Optimization of the Habshan II Amine Sweetening Unit

Abstract

Since Abu Dhabi Gas Industries Ltd. (GASCO) is one of the largest gas processing companies in the world with a capacity of over 5.5 billion standard cubic feet of gas per day, optimization of its facilities is of great interest. As a part of this effort, GASCO has partnered with the Petroleum Institute and Bryan Research and Engineering, Inc. to optimize its amine sweetening units. The first step in the optimization is to compare the latest electrolytic ProMax process simulation model to extensive operating data from the Habshan II facility to ensure good representation. The model is then used to optimize the Habshan II facility by analyzing the impact of the operating parameters such as circulation rate, amine concentration, temperatures, and reboiler duty on the plant performance. Finally, the outcome of the model is used to show the financial benefits to the plant.

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1. INTRODUCTION

Robust predictive modeling is essential when optimizing process units in a gas plant, especially for electrolytic systems like amine sweetening. Historically, amine sweetening has been a very difficult system to model, often leading companies to search for a model that accurately represents their system and has the ability to predict results when process parameters are changed.

The properties and conditions faced in the Middle East often highlight the necessity for robust models. Highly sour gases with more than 10% H_2S and CO_2 and ambient temperatures near 50 C makes the conditions in this region unique.

The Petroleum Institute (PI), Abu Dhabi Gas Industries Ltd. (GASCO), and Bryan Research and Engineering Inc. (BR&E) partnered to investigate operating cost savings for the Habshan II amine sweeting unit. To do so, ProMax® was used to model the Habshan II amine sweetening unit to ensure the model properly represents the plant operations (1). ProMax was then used to examine the plant in detail for opportunities to optimize the operations.

GASCO operates several methyl diethanolamine (MDEA) units, such as the Habshan II unit shown in **Figure 1**. Unlike primary and secondary amines, MDEA is commonly used for selective removal of H_2S while slipping some CO_2 into the sweet gas.

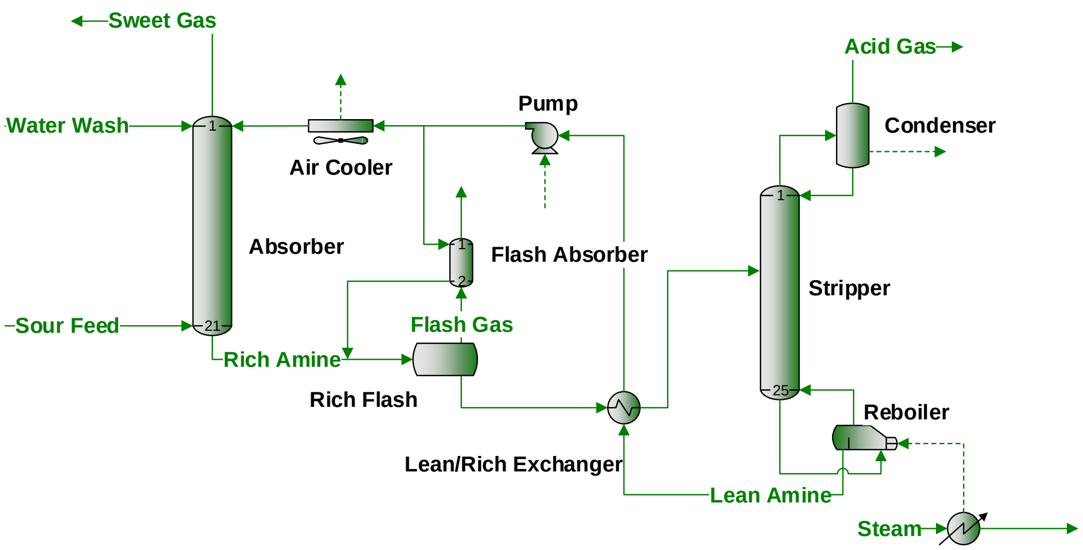

Figure 1: Typical GASCO MDEA Sweetening Unit

2.0 MODEL VALIDATION

GASCO provided operating and lab data for the Habshan II amine sweetening unit which spanned 308 days of 2013.

Since an in depth amine analysis was not available, it was required first to determine whether heat stable salts (HSS) existed in the system, and if so, in what amounts. HSS exist in many amine units and typically form in some capacity as soon as the plant begins operating. ProMax accounts for HSS in plants routinely by modeling the ions in solution.

