INCORPORATION OF PRODUCER CONTRACTS IN GAS PLANT OPTIMIZATION TECHNIQUES

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Abstract

Most process engineers consider gas plant economics only in terms of minimizing utilities and maximizing product, and they are leaving money on the table because of it. One aspect that should play a major role in optimization analysis, but commonly gets overlooked, is considering how contract structures with upstream producers and downstream markets affect gas plant profitability. Highest recoveries and lowest utilities are not always the true economic optimal points, especially when under fixed recovery contracts.

A more wholistic approach considers producer contract structures and incorporates them into an overall economic function of the plant. These factors, integrated with a process simulator, show the true economic optimal operating conditions. To demonstrate the importance of process engineers understanding and capitalizing on producer contracts, this approach is applied to scenarios in which the contract structures would be a key factor in determining the optimal operating conditions of a gas plant.

Introduction

The purpose of this paper is to present the case that commercial aspects of gas plants should be incorporated into engineering efforts to optimize gas processing operations. The primary commercial aspects we will focus on are the existing contracts between the gas producer(s) and processor, and how different general forms of these contracts will tend to impact what the true economic optimal operating points are within a gas processing facility.

To do this, we will focus on and model a gas processing plant that represents a typical processing scheme. This plant has been designed to process 60 million standard cubic feet per day (MMSCFD) of gas cryogenically to produce natural gas liquids (NGLs). This facility utilizes the Gas Subcooled Process (GSP) configuration, along with mechanical refrigeration, to produce these cryogenic conditions. The plant also has the capacity to treat incoming gas with an amine treating unit, as well as dehydrate the gas with a molecular sieve unit.

It is important to note that all operating and commercial values used in this case study are not accurate to the real plant or contracts this scenario was based on, but have been changed to be representative of generic, industry standard values.

Although our analysis will focus on one specific plant, along with a long list of economic and operating assumptions, our goal is to highlight that our overall procedure is a more wholistic approach to economic analysis. With this report, we hope to encourage the gas processing industry to equip engineering staff with the commercial information and understanding such that true economic efficiencies can be achieved.

Definition of key terms

In an effort to minimize confusion, terms commonly used throughout this report that we deemed worthy of defining generally are listed below. Any term that may vary in definition throughout the report depending on context will be defined within that context.

Producer: The company who produces the gas in question, usually by methods of drilling.

Processor: The company who operates the processing facility.

Revenue: Any money a party receives from either selling products or for services charged.

Net Revenue: The overall revenue to the party, considering operating costs, fees incurred, or other losses of any kind. In most cases throughout the report, any losses considered when calculating Net Revenue will be outlined.

Commodity: Any product or material that can be sold in the market, usually in reference to the products typically produced at gas processing facilities (natural gas and NGL liquids)

Thermal Content: The thermal content of a gas is determined by multiplying the flowrate of the gas by the gross ideal gas heating value. Units will typically be reported in millions of British thermal units per year (MMBtu/yr) throughout this report.

Recovery: Any amount of product that is liquefied and sold as NGL is said to be recovered from the inlet sales gas.

Rejection: Any amount of product that is sold as residue gas is said to be rejected.

Residue Gas: The gas product from the processing facility, which is sold as natural gas.

Processor Revenue Structures

The ways a gas processor is paid can vary based on the structure of the contract agreed upon with gas producers. We will be incorporating contracts that fall under two different processor revenue structures, and it will be important to understand how this basic shift in the revenue structure will change the drivers for profit.

Fee-Based Contracts

The first general category of processor revenue structure is commonly referred to as fee or volume based. These contracts will provide some metric of fixed nature to decide how the processor will be paid for its services. In general, a fee-based structure is a lower financial risk option for the processor because the payment structure for processing is independent of commodity price. It is instead based on the processing of a specific volume of gas.

It is important to note that in most fee-based contracts, the producer is the one who ultimately receives revenue from the end products. The processor is simply paid a fee to process the gas. If the processor is the one to sell end products, then these contracts will state that the producer will receive 100% of product revenue.

Commodity-Based Contracts

The second processor revenue structure can take several forms, but ultimately is one that includes current commodity pricing. Under these contracts, a processor’s revenue is impacted as natural gas or NGL product prices vary within the market. This makes commodity-based contracts a higher risk option for the processor. With the added risk, however, comes an added ability to improve economics through operating conditions, so engineering analysis is more important in these cases.

In commodity-based contracts, the processor generally receives the initial revenue from the sale of end products. The processor then pays back the producer for the gas received.

Contracts used for this analysis

We will be using contracts in this analysis that fall under three main forms [1]: Fixed Fee, Fixed Recovery, and Percentage of Proceeds.

Fixed Fee

A fixed fee contract is the prime example of the fee-based processor revenue structure. These contracts will have a straightforward fee schedule that will determine how the processor will be paid for the services their facility will provide. In some cases this fee is flat, in others there may be a staggered fee schedule based on overall volumes, as shown in Table 1.

Table 1. Example of Staggered Fee Schedule Under a Fixed Fee

Average Production (MMcfd)	Fee ($/MMBtu)
40 <	0.40
20 – 39	0.50
< 20	0.60

In fixed fee contracts, the processor receives no revenue in optimizing ethane or propane recovery.

Fixed Recovery

Within a fixed recovery contract, the producer and processer agree upon fixed theoretical recovery percentages of the producer's gas for specific gas components. The amount paid to the producer is then based off the predicted amounts of each product using the agreed upon theoretical recovery, along with gas shrinkage factors that are typically referenced from the GPA 2145 publication and seen in Table 2 [2].

Table 2. Liquid Product Shrinkage Factors from GPA 2145

Theoretical Recovered Plant Product	Shrinkage Factor MMBtu per Gallon
Ethane	0.066340
Propane	0.091563
i-Butane	0.099630
n-Butane	0.103740
i-Pentane	0.109680
n-Pentane	0.110870
Hexanes Plus	0.117843

Fixed theoretical recovery percentages are typically established for multiple operating modes such as ethane rejection and ethane recovery as shown in Table 3. This is used solely to determine how much proceeds of product sales will go to the producer. Any proceeds due to deviating from these values are fully retained by the processor.

