in a given location and situation at a given time. If this fails to provide positive economics the final option is to *convert the methane to carbon dioxide* to generate potential GHG credits/offsets, which might be tradable and, therefore, implementation may be financed through offsets. A common component of all the managed options covered in this tool will be the base assumption that the various venting locations will be joined with a low pressure (200-350 kPa) gas pipeline network to allow for sharing of gas between have/have not sites and to bring surplus gas to central sites for use in one of the managed options or for conversion to CO2 by flaring.

5.2. **Input Site Data** – The main site data input table is similar to that from Tool B, however, the sites may be single wells, pads, groups of single wells or sections of wells. The data per site would be the combined data for all wells in that site or group. Managed options generally cover larger geographic areas and require larger volumes of surplus vent gas so the individual wells merge for area wide considerations. As most managed options will be longer payout, a four-year forecast is used for each site. Only four sites are allowed so the user has the option of subdividing all the wells or in running more than one Pool/Area as often even in a pool the situations may be quite different due to the age of the operation, volumes, existing infrastructure or intervening geographic features such as highways or rivers. In some cases smaller areas might be individually assessed first and then run again a one site as a larger study.

5.2.1. **Site ID** – A general identifier for the well, pad or well grouping. This could be sections, wells on a leg of a gas collection network or edge wells that are isolated from a larger group. Generally only sites or areas with relatively large excesses of vent gas should be included.

5.2.2. **Oil, WOR, GOR and Casing Pressure Forecasts** – As in Tool B forecasts are input that should be relatively easy to forecast for existing operations. The pressure value should be based on what pressure the majority of wells can deliver at without having a major impact on oil production.

5.2.3. **Water and Vent Gas Volumes and Energy Balance** – These are calculated in a similar fashion to the methods used in Tools A and B.

5.2.4. **Site Location Data** – These inputs under the production data are intended to locate the pool area in relation to key points that impact the managed options economics. All are distances to tie-in points from some logical point on a low pressure gas transfer system (LP Gas), or distances to a key source or outlet for water which is needed for two of the Enhanced Oil Recovery Options.

5.2.4.1. **LP Gas to LP Sales Tie-in –** Generally it is going to be less capital intensive to tie-in to a local gas utility sales line than to sell gas into a major gas collection pipeline. Also municipal or local utilities may be more willing to purchase vent gas for their use at a lower quality spec. A Low Pressure Sales line is likely to be closer to any operation than a High Pressure Sales system.

5.2.4.2. **LP Gas to HP Sales Tie-in –** Distance to the "normal" gas marketing network with assumed delivery pressure of 4000 to 7000 kPa and a requirement to meet the normal commercial water spec of 4 lb water/mmscf.

5.2.4.3. **LP Gas to 25 kVa Power Tie-in –** Distance from the LP gas collection system in the area to a 25 kVa power line.

5.2.4.4. **Average Distance to Water Disposal Site –** Where the produced water from the area goes to now for disposal. Transportation is assumed to be by truck and not having to send water to disposal would be an operating cost credit to the EOR Hot Water Option.

5.2.4.5. **Make-up Produced Water to Injector –** For the EOR Hot Water option produced water might be trucked from an area producing large amounts of water to an injector site with large amounts of vent gas that can be utilized to heat the water. The water does not have to be treated beyond tank treating to reduce sand and solids content.

5.2.4.6. **Fresh Water Source for Injector –** For the EOR Steam Injection option fresh water is required for the steam generators and needs to be transported by truck to the injector site, where surplus vent gas is available.

5.2.5. **Site Facilities Data –** This table generally characterizes the normal situation for each well or group of wells being considered on the assumption that similar wells are grouped together.

5.2.5.1. **Pump Drive Type –** Input choices are "Eng" if the majority of wells are equipped with gas-fired engine; "Elect" for either electric direct or electric hydraulic drives.

5.2.5.2. **Site to Injector –** Average distances from the wells in the site group to one or more locations that might be suitable as injectors for EOR schemes. This distance is mainly used for trucking water between sites. The injector wells may be watered out producers that have not yet been abandoned or, for methane injection, could be shallow depleted gas wells which could be used to store vent gas for future use.