The concentration of HSS plays a significant role in plant operations. To estimate the level of HSS in the Habshan II plant, all 308 days of data were modeled with three different HSS concentrations. The HSS level is not an artificial figure used to manipulate the model into matching operating data. Such a modeling technique may show good results for a single point, but would show poor representation for the year as a whole. Instead, a systematic approach was used by modeling three different levels of HSS, to be applied in three different models, spanning all 308 days.

The average results are shown in **Table 1** for all three HSS levels.

Table 1: Average Results with Different Levels of Heat Stable Salts in Solution

	Plant Data	0% HSS	0.2% HSS	0.5% HSS
H_2S Sweet Gas (ppm)	10.93	17.98	10.92	4.40
CO_2 Sweet Gas (mol%)	1.72	1.69	1.67	1.66

While the sweet gas H_2S concentration was clearly affected by the HSS concentration, the sweet gas CO_2 concentration remained relatively unaffected by HSS levels, as evidenced in **Table 1**.

The impact of HSS on the sweet gas H_2S concentration is shown in **Figure 2** for 20 days of relatively stable operating conditions.

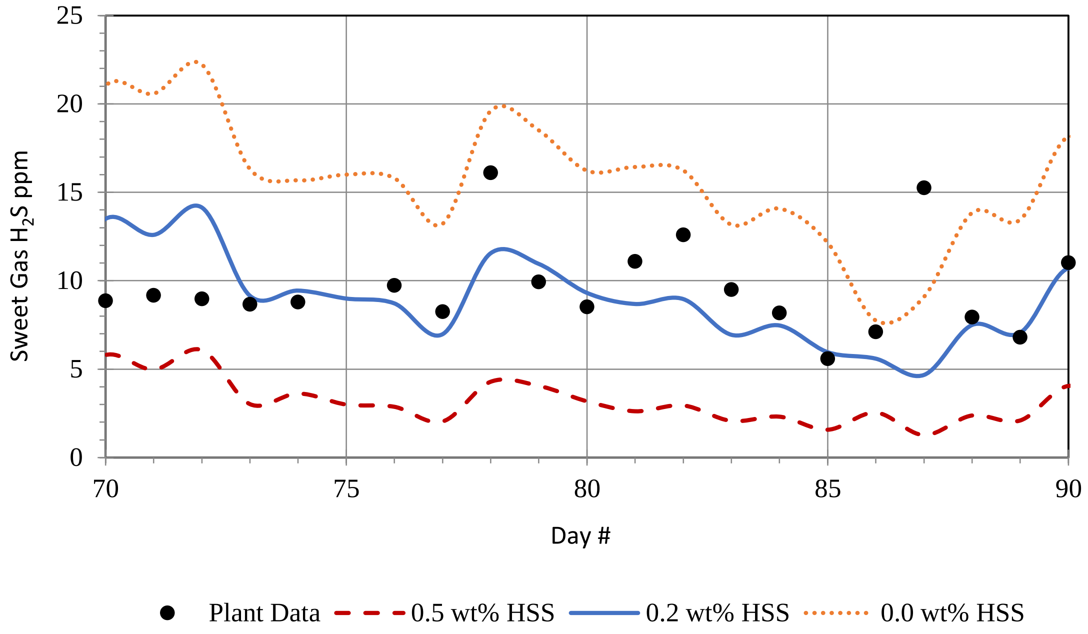

Figure 2: Heat Stable Salt Effects for Days 40-60

The HSS study indicated that the plant was operating with approximately 0.2 wt% HSS in solution. These findings may be confirmed by conducting an ionic chromatography analysis of a sample taken from the amine solution.

It is reasonable to accept the plant has 0.2 wt% of HSS because the plant matches the model consistently throughout the year.

Once HSS are accounted for, ProMax shows very good agreement with the operating data for predicting the H_2S concentration in the sweet gas.

With agreement between plant data and the model being established, the model has been verified and may now be used to optimize the Habshan II sweetening unit.

3.0 OPTIMIZATION

When identifying areas for optimization, it was beneficial to start with a snapshot of GASCO's typical operation. Day 68 was chosen due to it representing a typical set of plant data and good stability of plant operations on that day. The model validation is shown in **Table 2**.