Table 3. Example of Theoretical Recovery Values

Plant Product	Ethane Rejection	Ethane Recovery
Ethane	25%	80%
Propane	85%	93%
i-Butane	97%	97%
n-Butane	97%	97%
Natural Gasoline	99%	99%

For the residue gas, payment is based on the expected thermal content of the gas. This is determined by subtracting from the inlet gas thermal content the agreed upon plant fuel percentage, as well as the amount of thermal shrink based upon theoretical recoveries of liquid products.

In most fixed recovery contracts a processing fee will also be applied in a similar way to the fixed fee contract. This is to account for the costs assumed to process the gas up to the theoretical recovery values. Due to the nature of the profit structure for the processor, however, this would be considered a commodity-based revenue structure.

Under a Fixed Recovery contract, there is usually a financial incentive to turn inlet gas into its highest value product. If, under the assumed commodity pricing, ethane is more valuable as a liquid product, then the processor could generate more net revenue by recovering more than the theoretical recovery.

Percentage of Proceeds

A percentage of proceeds (POP), also known as percentage of liquids, contract is another form of a commodity-based contract. These contracts will establish a processor percentage, which determines the percentage of product revenue that the processor is entitled to. The remaining profit goes directly to the producer. The processor can also receive a base fee for the services. Under a POP contract the economic incentive to generate a higher value product, while still present, is less prevalent than under a fixed recovery contact because additional value is only partially retained.

Fuel gas is generally not mentioned, because now both parties have an aligned incentive to only use as much fuel gas as needed to maximize production of highest value products.

Economic Factors to Consider

There are numerous variables to consider when optimizing a gas plant. With the inclusion of contract structures and economic analysis, the complexity increases tremendously. Contract structure, fees, penalties, and commitments all have a critical impact on how to operate a facility for maximum profitability.

For this reason, we will outline the factors included in this case study, but each company and plant will have a unique makeup of considerations.

Several market factors come into consideration for this analysis, the most important being commodity prices. Several price points were considered when running the case study and Table 4 outlines the pricing ultimately used. These prices were all taken from May of 2012, and were used because they represented a recovery favored economy [3] [4]. This made our analysis easier, because it was obvious that running the model in the plant recovery mode was more favorable than the rejection flow scheme.

Table 4. Product Pricing

Product	Price
Natural Gas	$2.33 per MMBtu
Ethane	$0.50 per gallon
Propane	$1.00 per gallon
Iso-Butane	$1.95 per gallon
Normal Butane	$1.90 per gallon
Natural Gasoline	$2.25 per gallon

Another economic factor that was assumed in this report is electricity cost ($0.05 per kWh.).

Maintenance costs are also integral to plant economics, but were not included in this analysis due to their difficulty in comprehensively calculating, as well as the fact that most of our operational changes will not significantly impact maintenance costs. Any changes to operations that could impact maintenance schedules, however, should be incorporated to the best extent possible.

Other forms of operating costs were not included because they were considered fixed costs for the purposes of this analysis. Some of these costs include staffing, operating ancillary portions of the facility, and costs associated with safety and environmental compliance.

Other Process Constraints

Most contracts have a host of specifications on the inlet gas to the plant, including limits on gas pressure, composition of inerts or harmful components like oxygen and hydrogen sulfide (H_2S), gas temperature, and the presence of dust or other solids. For the purpose of this report, it is assumed that the received gas is meeting all these specifications. Most downstream transportation methods also have a host of specifications which play a major role in how the plant must condition the residue gas and NGLs. Our assumed transportation constraints are listed in Table 5.

Table 5. Downstream Transportation Constraints [5]

NGL Carbon Dioxide Volume	Max 0.35 L.V.% of the ethane
NGL Methane Volume	Max 0.50 L.V.% of total composition Max 1.50 L.V. % of the ethane
NGL Vapor Pressure	Max 600 psig
NGL Temperature	Max 90°F when Ethane is 65 mol% or more Max 110°F when Ethane is less than 65 mol%

Other assumed downstream specifications include a minimum residue gas pressure of 700 psig, a residue gas gross heating value between 950 Btu/scf and 1150 Btu/scf, and a transportation and fractionation (T&F) fee of $0.15 per gallon of NGL liquid. Although it is common for the processing company to also operate the transportation pipeline (and therefore not need to pay transportation fees), this analysis will consider all transportation fees as a cost to the processor.

The facility itself has some equipment restraints that must be represented in this analysis. For our scope, we assumed that no new equipment has been justified for approval, so current equipment limitations were necessary constraints to the analysis. Assumed equipment constraints are found in Table 6.

Table 6. Equipment Constraints

Refrigeration Compressors	Max 450 total hp
Residue Compressors	Max 2500 hp per parallel compressor Max 3 parallel compressors
Demethanizer	Max 95% fraction flooding
Heat Exchangers	Equal normal operating UA (If rated) 0% Fraction Overdesign

Optimization Procedure

The procedure for finding optimal operating points under various contracts are broken down into three main steps: building a process model, determining the correct objective functions, and running an optimization scheme to find the optimal set of operating conditions.

Building the Process Model

The first step in producing an accurate optimization procedure is to build a process model of the plant. This was done using ProMax® simulation software. For the given product pricing, it was determined that recovery mode would be the preferred operating mode for this analysis, which is reflected in the process flow in Figures 1 and 2.