5.2.5.3. **Site to LP Gas Tie-in (km) –** This should be the total length of pipeline that would be needed to tie all the wells in the "site" to a common gas collection network. The calculations assume that all pipe used would be the same type and size to simplify determining relative economics.

5.2.5.4. **Make-up Fuel Source –** Input choices are "**NG**" for natural gas or "**P**" for propane. The choice should reflect the make-up fuel used by most wells in the site grouping.

5.3. **User Input/Output –** The main user interface shows summary results as variables such as energy commodity prices change. Generally the site input sheet should stay relatively static for a given case study. This allows a number of runs to be easily made to determine which managed option(s) are best for a given location and commodity price scenario.

5.3.1. **Economic Parameters –** Additional commodity parameters are needed for managed options to allow the user to consider the impacts of "spreads" between energy sources. These inputs reflect the fact that commodities are usually purchased at a higher cost than what can be realized when the same commodities are sold. This assumes that contracting does not generate situations where buy and sell prices are reversed. Also included are factors for moving fluids that might be used for EOR options and to show potential values for GHG credits/offsets.

5.3.1.1. **Gas prices –** Commercial Gas (Buy) and (Sell) are for natural gas that are of essentially the same quality in terms of pressure and water content but with more paid to buy gas than can be received for selling it. The LP Line Gas value is used for a low pressure, lower quality gas that is useable for other oil and gas operations or, possibly for sale to a local gas co-op or municipality.

5.3.1.2. **Power prices –** Power (Buy) and (Sell) are similar to Commercial Gas. These are hard to determine as in a single day they may change by a large amount. They are also affected by whether the energy is needed 24 hours a day, if it is an "interruptable" load, or if the power is being sold at periods of peak power demand. Setting a price to use requires the user to be familiar with local power markets, electrical utilities and the basic power rate structures. (see Utility Power cost tool) The value used in the spreadsheet should only include the energy component of the power.

5.3.1.3. **Water Trucking Cost –** This is used as a standard number for trucking any type of water between sites or to/from other locations. Units are $/m3/km. In reality this will normally be a fixed loading or minimum haul distance with some increment for longer hauls so some effort might be required to determine an area specific number. $0.25/km-m3 was used in a previous study and seemed reasonable for short hauls and $0.10/km-m3 for longer hauls where loading time is not as big a factor.

5.3.1.4. **Water Disposal Cost –** Some commercial water disposal companies list their water disposal costs on their websites and are generally in the $3-$4/m3 range to cover the costs to clean-up, pump and inject produced water into a disposal aquifer. If a producer is using their own disposal facilities they should estimate a number that reflects their incremental costs based on unit volumes (i.e. usually treating chemicals and power to run injection pumps).

5.3.1.5. **Value of GHG Credit** – This assumes that the GHG reduction as a result of the methane conversion option will generate credits that might be traded. Values of between US$0.50-$2 have been seen. Currently many purchasers of credits prefer to buy offsets or credits for sources that would be uneconomic to recover, or where the recovery of the emission is not required by regulation. Because of this it may not be possible to sell credits that result from fuel displacement or managed options.

5.3.2. **Energy Demand Parameters** – The same as the other tools but should reflect the average values for the area including all sites.

5.3.3. **Low Pressure Gathering Constraints** – These factors affect the cost of pipelines joining wells and sites and identify where compression is needed.

5.3.3.1. **The Low System Pressure Cut-off** - Is used to set a pressure necessary for any site to feed gas into the network without the need for a compressor. Sites that had pressures below this cut-off will be taken as needing a single stage of compression to allow the gas to be shared with other sites or used for the managed options. Any gas not shared would continue to be vented.

5.3.3.2. **Average line size and materials** – In most cases 2-3" nominal pipe size should be assumed, to provide for gas flows in the 1000-3000 m3/d range allowable sizes are "**2**", "**3**", "**4**" and "**6**" inch. Cost estimates can be based on either Steel (input "**1**") or High Density Polyethylene (HDPE input "**2**"). HDPE is lower cost as it can be plowed in for sizes up to 6 inch.

5.3.4. **Summary Outputs – Fuel Displacement** – The first block in the outputs shows the results from fuel displacement options that should be implemented before considering managed options. This shows the volumes of methane not used for fuel displacement per year or per day, the potential value of the surplus at the Commercial (Sell) price and the potential size of GHG reductions that could be achieved if the methane is converted to CO_2.