Table 2: A Snapshot of Typical Operating Data

	Operating Data	ProMax
H_2S Sweet Gas (ppm)	8.95	8.91
CO_2 Sweet Gas (mol%)	1.04	0.94
Steam Rate (tonne/h)	75.2	75.2
Absorber Trays	21	21
Amine	45.5 wt% MDEA	45.5 wt% MDEA
Amine Circulation (m^3/hr)	665	665

While there are many variables to optimize in an amine sweetening unit, the variables considered in this study are shown in **Table 3**. The reboiler contributes to the operating cost of the plant more than any other variable. Therefore, each variable studied will show the impact on the steam consumption.

Table 3: Variables Considered when Optimizing Habshan II

Included in Study	**Not Included in Study**
Solvent circulation rate	Inlet gas compression
Rich loading	Inlet gas cooling
Solvent concentration	Refrigerant cooling of solvent
Reboiler duty	Solvent selection
Lean/Rich exchanger	
Regenerator pressure	

Since this study is focusing solely on optimizing the operating costs, optimization that includes capital expenditures were avoided. It is important to note that while the lean amine temperature is often a variable to optimize, Abu Dhabi's ambient temperature is over 40 C for more than 40% of the year. Therefore, as with most amine sweetening plants in the Middle East, the lean amine temperature is as low as an air cooler can achieve. For this reason, the lean amine temperature is not included.

3.1 SOLVENT CIRCULATION RATE

The solvent circulation rate is the most significant variable when it comes to steam consumption in the reboiler. In most amine sweetening units, steam consumption in the reboiler is directly proportional to solvent circulation. The duty supplied to the reboiler generates steam on the process side which then strips the acid gas out of the column.

There are three ways the reboiler duty is consumed. First, some reboiler duty is required for the sensible heat, which brings the temperature of the process side up to the bubble point. Then, reboiler duty is required for the latent heat or the heat of vaporization of the water. Finally, reboiler duty is required for heat of reaction, reversing the reactions which took place in the absorber, allowing the solution to release the acid gases. The sensible heat and latent heat are proportional to the solvent circulation rate. A larger solvent volumetric flow has more fluid to heat and change phases.

When the solvent circulation rate is decreased, the steam rate can also decrease, due to less steam being consumed by the sensible heat and the latent heat. However, the rich loading, a ratio of acid gasses to amine in the solution, will increase due to less moles of amine being in circulation if the same level of acid gas removal is maintained. A total acid gas rich loading of 0.55 is often considered the upper limit before corrosion becomes a large concern (1). For this system, a solvent circulation rate of 530 m^3/hr is the lowest recommended at the conditions seen on Day 68 to avoid the rich loading surpassing the 0.55 mark, as shown in **Figure 3**.

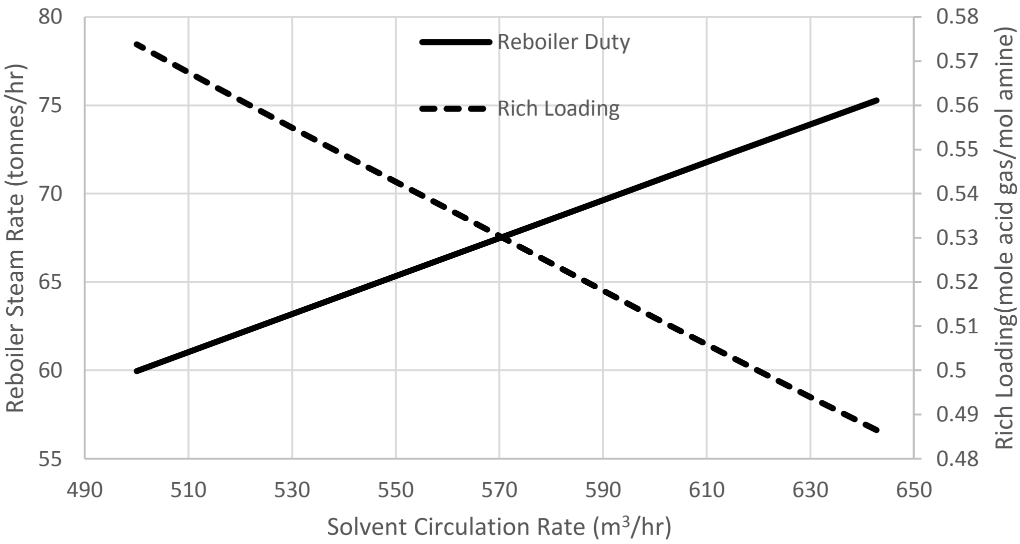

Figure 3: The Impact of Solvent Circulation Rate on the Reboiler Steam Consumption and Rich Loading