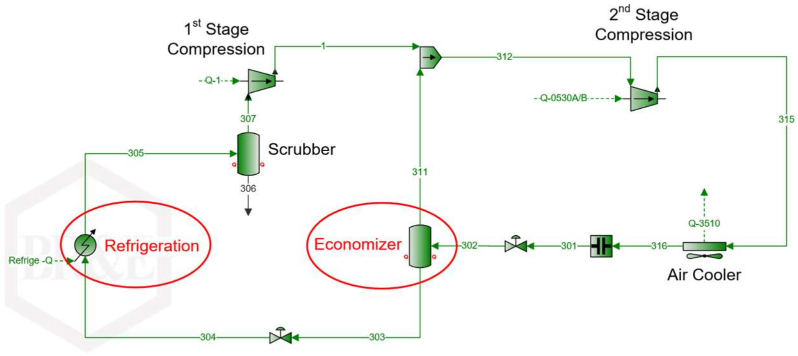


Figure 1. Propane refrigeration loop model

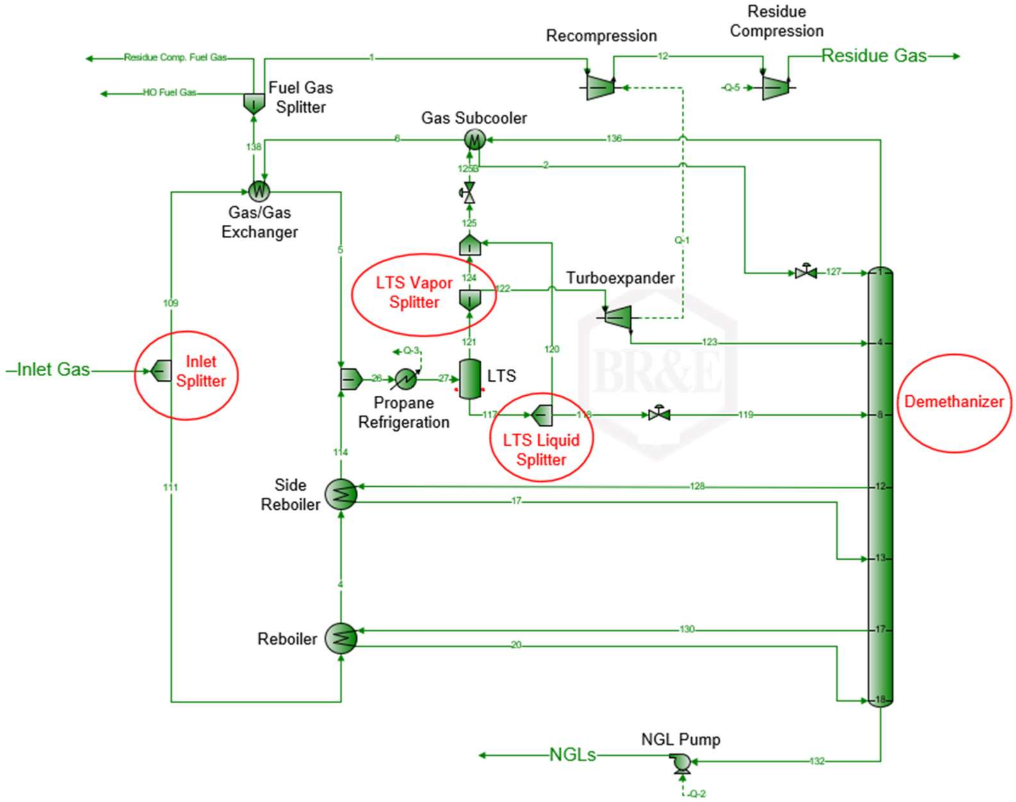


Figure 2. Cryo section model (in recovery mode)

For each contract analysis, there were six factors determined to be important to economically optimize. These were: inlet feed split fraction, low temperature separator (LTS) vapor split fraction, LTS liquid split fraction, tower pressure, propane loop economizer pressure, and propane refrigerant pressure.

Establishing Objective Functions

The next step in the optimization procedure is to establish the different objective functions that will be used to optimize the net revenue of each contract. A different objective function is needed for each contract structure, along with a fourth function to establish a typical procedure that does not include economics in its analysis.

Base Case

The base case is used to compare the three contract cases to a more common optimization procedure that process engineers use today. For our base case, the driving factor is not economics but rather ethane recovery. Our assumption under the base case is that higher ethane recovery is more favorable while operating in recovery mode.

Fixed Fee

The fixed fee contract is, in most ways, the simplest of the three contract structures. This is mainly because the processor profit is fixed by the base fee. The only variability to the processor is from the operating costs, so minimizing cost will always bring more profit, as long as all of our gas and liquid quality specifications are being met.

The objective function for the fixed fee contract takes this general form:

$$\text{Net Revenue} = \text{Fixed Fee} - \text{Operating Costs}$$

Fixed Recovery

Under the fixed recovery contract, the producer payout is a fixed value, based on the agreed upon theoretical recoveries. The processor profit is variable, because any deviation from the theoretical recoveries will vary how much profit is made from plant products.

The objective function for the fixed recovery contract takes this general form:

$$\text{Net Revenue} = \text{Product Revenue} - \text{T\&F Fees} - \text{Fixed Producer Payout} - \text{Operating Costs}$$

Under the fixed recovery contract, the processor is highly incentivized to increase production of more valuable products.

Percentage of Proceeds

The typical POP contract has both variable producer payout and variable product revenue because both parties are receiving a portion of the increased product revenue. This contract, therefore, also incentivizes optimized production like the fixed recovery does, but structures the incentive in a different way.

The objective function for the fixed recovery contract takes this general form:

$$\text{Net Revenue} = (\text{Product Revenue} - \text{T\&F Fees}) * \text{Processor Percentage} - \text{Operating Costs}$$

Under the POP contract, the processor is also incentivized to increase production of more valuable product, but not as highly as in the fixed recovery contract, because the processor is only receiving a portion of the increased revenue.

Optimization Schemes

For this analysis, two different optimization schemes were used, both centered around the built process models.

ProMax Scenario Tool®

The first optimization method used was performed through the ProMax Scenario Tool. This feature allows the user to automate hundreds of process runs, and was used to analyze a wide range of values for each independent variable. Once the wide ranges were run, the combination of values that produced the highest objective function value was evaluated to see if it was a true maximum value for the function. If any change in values lead to an increase in the objective function, then that would dictate the next set of runs the Scenario Tool was used to calculate.