5.3.5. **Summary Outputs – Managed Options** – The second block of output provides a summary of some key economic indicators for the various managed options. Cumulative Cash Flow shows the net benefit of the option over four years; Capital Required shows how much would have to be expended in the first year to implement the managed option; and Payout indicates how long it would take to payout the investment in each option. Producers need to understand their own business drivers to determine which indicator should take precedence: a) greatest net revenue; b) lowest capital cost; or c) quickest return on capital. It is assumed that the same methane will be used in all cases.

Information on the Managed Options considered is contained in the One Page options document supplied with these tools. The following descriptions provide a quick overview of the options, assumptions and how they can be implemented:

5.3.5.1. Low Pressure Gathering and Compression – This option is to install all the interconnecting pipelines and compressors need to collect gas from the sites to some central location. The economic benefit generated is in allowing sharing of gas between have and have not sites to displace additional purchased fuel/energy, but this is also a prerequisite to all the other options so the cost and benefit must be combined with the other managed options of interest. The costs shown allow for tie-in of all wells with large surpluses of vent gas. Compression cost used is $35k/1000m3 of capacity.

Special Case - Note that if no other managed options are being implemented, the economics of this case could be significantly improved by only installing pipe and compression/dehydration equipment for the volumes that need to be transported between sites to achieve an area energy balance. To see this case the user can use the tool to assess wells in a larger area by grouping wells with large deficits in vent fuel, and then gradually building a separate grouping of wells that have large surpluses starting with the well with the largest surplus that does not require compression. Wells with surplus gas can be added to the volumes and the required pipeline lengths added until there is no net surplus or deficit of gas shown in the first block of the Summary sheet. This would then show the economics for fuel displacement alone in an area, and most of the other managed options would be near zero as there would be no surplus gas to fuel them. EOR Hot Water will still show some benefit as even injecting warm water saves trucking water and paying for disposal. (Options in section 12.5 (gas drying), 12.6 (gas transportation) and 12.7 (compression) in the Option Summary document)

5.3.5.2. **Low Pressure Local Gas Sales –** This case assumes the surplus can be sold locally at a low pressure to a municipality, another oil company in the area or some other industrial user not worried about a tight fuel spec. This avoids the need for higher cost compression and dehydration systems and higher cost pipelines. The price received for the gas would likely be lower but there may also be an interest in the purchaser of the surplus vent gas also supplying the compression equipment and operators so this is assumed. (Options in section 12.5 (gas drying), 12.6 (gas transportation) and 12.7 (compression) in the Option Summary document)

5.3.5.3. **Gas Sales to Utility –** This would be the normal standard of producing high pressure, low water content gas for commercial sales. Generally this will not be very attractive for a stand alone, isolated operation unless volumes are very large but would be more attractive if some sort of gas production operation is already in the area, so the sale would be more like the Low Pressure Local Gas Sale case. (Options in section 12.5 (gas drying), 12.6 (gas transportation) and 12.7 (compression) in the Option Summary document)

5.3.5.4. **Power Generation and Sales –** Distributed power generation has become popular for reducing flaring emissions. For venting applications it should be even more attractive if the producing area is near 25 kVa power lines. There are many third party suppliers who would be interested in supplying the equipment and operating the facilities. This tool is based on the producers installing and operating the power generation facilities and power lines themselves. In reality few would be likely to do this but it is difficult to address all the potential combinations and situations, which might arise as a result of third party involvement. Especially when one province is a regulated monopoly and the other is just going through the deregulation process. (Options in section 12.8 (power generation) in the Option Summary document)

5.3.5.5. **EOR Hot Water Flood –** This case assumes that all the 75-80 degree, produced water in an area, and water from other operations or small volumes of untreated fresh water, can be collected, heated to 150-200 degrees C and injected into a well to generate a relatively low cost and simple hot water flood operation. The economics are driven by saving water disposal costs, reducing water-hauling costs and by incremental oil from heating the formation using an energy source that would otherwise have no value. (Option 12.9.2 in the Option Summary document)

5.3.5.6. **EOR Methane Injection –** While continuous methane flooding in heavy oil would likely have few supporters, there are methane injection options that have been proposed that might be more attractive:

Gas Storage - One option is to just inject the gas into a depressured shallow gas well, or an isolated shut-in producer, to store the gas for future use when gas rates decrease or for when the area energy demands increase with increasing water production. This case is not covered in the spreadsheet but it might be considered to be similar to the Low Pressure Local Gas Sale case.