While maintaining the same concentration of H_2S in the sweet gas, reducing the circulation rate by nearly 20% would reduce steam consumption by about 10 tonnes/hr. As the circulation rate decreases, less CO_2 will be absorbed into the solution. While it would become a concern if the sweet gas CO_2 concentration exceeded 2%, none of the cases shown exceed the CO_2 specification.

3.2 AMINE CONCENTRATION

The amine concentration is another variable to be considered. When used for applications other than tail gas treatment units, MDEA typically ranges from 40-50 wt% of the total solution (1). On average, GASCO's Habshan II plant operated with an MDEA concentration of 46% in the solvent, as measured by the lab. Again, Day 68 is used as the base case to demonstrate the effect of changing the MDEA concentration, shown in **Figure 4**.

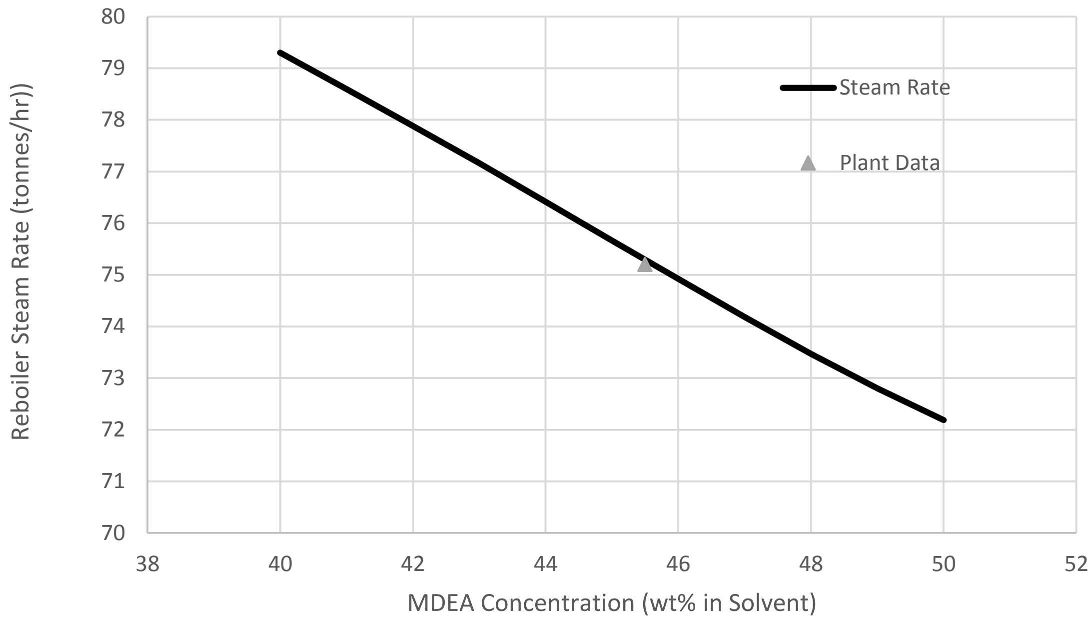

Figure 4: The Effect MDEA Concentration has on the Reboiler Steam Consumption Rate

Holding all other variables constant, as the MDEA concentration increases, the operator may reduce the reboiler duty by 2.5 tonnes/hr.

3.3 REGENERATOR INLET TEMPERATURE AND PRESSURE

Habshan II currently operates the regenerator at 1 barg, with the rich amine entering the column at 95.6 C. These two variables may be considered. The Lean/Rich Exchanger shown in **Figure 1** allows the process to integrate heat. The temperature of the amine is controlled by the exchanger, while the pressure of the regenerator is controlled by a valve just upstream of the column. Both variables are varied in **Figure 5**.

The 1 barg trend line indicates the rich amine temperature entering the regenerator should be about 99 C, which agrees with the rule of thumb (2). While 99 C is the optimum temperature when the regenerator is at 1 barg, once the pressure of the regenerator is increased to 1.5 barg, the trend line suggests a temperature of 107 C may be better.