This method, by comparison to the second, required more user input and evaluation, but also resulted in many more data points to justify that the true maximum was discovered.

ProMax Optimization Tool™

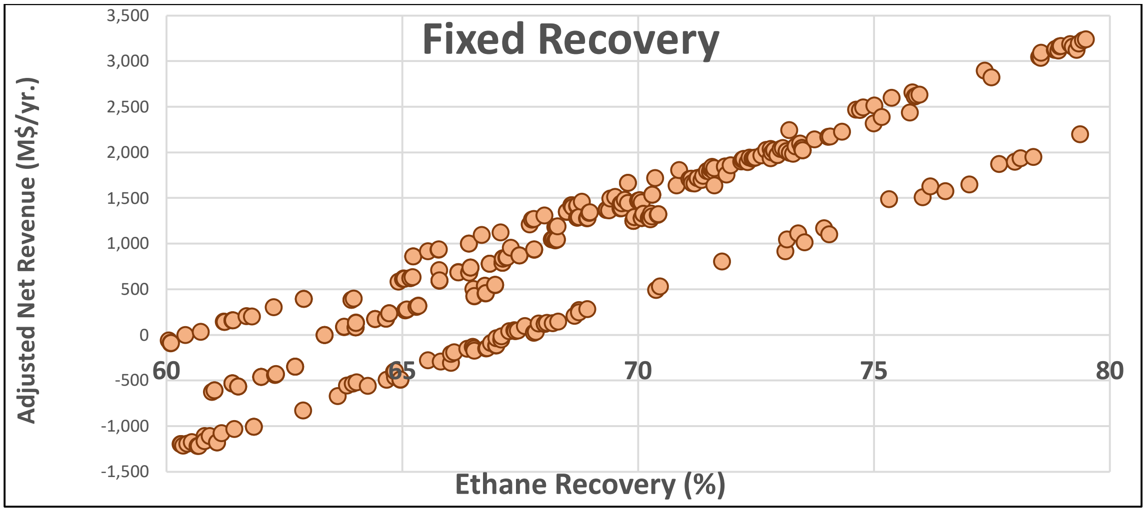
The second optimization method used was to run a more advanced optimization algorithm found in the ProMax Optimization Tool.

This tool allows the user to designate any number of independent variables, and requires that an objective function is defined. Both linear and non-linear constraints can be added to provide guidelines that any successful step cannot violate. Constraints were used not only to ensure that the final solution was in compliance with the mentioned downstream pipeline specifications, but also to enforce constant UA values for all heat exchangers in the model. By comparison, the Scenario Tool method required process solvers to keep constant UA values, which is not as optimal and takes additional time to converge.

This method proved to take a bit less time, and required less human interaction. It did not, however, provide as much hands-on data to prove its solution as the Scenario Tool method did.

Data and Results

The key result for this analysis is the data that came from each optimization technique. Because the Scenario Tool provided more data, it was initially analyzed. The graphs in Figure 3 contain all data points calculated for the three contracts, organized by the ethane recovery percentage that each run calculated. Each data set is adjusted, such that the optimal operating point at 60% recovery is the zero-dollar amount. While this approach was useful by giving each graph a similar scaling, it was mainly used to emphasize that our overall dollar values are not important, but rather the change in the values across the different potential operating points. Certain fixed costs and fees not considered would certainly change the overall values of these objective functions, but our only concern was to capture all of the factors that would vary with changes in operating conditions.