Methane Pressure Cycling – Methane injection cycling, has been proposed, by the Saskatchewan Research Council, to provide an assist to the Cold Heavy Oil Production (CHOP) mechanism. Gas would be injected on a cyclic basis into a producer to recharge the oil with gas. The pipeline network, with portable compressor units, would allow each well on the system to be stimulated. (Option 12.9.2 and 12.9.6 in the Option Summary document) In this case the producer is also storing gas so there is an assumed future cash flow for stored gas credited to the year in which it was conserved.

5.3.5.7. **EOR Steam Injection** – This case would be a small-scale thermal operation with the major benefit over larger operations of having a free source of fuel for steam generation. A fresh or treated water source would be required and costs would be incurred for recompleting or redrilling wells to use in a high temperature service. This might be mitigated by injecting steam down the tubing with simultaneous injection of methane down the annulus to keep the casing from seeing high steam temperatures and reduce heat losses to the over burden. The spreadsheet only addresses a single straightforward steam injection scheme so variations would have to be addressed with other tools. (Option 12.9.3 and 12.9.7 in the Option Summary document)

5.3.5.8. **Flare Surplus Gas for GHG Credits –** This option in the spreadsheet would make use of the gas gathering system to get the surplus gas to a single site for flaring (open or enclosed flare) which is likely the least expensive conversion option for large volumes of gas in an area as it avoids flares or other equipment going into every lease. Revenue in this case is limited to assumed GHG credits/offsets, but there is also a regulatory consideration if there is intangible value placed on reducing vent emissions to allow oil production to continue. While this tends to be the lowest capital cost option it is only reduces the GHG impact of wasting the resource. (Options in section 12.10 (methane conversion) in the Option Summary document).

5.4. **Plot of Cash Flow Comparisons –** This plot shows the annual cash flow profiles for the various options.

5.4.1. **Intersite Transfer –** As indicated above the first option is for intersite transfer to make the gas available at one or more sites in the area and this cash flow profile should be added to all the other ones including flaring to get a combined picture.

5.4.2. **General Interpretation of Plots –** The plots show the relative relationships between the options for a given scenario and production forecast, assuming the intersite transfer system is already in place. Users should try changing a number of variables to test sensitivity, including commodity prices, oil recovery factors for EOR schemes, GOR and WOR forecasts, then consider the most robust (consistently better) options in more detail. A managed option that stays high in value no matter what the scenario is likely a good option to go with to minimize risk.

5.5. **Use of Detailed Sheets –** As in the other tools there are backup detail sheets in this tool. The key factors that can be adjusted by the user in the detail sheets are cost estimation factors for capital and operating costs, and oil recovery factors for the EOR processes. In all these cases New Paradigm has provided some initial values, but in this case there is a much wider range of uncertainty in our inputs as they tend to be more dependent on capacity, quality and reservoir related factors than the estimates that were used in Tool B. As a result all of the default values in the detail sheets should be reviewed and tested.

5.5.1. **Sheets C1, C2, C3 and C4 –** These sheets mirror the User Interface sheets. The main user input is on sheet C3 where the user can select to use either "Default" or "User" values. It is likely that in most cases users will want to adjust the default values.

5.5.2. **C5 Comparison Options –** This is the input data for the plot of cash flows for the managed options.

5.5.3. **C6 Low Pressure Gathering –** Basic gathering system for vent gas and low pressure gas sales but there is also detail for an increment to first tie-in wells that don't require compression, then tie-in wells that need it. The two increments are combined, but the detail sheet provides information on the relative costs of the two increments. Also Users can input alternate cost factors for compression based on $/1000m3/d increments, operating cost as a function of capital and costs per kilometer for various types and sizes of lines.