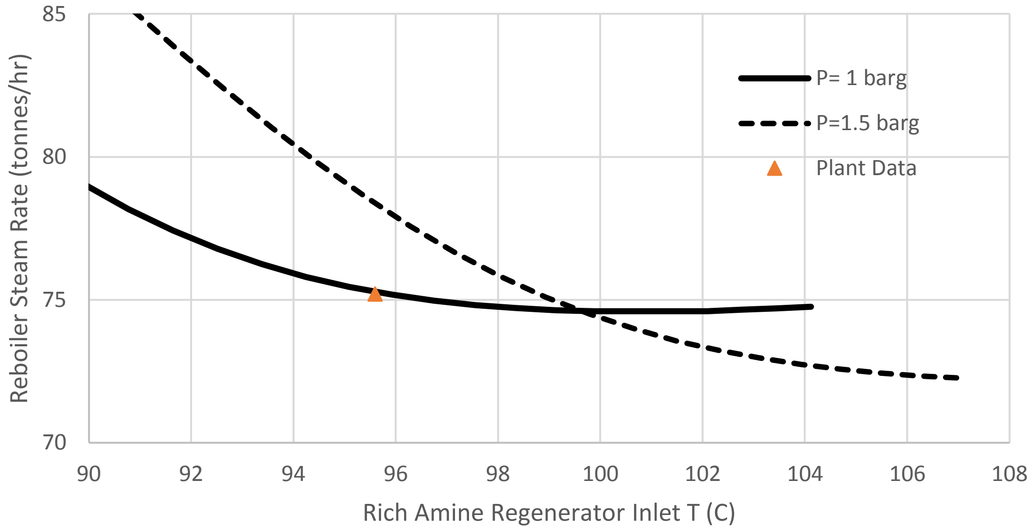

Figure 5*:* The Effect the Lean/Rich Exchanger and Regenerator Pressure Have on the Reboiler Steam Consumption

Increasing the pressure of the regenerator by 0.5 barg should decrease the steam rate by 3 tonnes/hr. These findings are in line with experimental data presented previously (3).

3.4 HEAT STABLE SALTS

Heat stable salts form when the amine reacts with acid components other than H_2S and CO_2. HSS assist in regenerating MDEA and achieving lower H_2S lean loadings, while leaving CO_2 largely unchanged.

If HSS are left unmanaged, they may interfere with acid gas absorption in the absorber and cause corrosion throughout the plant. While heat stable salts are unavoidable, they can be managed. In fact, if monitored and managed properly, the sweetening process may be enhanced in the presence of low concentrations of HSS.

Quarterly monitoring of HSS is recommended (4). Even so, it is important to know how much HSS is desired. Day 68 is the base case once again to evaluate the influence HSS have on the process in **Figure 6**.