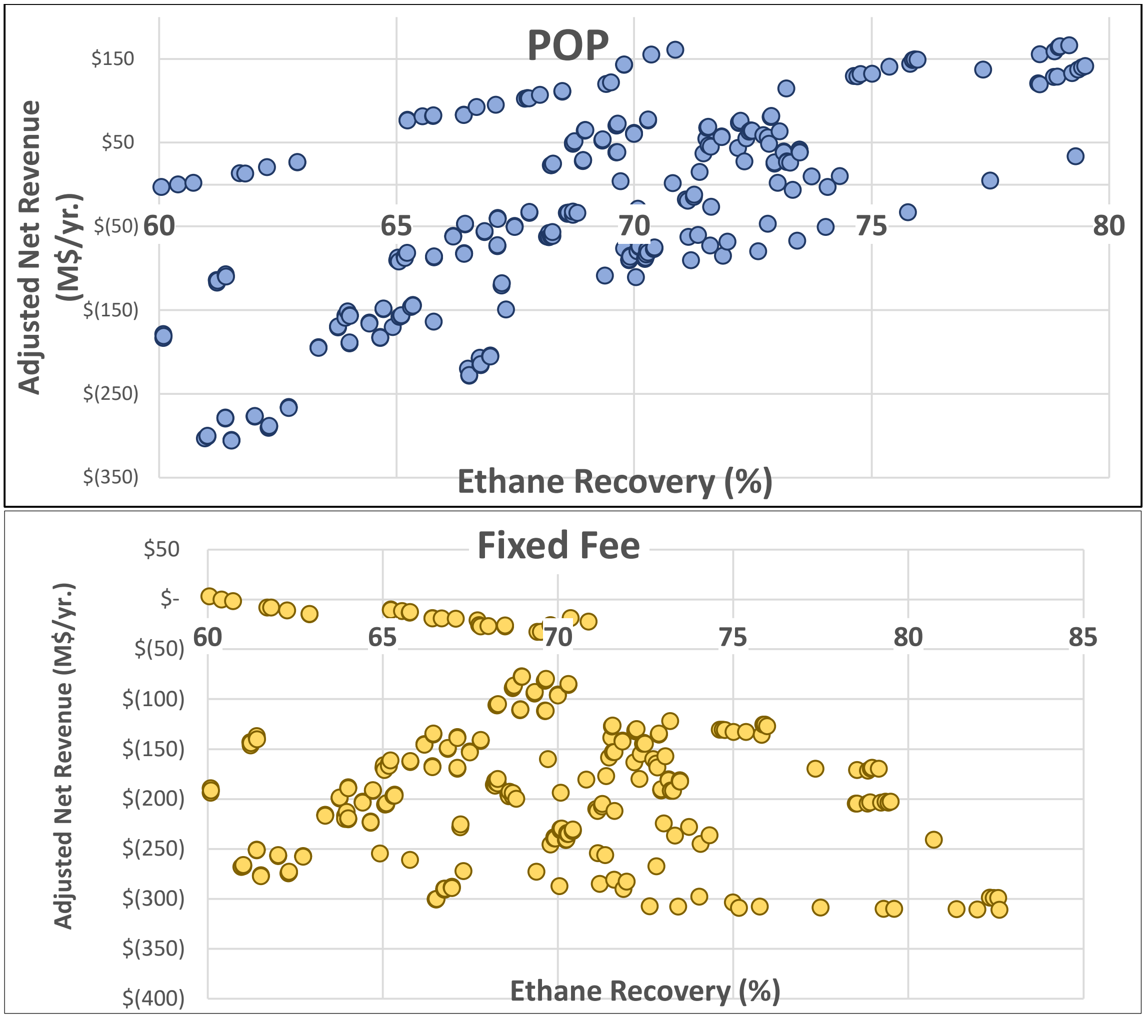


Figure 3. Scenario Tool Data

The data shows that both commodity-based contracts are continuously incentivized to increase ethane recovery, while the fee-based contract is not. On its face, these trends make sense because only commodity-based structures give the processor a financial incentive to increase cost in order to increase product yield.

The next step was to use the Optimization Tool, to see if it could find higher ethane recovery operating points, and if those points would continue to produce a linear trend in the commodity-based contract graphs – or if some higher recovery points were not actually the optimal economic points. The results of the Optimization Tool analysis are displayed in Figure 4.

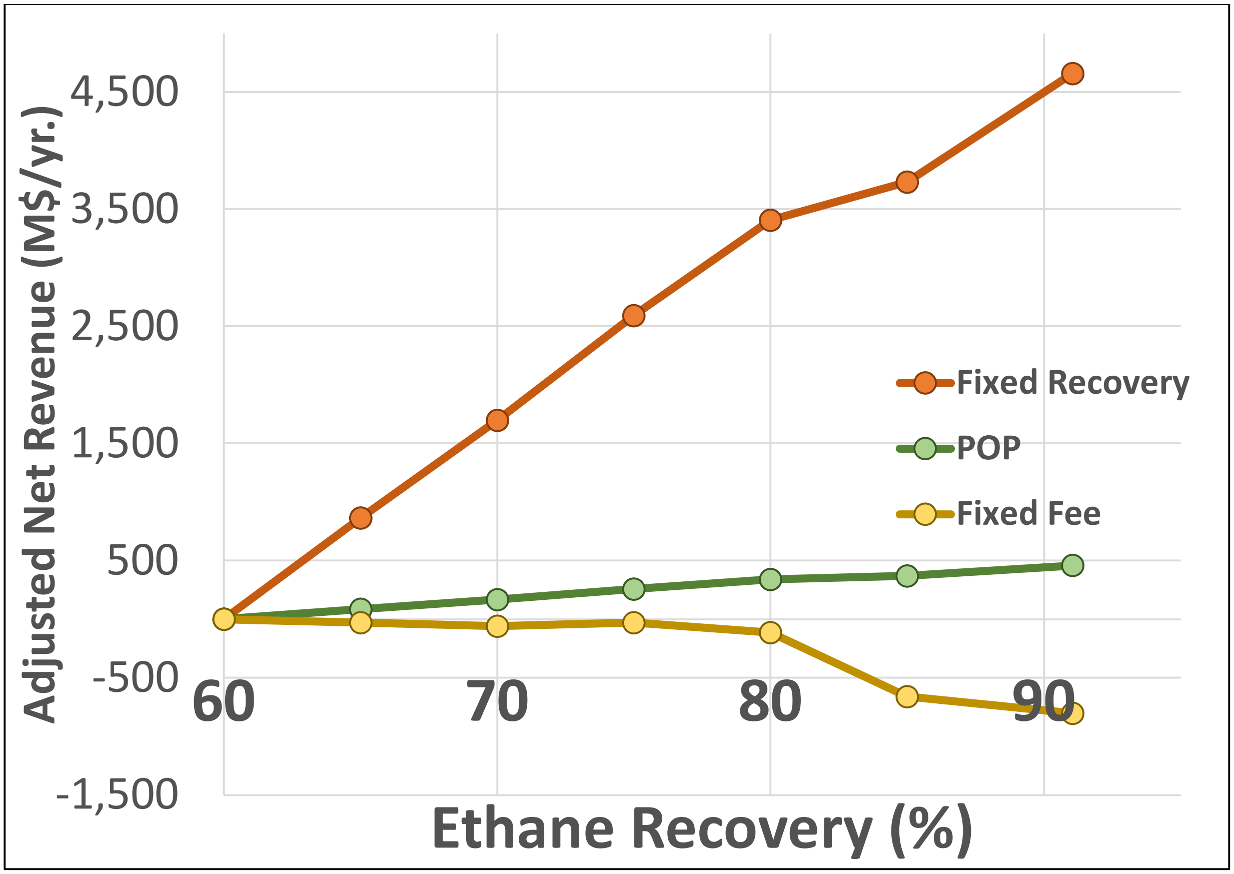


Figure 4. Optimization Tool Data

The optimization tool was able to find operating points that the manual method could not, achieving a maximum of 91% recovery. Even with this additional recovery, each contract still produced consistent trends. At no point did increased compression cost counteract the increase in revenue, even in the percentage of proceeds contract, which is much less commodity incentivized.

This is not to say that every such plant will act this way. In each case, it is important to accurately model the compression and costs incurred, to confirm that this trend will also hold true. This plant has mechanical limitations that limit its ability to push to higher recovery values that may potentially reverse the trend. This study cannot characterize all possible plant economics, so it important to note that these results are specific only to this plant considered.