5.5.4. **C7 Compression Options** – For commercial gas treatment, compression, metering and pipelining for sales case. In this sheet users can input sales gas pressure, sales gas line size, and cost factors per 1000 m3/d of gas and operating costs. As facilities costs increase with pressure a simple escalator, based on the number of stages of compressor required has been used to adjust for the sales gas pressure. Only steel pipe is allowed as HDPE is not suitable at higher pressures and temperatures.

5.5.5. **C8 Power Options** – Similar to compression options but costs input are for cost/kW of capacity installed, cost per kilometer of power line, a fixed cost for power conversion and operating costs based on a $/kwh factor.

5.5.6. **C9a EOR Hot Water –** For all the EOR option sheets the reservoir response is set by a factor with units of m3 of oil/1000 m3 of vent gas used. Users should calculate these factors for other operations and or obtain feedback from reservoir engineers to assess what value might be appropriate for each type of EOR method. Bench marks for the range are: Gas Storage only recovery = 0; Cold Lake Thermal Operations are normally in the range of 3 m3/1000 m3. For the initial value for Hot Water New Paradigm has used 1.5 m3/1000 m3.

5.5.7. **C9b EOR Reinjection –** For gas reinjection a recovery factor of 0.5 m3/1000 m3 has been used initially and there is also an input to cover the value of injected gas as future fuel. The credit should be assessed based on future fuel supplies expected and the estimated change in demand but generally should be some fraction of the value assessed for low-pressure sales. Costs for compression equipment are similar to those for the compression and gas sale option, however, there is no need for high-pressure pipelines and the required injection pressures may be lower than what would be required for commercial gas sales.

5.5.8. **C9c EOR Steam –** For steam injection a recovery factor of 2 m3/1000 m3 has been used initially (about 2/3 of a Cold Lake commercial steam operation). Estimating factors are separate for the water pumps and the steam generators. No adjustment is made for steam injection pressure as most steam generators are designed to produce steam at high pressure to keep velocities in the generators low. Other inputs are the cost to convert a well to high temperature injection and the cost to convert a lease to accommodate a steam generator and fresh water tankage.

5.5.9. **C10 Methane Conversion –** Inputs are a cost increment per 1000 m3/d of gas being flared and lease preparation per increment. This assumes that a number of leases might be fitted with flare stacks or enclosed flares to convert gas close to the areas with the most surplus and avoiding compressing and pipelining gas just to flare it. It is assumed that the operating cost for a flare system would be lower than for other types of equipment. Revenues are from GHG credits.

6. Utility Power Costs

6.1. **General Description and Use –** This spreadsheet provides a sample of three power calculations, 2 for Alberta and 1 for Saskatchewan. These are provided for users to understand the impacts of various cost factors on power rates, but users should check with their own power managers to determine what schedules would apply in a given operation and what value to use if power demand is reduced through use of vent gas to back out purchased energy, or sold back into the grid under the power generation option.

7. Further Information on Options

7.1. **Option Summaries Document –** Included on the Heavy Oil Vent Gas Tools CD-ROM is a pdf version of the Options Summaries document originally produced for the study. This document is the basis for vent gas options workshops which New Paradigm conducted in 2001 in Calgary and Lloydminster. If the user is unfamiliar with the options this document should be reviewed and used as a reference tool.

7.1.1. **Flowcharts –** These seven flowcharts lead users through the various options and decision points in determining what options to consider to maximize the economic benefit of vent gas volume reduction.

7.1.2. **Technical Comparison Tables –** These tables compare options that compete with each other at various points in the flowcharts. In some cases a technical issue may disallow an option from consideration, even though the spreadsheet tool is indicating it as being a viable option.

7.1.3. **One Page Option Sheets –** One page descriptions of 60+ options developed for the original study. Each sheet contains a basic description of the option, a photo or diagram, contacts (vendors and producers), costs and issues that affect the successful implementation of the option.

7.2. **Revisions and New Options –** Over time the tools on the tools CD-Rom will become dated and hopefully no longer needed as venting will be reduced to low levels, and there will no longer be an incentive to reduce them. Given the limited expected life of these tools it is not expected that the tools will be revised. However, an upgrade of one page options is already underway to include information from the Vent Options workshops and hopefully success stories will gradually be published by the users.

7.2.1. Website Updates – If any updates are completed a notice will be provided on the New Paradigm Engineering Ltd website www.newparadigm.ab.ca .