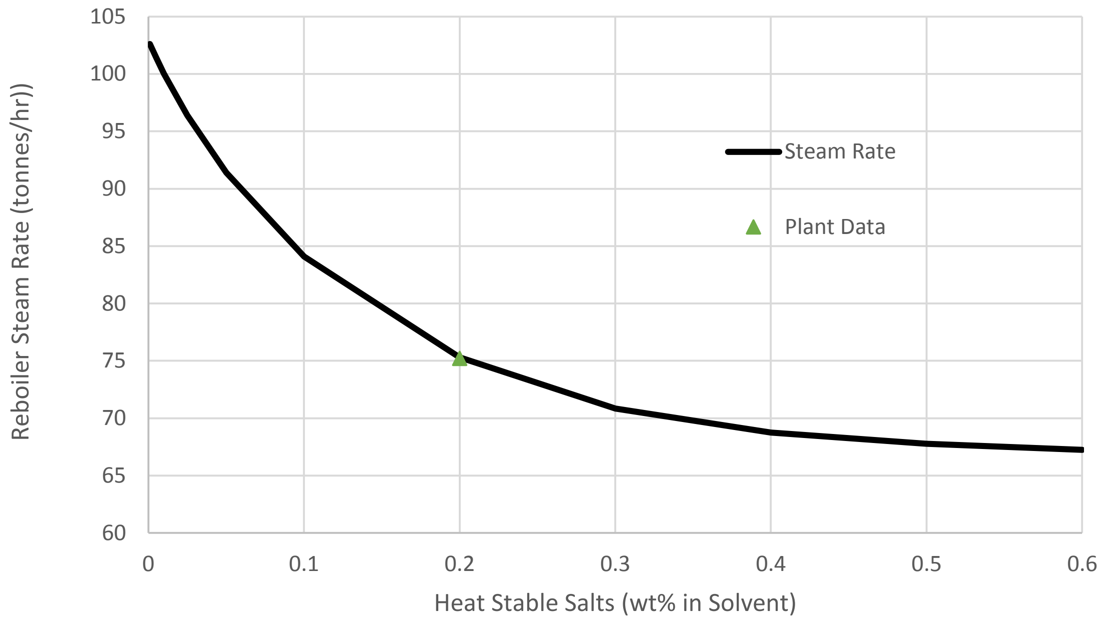

Figure 6: The Impact of Heat Stable Salts on the Sweet Gas

The presence of HSS clearly show an advantage of reducing the steam consumption while maintaining a constant sweet gas concentration. Higher levels of HSS appear to be beneficial to the plant at concentrations up to 0.6 wt% of the solvent. While the exact upper limit of HSS has not been established concerning corrosion in the plant, 0.5 wt% is a conservative value to use until more data become available (4).

However, **Figure 6** shows diminishing returns as the HSS concentration increases past 0.4 wt% of the solvent. Therefore, it is reasonable to allow HSS to increase to 0.4 wt%, which should allow the steam rate to decrease by 6.5 tonnes/hr

3.5 OPTIMIZATION SUMMARY

Each variable considered for optimization is summarized in **Table 4**.

Table 4: Summary of Optimization Study

Optimization Variable	Reduction in Steam Rate
Reduction in Solvent Circulation Rate	10 tonnes/hr
Increasing MDEA Concentration	2.5 tonnes/hr
Increasing Regenerator Inlet T and P	3 tonnes/hr
Increasing HSS	6.5 tonnes/hr

If all variables are optimized in conjunction, the potential savings from operational changes are outlined in **Table 5**. Interestingly, if all the variables are considered together, the steam rate reduction is compounded. The circulation rate may be reduced further than when it is considered in isolation because the increase in MDEA concentration to 50 wt% increased the moles of amine in circulation. That may be counteracted by reducing the circulation rate, which then reduces the reboiler duty required for sensible and latent heat.

Table 5: Comparison of the Base Case and Optimized Case

	Day 68	Optimized
H_2S Sweet Gas (ppm)	8.95	8.77
CO_2 Sweet Gas (mol%)	1.04	2.00%
Steam Rate (tonne/h)	75.2	51
MDEA Concentration (wt%)	45.5	50
Amine Circulation (m^3/hr)	665	475
Regenerator Pressure (barg)	1.07	1.5
Regenerator Feed Temperature (C)	95.6	107
Heat Stable Salts (wt%)	0.2	0.4

CONCLUSION

GASCO now has a demonstrated, robust and predictive ProMax model that accurately represents plant operations. The project was successful in creating a model that accurately predicts sweet gas concentrations of H_2S and CO_2.

Preliminary optimization suggests a reduction of 24 tonnes of steam per hour (about 20% reduction) is possible. This is accomplished by increasing the MDEA concentration to 50 wt%, increasing the rich amine temperature entering the regeneration column to 107 C, increasing the pressure of the regenerator by 0.5 barg to 1.5 barg, increasing the HSS concentration to 0.4 wt%, and reducing the solvent circulation rate by 25%. A 24 tonnes/hr reduction in steam may amount to roughly 1.3 million USD in savings per year (5).

References

1. **Gas Processors Suppliers Association.** *Engineering Data Book.* Tulsa : s.n., 1998.

2. *An Evaluation of the General "Rules of Thumb" in Amine Sweetening Unit Design and Operation.* **Addington, Luke and Ness, Chris.** 2010.

3. *Demonstration of High Pressure Acid-gas Capture Technology (HiPACT).* **Komi, Takchiro, et al.** Norman : s.n., 2012. Laurence Reid.

4. **Sheilan, Michael H., et al.** *Amine Treating and Sour Water Stripping.* 2006.

5. **US Energy Information Administration.** [Online] http://www.eia.gov/naturalgas/weekly/.