One last analysis was done to test the linear nature of these results. Two specific mechanical limitations were identified as the main two bottlenecks for increased ethane recovery: refrigeration compression (maximum of 450 hp) and residue compression (maximum of three parallel units, giving 7500 total hp). These not only are two areas that could impact the maximum recovery of the plant, but they are two areas where operators commonly consider capital investment upgrades.

Two more optimization procedures were run, one which doubled the maximum allowable refrigeration power, and one which added a fourth parallel residue compressor to the plant. For each scenario, we attempted to maximize the ethane recovery to see how these limitations were impacting our maximum recovery case. The resulting question was whether these increased recovery cases followed the linear trend seen thus far. The results are found in Figure 5, and do not include the added capital cost of making these adjustments.

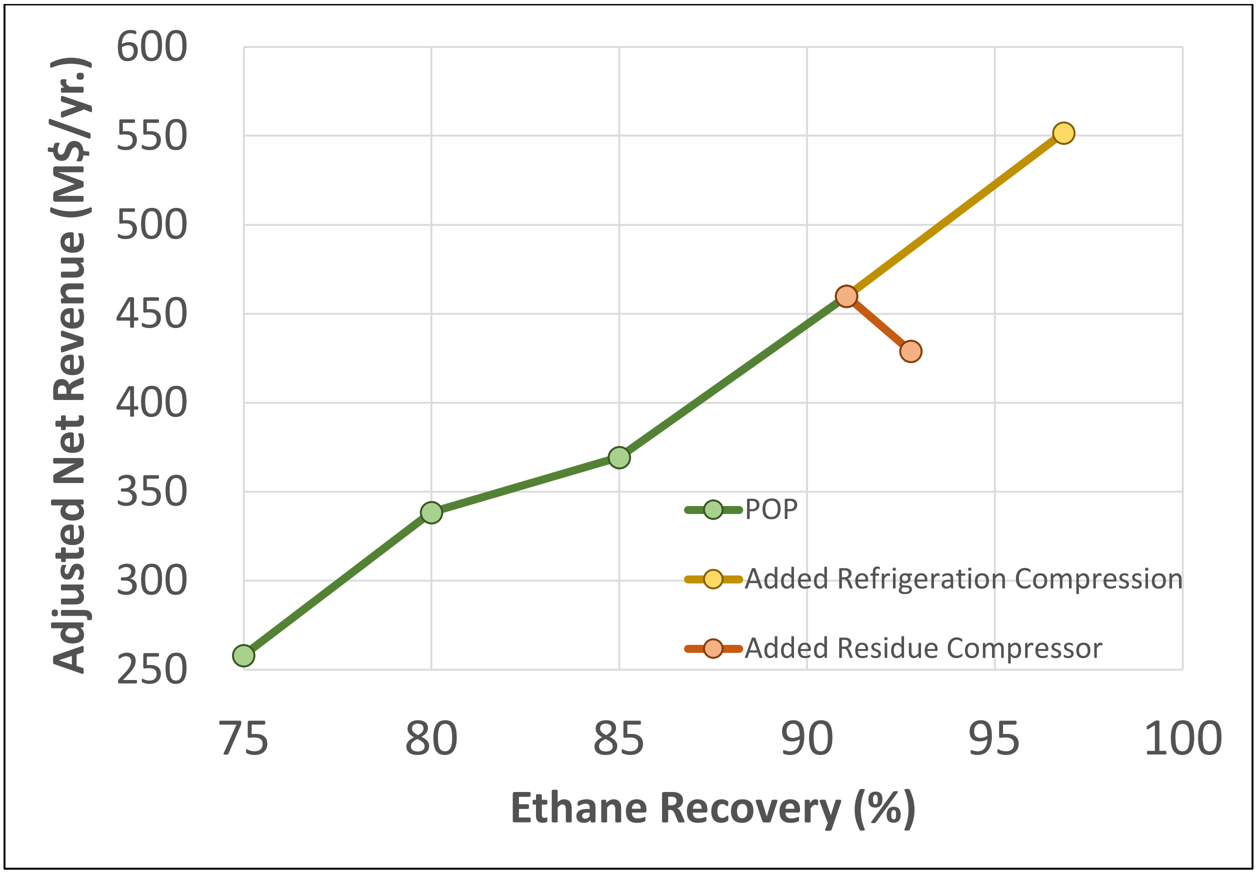
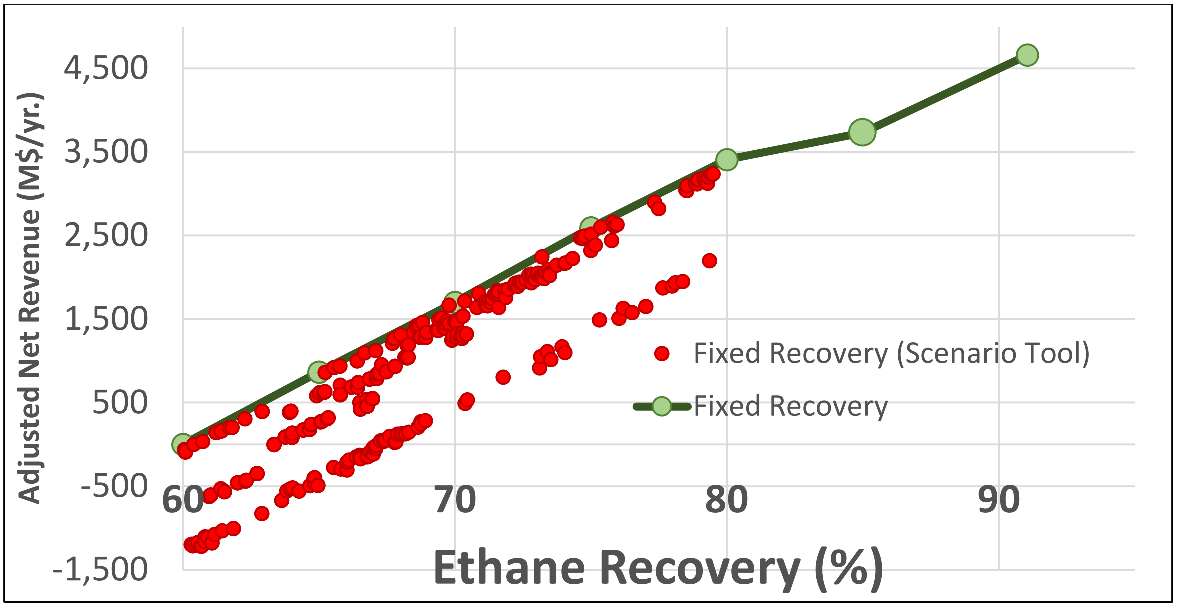


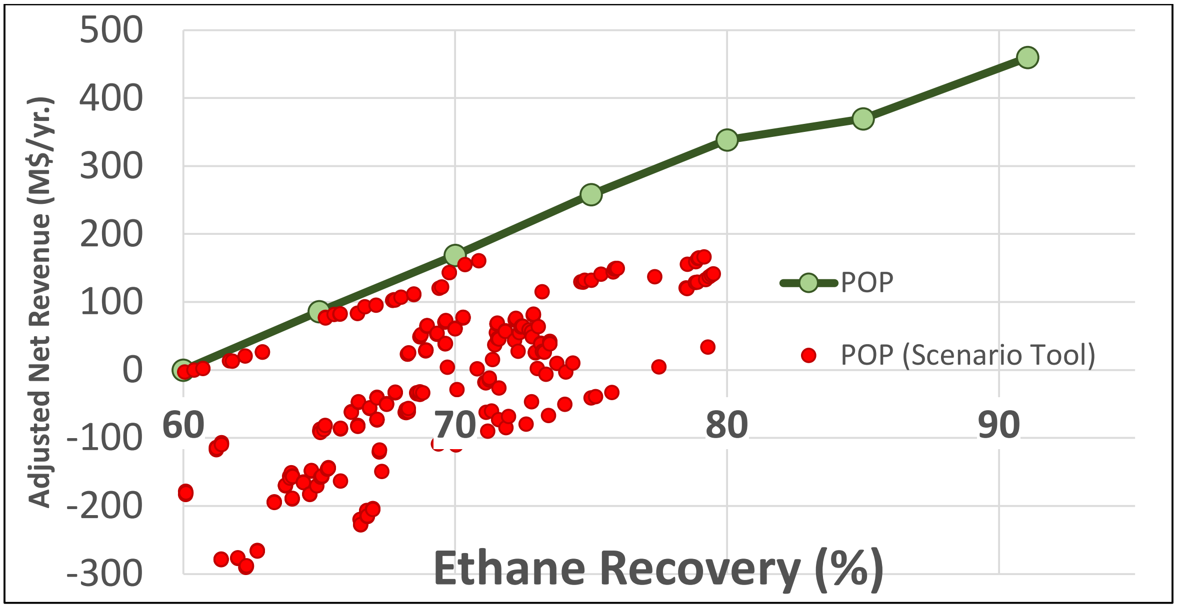
Figure 5. Loosened Mechanical Limitations Results

In the case of adding a fourth residue compressor the results show that even without considering increased capital costs, this would result in decreased revenues. These results not only show that some higher recovery cases are not beneficial in a commodity-based contract structure, but that this analysis is also useful in determining the most effective way to spend capital costs when several options are available.

Validating the Optimization Tool

Because the Optimization tool uses an advanced algorithm to achieve its optimal values, we felt it important to validate its results in some way. In theory, the Optimization Tool should provide points along the ethane recovery scale that represent the maximum revenue points on the Scenario Tool graphs. In essence, the Scenario Tool method should be able to validate the Optimization Tool, and this can be visually evaluated by superimposing the graphs of the two methods on top of each other. You can see the results of this in Figure 6. In each case, the solid line represents the Optimization Tool values, and the single points are the data generated from the Scenario Tool method.


Adjusted Net Revenue (M$/yr.)
4,500
3,500
2,500
1,500
500
-500
-1,500
60
70
80
90
Ethane Recovery (%)
Fixed Recovery (Scenario Tool)
Fixed Recovery


Adjusted Net Revenue (M$/yr.)
500
400
300
200
100
0
-100
-200
-300
60
70
80
90
Ethane Recovery (%)
POP
POP (Scenario Tool)

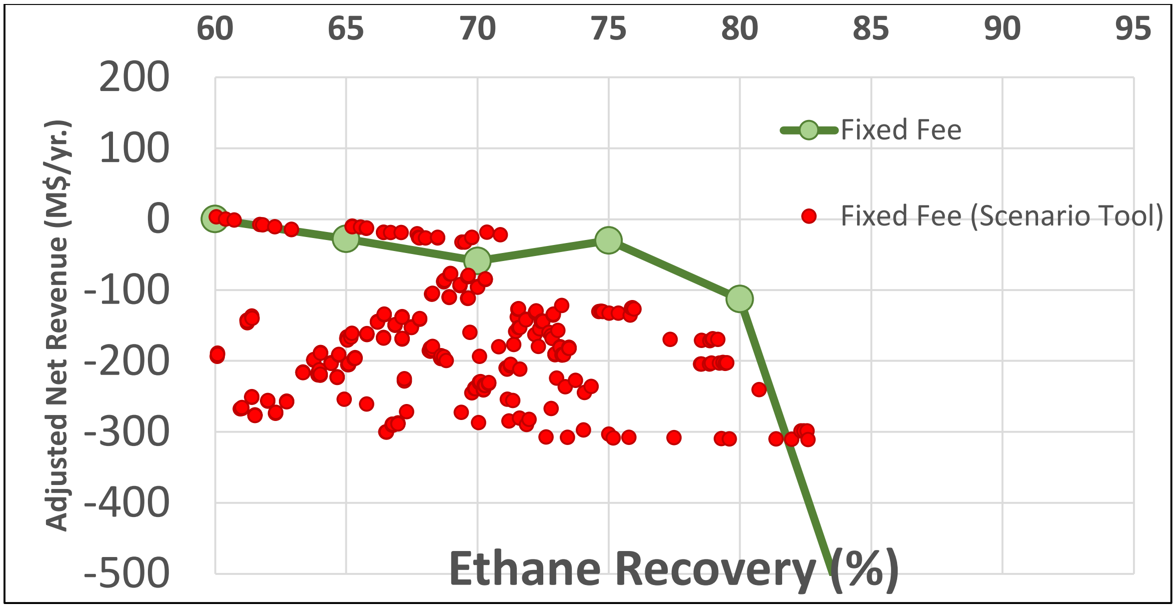


Figure 6. Optimization Tool Validation

With exception to one or two points along the fixed fee graph, this data shows that the Optimization Tool was able to at least find the same maximum as the manual method, if not a better one.

Mixed Contract Analysis

Given that each contract has largely linear trends, one step further is to evaluate plants with multiple contracts. It is common to have gas sources from multiple producers all fed into one processing facility. This allows the chance to have a percentage of gas under a fee-based contract and a percentage under a commodity-based one. In these situations, which contract will be the dominant factor? As imagined, it greatly depends on the amount of gas under which type of contract. Examples of mixed contract optimizations are found in Figure 7.

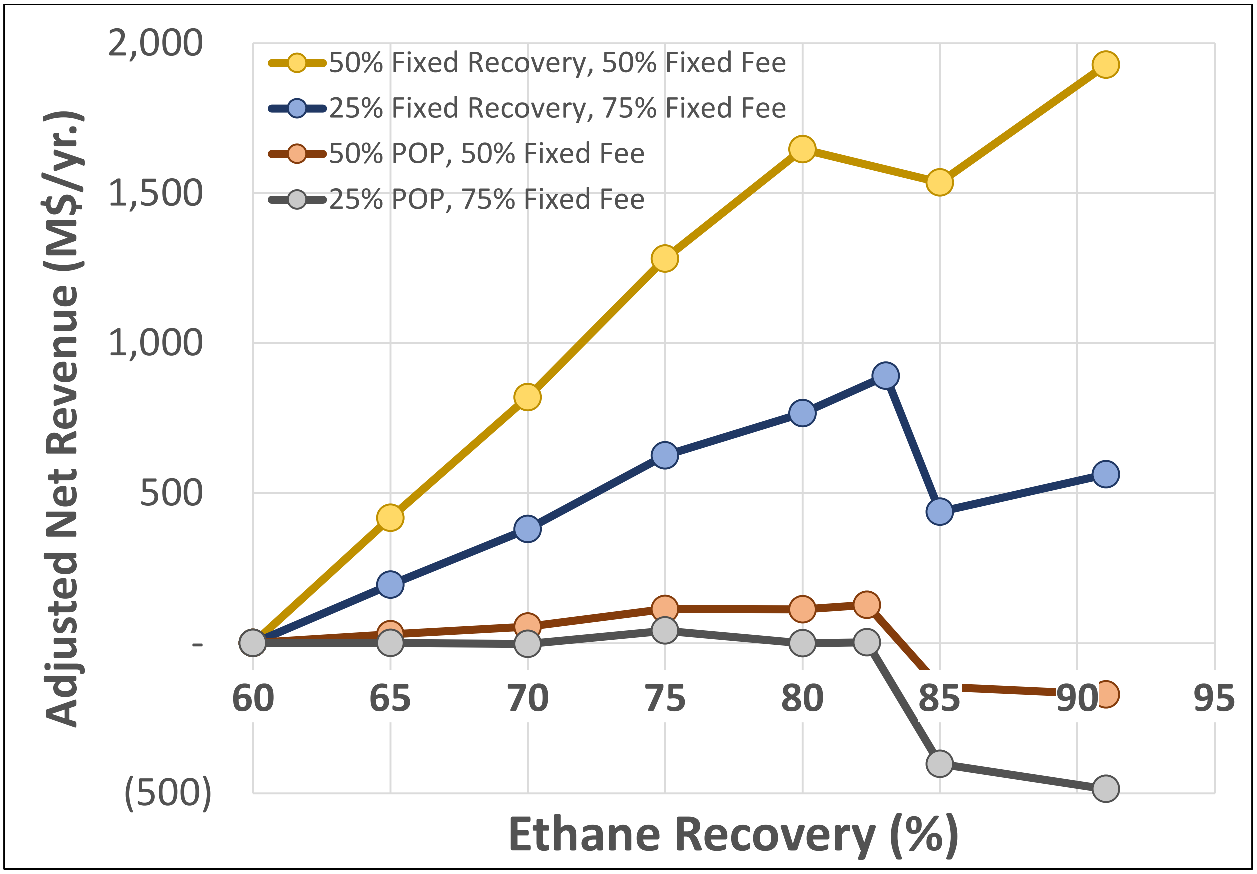


Figure 7. Net Revenues of Mixed Contracts

The chart in Table 7 shows, for each mixed contract situation analyzed, the monetary value that could be earned by performing this analysis instead of a simple ethane recovery maximization.

Table 7. Economic Value of Contract Evaluation

Contract	Optimal Ethane Recovery	Revenue Increase from Maximum Ethane Analysis
	%	$/yr
50% Fixed Recovery, 50% Fixed Fee	91.0	-
25% Fixed Recovery, 75% Fixed Fee	83.0	327,654
50% POP, 50% Fixed Fee	82.3	298,900
25% POP, 75% Fixed Fee	75.0	528,308

Summary

Although these values are guaranteed to vary for each and every plant, the example provided is an appealing justification for the importance of considering contract structures and specifics when optimizing a gas plant. Process engineers who are responsible for optimizing these facilities should have access to this information, and should be using this information to adequately perform their role in making the company's assets run as effectively as possible. This form of analysis will not only impact operation decisions but can also be instrumental when considering impactful capital cost projects.

Through tools like process simulation and optimization algorithms, midstream operators could be finding ways to significantly increase their revenues, especially in complex situations where multiple contract structures can cloud the optimal operating conditions from plain sight.

References

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